Research Review: The Role of Transmission in the Context of Deep Decarbonization

Prepared for Electricity Canada

April 2022

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Executive Summary

Realization of Canada's decarbonization ambitions will require dramatic shifts across all sectors. Reaching net-zero grid emission by 2035 and net-zero economy-wide emissions by 2050 will require substantial investment across all sectors over the long run, with initial investments focused on the electricity sector. To manage this transition in a low-cost manner, it is imperative that investment in generation resources including wind, solar, hydro, and batteries are optimized across jurisdictions using transmission. Interconnected regions will play a crucial role in achieving net-zero in Canada.

Electricity Canada retained E3 to prepare this study of the potential roles of transmission in helping Canada to meet its national carbon goals. E3 conducted a literature review on net-zero and deep decarbonization studies across North America to identify takeaways related to transmission development in the context of decarbonization. The two main themes are, firstly, that emissions reductions require more clean renewable energy which requires more transmission, and secondly, that enabling inter-regional transmission development provides lower system costs relative to cases in which resource development is restricted to within region. Within the context of these fundamental ideas, we identify four major transmission "use cases" in grid decarbonization: (1) delivering large quantities of clean energy from remote locations; (2) facilitating efficient and reliable operations by improving load and resource diversity; (3) improved reliability and gird strengthening, and (4) facilitating electrification. While many proposed large transmission projects provide benefits across multiple use cases, most are built largely for one of these primary purposes. The studies highlight these general use cases either conceptually or through identification of specific areas of transmission development. E3 uses these studies to identify a few examples of potential inter-provincial transmission projects and points out their potential use cases within the Canadian context.

E3 also identified barriers to large-scale transmission development and potential solutions to help overcome these barriers. Barriers range from planning and permitting, to cost allocation that may impede one's ability to realize the full potential of transmission in achieving net-zero targets. The Canadian electricity system is unique, not only in its geography, but also given its provincial regulatory structure. This report highlights barriers that are most relevant to the unique Canadian circumstances. These include natural land barriers, planning and permitting, provincial regulatory structure, and cost allocation. There are ways to help overcome these hurdles to Canadian transmission development.

The report provides three general recommendations for Canada: (1) develop a clear inter-provincial planning process involving provinces, the federal government, and the First Nations; (2) establish a fair and reasonable cost allocation methodology to be used across Canada; and (3) to continue to explore Canada – U.S. transmission development that can provide financial benefits to Canada.

1 Background

Canada has established very aggressive greenhouse gas (GHG) reduction targets. The recent Canadian Net-Zero Emissions Accountability Act requires Canada to achieve net-zero GHG emissions by 2050. Canada has also set interim GHG emissions targets of 40%-45% reductions by 2030 relative to 2005 levels[1] and net-zero emissions from the electric sector by 2035. These commitments will require a significant transformation across all sectors of the economy, but most prominently and immediately in the electricity sector.

Globally, as countries develop net-zero goals, an increasing number of studies have provided insights into the various pathways for achieving net-zero emissions while at the same time highlighting the challenges associated with deep decarbonization. The most common themes are rapid scale-up of clean electricity generation sources, electrification of transportation and building sector end uses, distributed energy resources including conservation and energy efficiency, and carbon-neutral fuels.

While part of the net zero picture is coming into focus, there are still many questions remaining about Canada's transition to net-zero, both in the electricity sector and across the entire economy. For example, while it is well understood that increasing wind and solar generation will play a key role in reducing electric sector carbon emissions, it is less clear which low-carbon generation sources will be predominant in serving electric loads during times when wind and solar aren't available. Additionally, it is increasingly understood the electricity sector will play a key role in economy-wide decarbonization in all regions through electrification of end uses currently served through fossil fuel combustion. However, meeting the need for heating and mobility during the types of extreme cold weather events that Canada can experience would be very challenging with electric power alone.

One of the key issues, crucial to understanding the transition to net-zero, is the role of electricity transmission infrastructure in deep decarbonization. New transmission is likely to be needed to deliver clean energy from remote locations to load centers, to access load and resource diversity across broader regions, and to serve electric loads that are growing due to electrification. This study seeks to take a broad look at current deep decarbonization studies with a particular focus on transmission to provide Electricity Canada with a clear understanding of all the potential roles for electricity transmission in the net-zero transition.

2 Deep Decarbonization Research Scan

Deep decarbonization studies are inherently built on a number of forward-looking assumptions based on both the information available today and the targeted questions of the research. This section summarizes some of the studies that were reviewed as part of this effort, the key assumptions therein, the general

[1] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

"use-cases" for transmission provided in the studies, and the barriers to achieving the benefits of transmission.

2.1 Overview of Studies

The literature review focuses mostly on the role of large-scale, interregional transmission projects in achieving net zero GHG emissions, as opposed to the projects that serve individual states or provinces. Though one study looks at the differences between planning at the state level relative to other degrees of coordinated regional planning, we do not directly address individual state or provincial level decarbonization studies in this literature review. Table 2-1 outlines the studies that were reviewed as part of the research scan including the studies' footprint.

Table 2-1 Summary of Reviewed Studies

I.D.	Study	Region
[1]	Canada's Energy Future 2021 (*Canada Energy Regulator)*	Canada – 10 provinces
[2]	Power Without Borders: Moving Towards an Integrated Western Grid *(Canada West Foundation)*	Canada – Western provinces (BC, AB, SK, MB)
[3]	Western Regional Electricity Cooperation and Strategic Infrastructure (RECSI) Study *(General Electric)*	Canada – Western provinces (BC, AB, SK, MB)
[4]	Getting on an Efficient Decarbonization Track *(HEC Montreal)*	U.S. & Canada – Eastern Interconnection
[5]	The North American Renewable Integration Study: A Canadian Perspective *(NREL)*	U.S. & Canada – All regions
[6]	Net Zero America Study *(Princeton)*	U.S. – All states
[7]	The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System *(MIT)*	U.S. – All contiguous states
[8]	Pathways to Deep Decarbonization in the United States *(E3, LBNL,PNNL)*	U.S. – All states[2]
[9]	Building Blocks for a Low-Carbon Economy: Catalytic Policy and Infrastructure for Decarbonizing the United States by 2050 *(WRI)*	U.S. – All states[3]

[2] Emissions accounting was done for all states, the electricity dispatch modelling used the three U.S. grid interconnections
[3] Emissions accounting was done for all states, the electricity dispatch modelling used the three U.S. grid interconnections

[10]	Consumer, Employment, and Environmental Benefits of Electricity Transmission Expansion in the Eastern U.S. *(ACEG)*	U.S. – Eastern Interconnection

As noted above, the studies cover a broad spectrum of different assumptions. Studies [1] through [3] focus on Canada and its provinces, studies [4] and [5] look at North American decarbonization across Canada and the United States, and studies [6] through [10] assess decarbonization across the United States. Studies [8] and [9] only briefly address the need for transmission due to the increase in renewable resource development, while the other studies provide more insight and analysis into the role of transmission in deep decarbonization or net-zero scenarios.

The levels of decarbonization investigated across the reviewed literature include a variety of alternatives ranging from most to least stringent:

Most literature emphasizes the importance of inter-regional transmission and its value in helping to reduce system cost. The transmission assumptions within the reviewed studies range from intra-state or intra-provincial isolated planning to inter-regional and interconnection coordination:

Table 2-2 summarizes the scenarios within each of the studies along with some of the key decarbonization and transmission assumptions.

Table 2-2 Study Assumptions

Study	Scenarios	Decarbonization Assumptions	Transmission Assumptions
[1] – Canada Energy Regulator Report	Study provides a base net-zero electricity case as well as several sensitivity scenarios.	No emissions target used as inputs in the model. Modelling used a carbon price as a proxy for the cost of removing carbon.	All scenarios allow new inter-provincial transmission, one sensitivity does not.
[2] – Western Canadian Integration Report	No modeling done as part of this report. Report uses other studies and research to reflect on Canadian grid integration.	No modeling assumptions as part of this report	No transmission assumptions as part of this report

[3] – RECSI Study	Calculated production cost and emissions reductions for several projects.	No decarbonization target	Specific transmission projects
[4] – HEC Montreal Regional Market Study	Scenarios assess different load growths and different transmission expansion policies.	GHG emissions constraints based on 2030 and 2050 federal, provincial, or U.S. state targets.	One scenario allows transmission intertie build between provinces and states, the other allows no additional intertie build.
[5] – NARIS	Four scenarios with different levels of emissions targets, electrification, and resource costs	Canadian GHG emission reductions of either 80% or 92% relative to 2005 levels depending on the scenario	Scenarios that allow new interconnections across Canada and U.S. Provides estimates of the value of transmission coordination across North America
[6] – Net Zero Princeton Study	Multiple scenarios with varying degrees of electrification and clean energy resource potential	Economy-wide net-zero emissions target of -0.17 GtCO2 in 2050	Allows inter- and intra-state transmission expansion for solar and wind for a subset of the scenarios in the study. Provides insight into transmission expansion costs to support wind and solar generation
[7] – MIT Value of Inter-Regional Transmission Study	Multiple scenarios that address varying levels of transmission expansion collaboration across the United States	0%, 95%, 99%, and 100% Clean Energy Standard (CES)	Developed scenarios with various degrees of transmission coordination: isolated state, intra-planning area, inter-planning area, inter-synchronous area. Illustrates the affects of transmission development coordination on cost of electricity
[8] – U.S. Decarbonization Pathways Study	Four decarbonization scenarios: High Renewables Case, High Nuclear Case, High CCS case, Mixed Case	80% economy-wide emissions reduction relative to 2005 levels by 2050	Transmission costs only associated with resource build out across the U.S. Address transmission development to accommodate new renewable resources

[9] – WRI Decarbonization Policy Study	Four policy scenario cases	Economy-wide net GHG reduction targets relative to 2005 levels vary by scenario: 31%-50% by 2030 and 34%-100% by 2050	Allows for high-voltage transmission expansion to accommodate increases in resource development. No significant analysis on transmission, costs for transmission are imbedded within resource costs
[10] – ACEG Transmission Expansion Benefits Study	Four scenarios: weak/strong carbon policy with high solar/wind deployment	Electric sector carbon emissions reduction targets relative to 2005 levels: 48% in the weak carbon case and 57.34% in the strong carbon case.	Allows the development of inter-state transmission development. Analyzes inter-state transmission value to accommodate carbon policies

While Table 2-1 and Table 2-2 show a wide range of study goals and footprints, there are two key themes that are prevalent across all studies.

1. Transmission is needed to access renewable generation in areas with strong wind or solar potential.
2. Inter-regional transmission coordination is valuable in reducing system cost.

In addition to these themes being identified as core to decarbonization, they are also demonstrated in practice today across Canada in the US.

Our review finds that transmission helps facilitate decarbonization by enabling delivery of renewable generation from remote areas, where the quality of the resource is high. Princeton[4] and ACEG[5], in particular, highlight the role of transmission in delivering remote renewable resources to load centers under higher decarbonization targets.

Several studies highlight the benefits of inter-regional transmission as opposed to intra-province or intra-state transmission development. MIT[6] shows that integrated transmission development provides cost savings relative to isolated, less integrated development, while HEC[7] and NREL[8] also reach a similar conclusion specifically on the value of Canadian – U.S. transmission.

Although not the main focus of this report, it is also worth mentioning that several studies also found that transmission need can be alleviated, relative to a scenario of renewable-only clean energy, if the definition of clean energy resources extends beyond renewables to nuclear, bio-fuels, or conventional gas with CCS.

[4] Net Zero Princeton Study
[5] ACEG Transmission Expansion Benefits Study
[6] MIT Value of Inter-Regional Transmission Study
[7] HEC Montreal Regional Market Study
[8] NREL's NARIS

It has been demonstrated in numerous studies, including those conducted by E3, that the incremental costs associated with deep decarbonization solely with renewables are relatively low at first, but reach an inflection point where cost increases become prohibitive as the amount of renewable capacity and energy storage that are required to maintain reliability without firm resources grows exponentially. “Clean firm” resources can help reduce the quantity of renewable resources on the system, which also reduces the transmission need associated with building out those renewable resources.[9]

2.2 Literature Transmission Use Cases

A review of both the studies and current transmission planning in North America highlights four main use cases for transmission in achieving net-zero or deep decarbonization. The following sections, along with Figure 1, describe these use cases in more detail. These use cases are the archetype project functions that allow transmission to unlock benefits be they increase access to renewables or benefits of inter-regional transmission. In reality, each transmission project facilitates each of these functions to varying degrees even as one driving architype generally serves as the project anchor.

*2.2.1 Connecting Remote Renewable Resources (**Blue** in Figure 1)*

The principal use case for transmission in a net-zero framework is to connect remote renewable resources. Numerous studies provide examples of this type of use case. Princeton shows significant transmission development to deliver wind resources from the Great Plains to load centres to the East. ACEG similarly highlights the need for transmission build to connect rich wind resources as well as solar resources to the Eastern load pockets. Conceptually, MIT also points to increases in transmission capacity between The Rocky Mountains and California as an example of inter-regional transmission need. CER[10] highlights the role of the Atlantic Loop project in delivering hydropower from Quebec and/or Labrador to the Maritime Provinces.

Functionally these transmission assets are required as, unlike thermal generation, renewable resources are geographically dependent and cannot be sited close to load centers in many cases – for example, connecting the solar and wind potential in Southern Alberta to loads in Calgary, Edmonton and Northern Alberta requires transmission. This is not a new phenomenon in Canada either. Significant transmission has been built to connect large-scale hydro projects in BC, Ontario, Quebec and Atlantic Canada to load centers throughout the country. NREL shows the importance of hydro resources from Quebec to neighbouring provinces and states

*2.2.2 Load and Resource Diversity (**Gold** in Figure 1)*

Entities within regions or provinces have inherently different resource mixes based on geographical differences as well as historical energy policies. Some have more thermal resources while others may have more hydro or renewables. Some regions may have wintertime electricity peaks, while other systems may

[9] https://issues.org/california-decarbonizing-power-wind-solar-nuclear-gas/
[10] The Canada Energy Regulator’s Energy Future Report

peak in the summertime. Some regions may be rich in wind power while others have better solar resources. Creating transmission connections between systems with different characteristics facilitates sharing both clean energy and capacity products between them.

Connecting two areas that have different seasonal peaks can help reduce their individual need for capacity by sharing. Even establishing connections between renewable-heavy regions can be beneficial. If the regions span multiple weather zones, establishing links between these areas can help reduce overall renewable as well as load variability.

Transmission projects that promote the sharing of resources and load across different regions help within the context of net-zero. RECSI[11] identifies an intertie between Saskatchewan and Manitoba that would help link the hydro rich region of Manitoba with the solar and wind resources in Saskatchewan. Similarly, MIT alludes to the complimentary nature of wind in the Midwest U.S. and solar in the Southeast U.S. CER also points to increased need for transmission between the western provinces to enable resources sharing between hydro rich areas and potential solar and wind resource in Alberta and Saskatchewan.

*2.2.3 Reliability and Strengthening Weak Grids (**Purple** in Figure 1)*

As intermittent and energy limited resources are increasingly added to the system and thermal capacity is retired in pursuit of decarbonization, grid strength and stability become increasingly important for maintaining operational reliability. Power systems that mostly rely on lower-voltage transmission with relatively weak ties to the larger regional interconnection are more likely to face limits on their ability to integrate renewable energy due to inertia and grid stability challenges. Greater interconnection to the larger bulk grid strengthens these weak grids by tying their real-time conditions to the much more robust and stable Eastern or Western Interconnections. This benefit is especially important for smaller systems that are only weakly tied to the Interconnection such as the Maritime Provinces or Saskatchewan.

New transmission provides other reliability benefits such as improving long-run resource adequacy by enabling firm generation in one region to serve loads in another during times of extreme need. NREL touches on this by noting the benefits of transmission to reliability in a deeply decarbonized future, especially lines such as British Columbia to the U.S. Pacific Northwest. This is particularly noteworthy as the U.S. Northwest finds itself in growing need of capacity and has some of the most aggressive decarbonization policies in North America, whereas BC Hydro frequently has excess capacity to sell.

MIT shows that potential interconnections to ERCOT from neighboring regions could help reduce electricity costs through large scale inter-regional transmission development. Given Texas' recent challenges during winter storm Uri, these transmission lines are seen as a potential means to shore up reliability to the ERCOT grid by facilitating energy transfers over broader regions that are not all facing extreme weather at the same time. Another example highlighted in CER is increased transmission capacity between New Brunswick and Prince Edward Island. The Atlantic provinces including New Brunswick, Prince Edward Island, and Nova Scotia are relatively weakly connected to the rest of the Eastern Interconnection creating the potential for stability and inertia challenges under high renewable

[11] RECSI Study

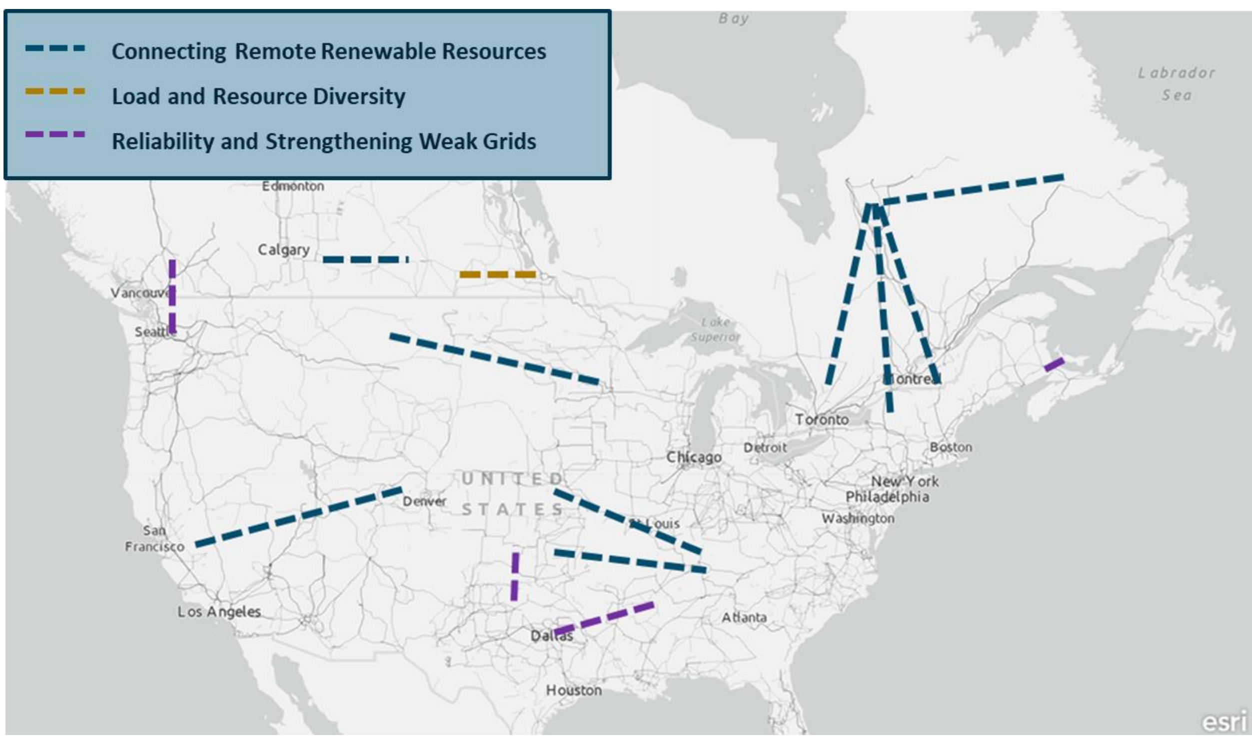
penetration. Increasing connections to other provinces can help manage these weak grid issues as more variable generation replaces firm conventional generation.

2.2.4 Facilitating Electrification

The research scan also reveals the effects of electrification on transmission needs. Achieving economy wide net-zero by 2050 in Canada requires significant decarbonization beyond the electricity sector including transportation, buildings, and industrial processes. Decarbonizing these sectors requires electrification that must occur along with the decarbonization of the electricity sector. As entities or regions seek to decarbonize their economies and achieve net-zero targets, electrification will become more prominent, resulting in significant increases in electric load. Some studies (e.g., Princeton) indicate that U.S. peak electric load might double over the next 30 years, while the CER study indicates that electric load may increase 44% in Canada due solely to the effect of policy-driven electrification and net-zero goals.

To accommodate electrification load there will need to be substantial investment in transmission for two reasons. Firstly, increased load will require increased generation capacity as demonstrated in CER, for which transmission will be needed to deliver the resources to load. Secondly, load pockets will grow in both need and footprint, requiring upgrades to existing transmission capacity. While it is difficult to point to transmission projects built specifically for electrification, it is a widespread use case of transmission that extends beyond the inter-regional projects and into the intra-regional and distribution level projects as well.

Figure 1 Illustrative Conceptual and Specific Transmission Projects from Literature



Underlying Map from S&P Global, March 2022

2.3 Barriers to Transmission Development

While the benefits of transmission as part of decarbonization are clear, there are significant barriers to developing this capital-intensive infrastructure with multi-year or decade development timelines in designing, permitting and constructing greenfield transmission lines. Based on the research scan, E3 has identified six core barriers to transmission development:

1. **Planning Processes:** Planning processes are rigorous and must go through numerous different steps involving multiple stakeholders including economic, environmental and social justice stakeholders as well as First Nations' interests. Most processes require assessment of project alternatives designed to ensure that the specific project at hand is the best option. Inter-regional transmission planning processes are either non-existent (as is mostly the case in Canada) or tend to serve as a barrier by providing an additional step in the process. All of these planning steps require many years of analysis and stakeholder engagement.
2. **Permitting:** Obtaining the proper permits often takes many years and requires millions of dollars of studies. Permitting can be particularly complex for inter-regional or inter-provincial transmission projects that cross multiple land classifications including First Nations lands.
3. **Capital Cost:** Transmission line development is extremely capital-intensive, even for short-distance projects. This creates a high barrier to entry for all proposed projects.
4. **Long Distances:** New transmission in North America must often cover vast distances, particularly for remote renewable resources. Long distances increase the cost and difficulty of developing new projects.
5. **Jurisdictional Challenges:** Large projects often cross multiple state, provincial or even international boundaries, as well as First Nations lands, creating challenges lining up policy and permitting processes across the multiple governmental entities with jurisdiction over a portion of the project.
6. **Cost Allocation:** If multiple parties are involved in developing inter-regional transmission a fair allocation of the project costs must be agreed on. This is particularly the case for multi-jurisdictional projects where the benefits are not evenly spread among the participants. In Canada, bilateral agreements between neighboring provinces may be sufficient in many cases and are more straightforward.

It is clear from this review that while the benefits of interregional transmission are large and multifaceted, the barriers that these projects face are real and can significantly to hinder the development of new infrastructure development. Many of the barriers identified here are specific to project location, configuration, and use case; hence, it is important to look at how these use cases and barriers apply to specific relevant projects in Canada.

3 Transmission in a Net-Zero Canada

3.1 The Canadian Electricity System

The Canadian electricity sector is unique in generation mix, geography, and regulatory structure when compared with other North American jurisdictions. Regulation of the sector takes place at the provincial level with limited regulation of transmission lines that cross provincial boundaries. Except for Alberta, vertically integrated utilities develop the provincial transmission grid and generation resource mix to benefit the province and ratepayers as much as possible. In Alberta, transmission and distribution functions are provided by unbundled utilities and generation is provided in a competitive, energy-only market.

Given the provincial boundaries in Canada, the abundance of vertically integrated utilities, and the nature of regulation, transmission in provinces has largely been focused on North to South corridors connecting resources to load centers within each province, and from provincial load centers to US load centers on the other side of the border. Some connectivity exists between provinces; however these connections are generally small relative to the size of the markets being connected. In addition, most extra-provincial interconnections have focused on international trade with the US as opposed to a trans-Canadian network. This is again a function of Canadian geography in that Canadian load centers are often much closer to US load centers on the other side of the international border than they are to other Canadian load centers in neighboring provinces.

Most Canadian provinces operate nearly as islands, with limited connectivity amongst Western Provinces (BC, Alberta, Saskatchewan, and Manitoba) and similarly limited connectivity between the Eastern Provinces (Ontario, Quebec, and Atlantic Canada).

Canada’s generation mix is also unique with roughly 60% of electricity generation coming from hydroelectric sources. B.C., Manitoba, Quebec, Newfoundland and Labrador, and Yukon all generate over 80% of their electricity from hydropower, while Alberta, Saskatchewan, and Nova Scotia primarily generate their electricity from fossil fuels.[12] As of 2019, non-hydro renewables make up 7% of generation and is mostly located in Alberta, Ontario, and the Maritimes.[13]

3.2 Identified Transmission Projects in Canada

Given the realities of the Canadian system and transmission use cases outlined in Section 2.2, we examine here a set of example transmission projects that could be explored for their potential to help Canada reach its net-zero goals.

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[12] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

[13] https://www.nrcan.gc.ca/sites/nrcan/files/energy/energy_fact/2021-2022/PDF/2021_Energy-factbook_december23_EN_accessible.pdf

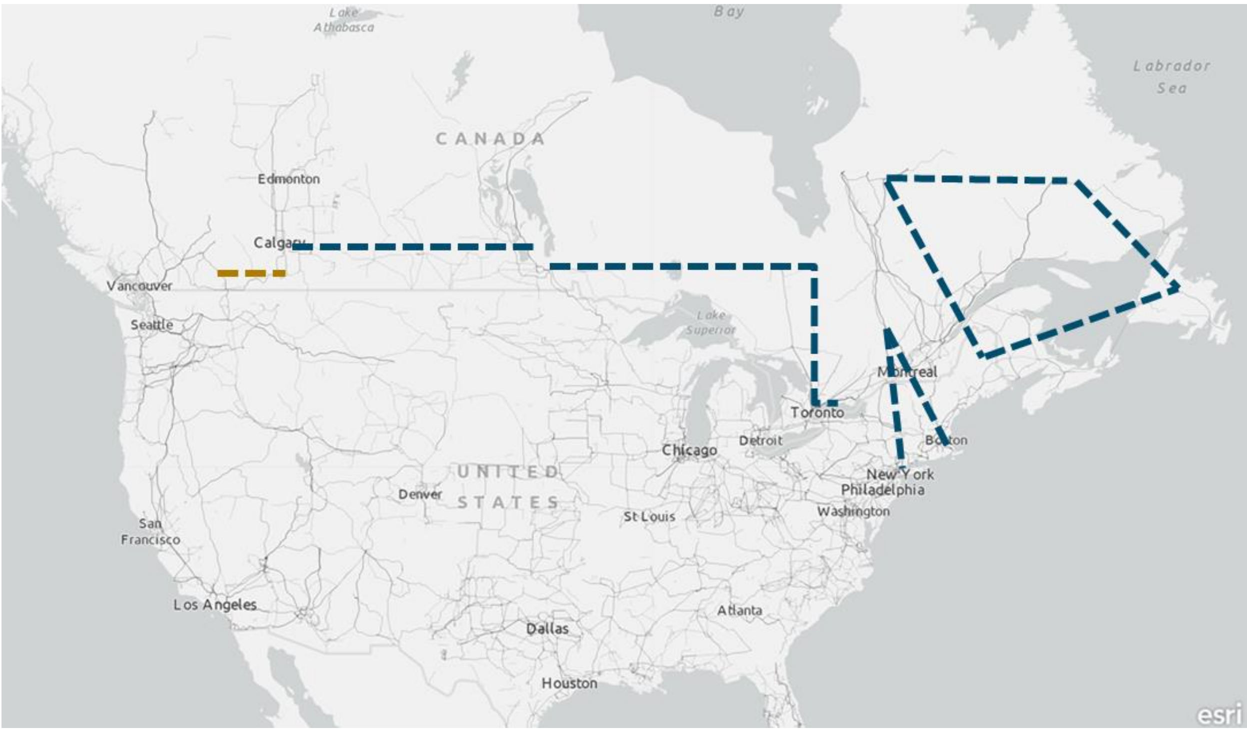
Canada will need to develop an estimated 57 GW of wind and 26 GW of solar by 2050 to meet net-zero targets according to the CER. Most of these renewables are expected to come from British Columbia, Alberta, Saskatchewan, Ontario, and Quebec. High quality renewable resources are available within Canada, but the challenge is getting these resources connected to provinces and load centers that need them given the unique traits of the Canadian system and the sheer magnitude of the estimated capacity of renewables by 2050. These needs mostly fall under the '*Connecting Remote Renewable Resources*' and '*Load and Resource Diversity*' use case categories.

Given the identified use cases for Canada and referencing a few projects alluded to in the studies, five potential projects are identified along with their primary use case in Table 3-1. Figure 2 also shows the five potential projects geographically.

Table 3-1 Identified Potential Canadian Transmission Projects

Proposed Sample Projects	Primary Use Case
Atlantic Loop	**Connection of remote renewable resource**
Champlain Hudson Power Express or NECEC	**Connection of remote renewable resource**
Manitoba – Ontario	**Connection of remote renewable resource**
Alberta – Saskatchewan – Manitoba	**Connection of remote renewable resource**
B.C. - Alberta	**Load & resource diversity**

Figure 2 Illustrative Potential Canada Transmission Projects



Underlying Map from S&P Global, March 2022

3.3 Canadian Transmission Project Use Cases

Though each of the potential projects has been defined by its primary use case, all projects have benefits across multiple use cases, with their relative importance varying over time as Canada transitions to net-zero. As an example, in the first phase of developing transmission, projects may be more focused on connecting renewable resources, however over time as renewable deployment grows and emissions reductions reach net-zero, the focus and use case will shift more towards load and resource diversity as well as reliability and grid strengthening. Table 3-2 shows the use cases applicable to each of the potential projects outlined in Section 3.2.

Table 3-2 Potential Canada Transmission Project Use Cases

	Connection of Remote Resources	Load & Resource Diversity	Reliability & Grid Strengthening	Facilitate System Electrification
Atlantic Loop	✓	✓	✓	✓
Champlain Hudson Power Express or NECEC	✓		✓	

Manitoba – Ontario	✓	✓	
Alberta – Saskatchewan – Manitoba	✓	✓	✓
B.C. – Alberta	✓	✓	✓

1. **Atlantic Loop:** The Atlantic Loop project would encompass all use cases. This large multi-provincial project would help deliver hydropower from Quebec and/or Labrador to the Maritimes and would also allow for load and resource diversity among the different provinces. The portion of the project that interconnects the Maritimes provides grid strengthening and reliability benefits as well and would help facilitate the ongoing electrification within provinces such as Nova Scotia.
2. **Champlain Hudson Power Express or NECEC:** These projects mainly serve as a means of providing remote hydro resources from Quebec to New York or New England. It also provides reliability benefits to the US jurisdictions in the form of firm capacity. From a Canadian perspective, the primary benefit of these projects is to generate export revenues to help reduce electric rates and provide dividends to provincial governments.
3. **Manitoba – Ontario:** This line would help link Manitoba hydro to eastern load centers in Ontario. The project could also provide load diversity due both to the time zone difference as well as resource diversity between wind and hydropower in Manitoba and Ontario's mix of nuclear, hydropower and wind.
4. **Alberta – Saskatchewan – Manitoba:** These lines help connect potential remote renewable resources in Alberta and Saskatchewan while also connecting Manitoba hydro to Saskatchewan and ultimately Alberta as well. Increasing the interconnection capacity between the western provinces increases reliability across the west and contributes to strengthening the western Canadian grid. A challenge for the western portion of this project is that Alberta is a part of the Western Interconnection, requiring AC-DC-AC power converters at the boundary with Saskatchewan.
5. **B.C. – Alberta:** This line provides both load and resource diversity as well as grid strengthening benefits between BC and Alberta, both of which are within the Western Interconnection.

3.4 Barriers and Solutions to Transmission in Canada

The barriers associated with developing Canadian transmission and potential solutions can be grouped into four different categories.

3.4.1 Natural Land Barriers

The geography of Canada discourages any development of long east-west transmission lines with a mountainous region to the west, large plains across the center of the country, and the Atlantic coast to the east. Instead, trade opportunities with the US have led to a more north-south integrated grid with relatively weak inter-provincial ties.

Unfortunately, these is no ready-made solution to this barrier which is a function of Canada's geography. Technology solutions may help overcome these barriers in the long term. Reuse of existing rights-of-way along major highways or pipeline corridors may be one way to reduce the cost of long transmission line development.

3.4.2 Planning and Permitting

Planning and permitting timelines can be a hinderance to Canadian transmission especially when considering inter-provincial lines. It is especially salient given the established emissions reductions targets for 2035 and 2050 will require significant transmission development in the near-term.

Since transmission project lead times are quite long, and keeping in mind the 2035 policy goals, a potential solution would be to fast-track important projects that help meet public policy goals or fast track projects according to a set of specific criteria or use cases. These would be important decisions which would need the partnership of the First Nations.

3.4.3 Provincial Regulatory Structure

The current provincial regulatory framework encourages focus on within-province transmission development rather than across provinces. Most transmission development happens within provinces subject to their regulatory rules and guidelines. At the same time, Canada's jurisdictional topography is less complex than in the US, making it possible for transmission to be facilitated with bilateral or even multilateral agreements without the involvement of a federal regulator as in the US.

As Canada set its sights on net-zero, more formal collaboration between provinces may help reduce barriers to transmission development. Aligning regulatory bodies to provide consistent coordinated planning would help bridge this gap and help create a more integrated Canadian grid.

3.4.4 Cost Allocation

While provinces have extensive experience in developing bilateral inter-provincial transmission, discussion involving more than two parties may be significantly more challenging in terms of allocating costs.

Establishing a cost allocation framework is a critical step for successfully developing large inter-provincial projects. This has become apparent in the US when looking at the difference between regional planning groups that have been largely unsuccessful and do not have a cost allocation framework, and Regional Transmission Organizations (RTOs) that have been successful and do have a cost allocation framework. The US Federal Regulatory Commission (FERC) addressed interregional transmission planning under Order 1000 which established regional transmission planning organizations. However, while FERC generally noted a preference for costs to be allocated based on benefits received, it did not establish a mandatory cost allocation framework for interstate transmission. On the whole, the Order 1000 regional planning processes have been unsuccessful in spurring the development of interstate transmission. By contrast, the multi-state RTOs – which include the Independent System Operator of New England, the PJM Interconnection, the Mid-Continent Independent System Operator, and the Southwest Power Pool – have addressed transmission cost allocation in their tariffs and have been much more successful in identifying and approving multi-state transmission projects.

4 Conclusions

The literature review establishes the main use cases of transmission in achieving net-zero targets and leads to several sample projects in Canada that could help meet 2035 and 2050 decarbonization goals. The challenges in developing these projects, along with other Canadian transmission projects, stem principally from general permitting and planning timelines as well as Canada's unique geography and regulatory structure. The barriers to developing transmission in Canada can be addressed though specific recommendations that would help promote regional coordination and establish procedures to help streamline inter-provincial transmission development.

4.1 Recommendations and Areas of Further Study

Canada's net-zero goals will require transmission to be strategically developed across the country. Based on the findings in this report there are three recommendations for Canada and Electricity Canada to pursue:

1. **Support the development of a formal inter-provincial planning process**:
   Creating an inter-provincial planning process within Canada could help overcome some of the barriers addressed in this report. The framework should be centered around a net-zero Canadian study that assesses general transmission needs across the country. This may either be an existing study or a federally funded study that can serve as a common starting point amongst provinces, territories, and the First Nations. In parallel or depending on the outcomes of the net-zero study, Canada can form regional planning groups with oversight and assistance from the Federal government that are designed to identify key projects necessary for achieving net-zero targets. There are lessons to be learned by Canada from the regional planning groups established in the U.S. under FERC's Order 1000. Currently, U.S. regional planning groups convene, discuss, and execute on region transmission projects with minimal oversight from a more general governing body. This, in part, contributes to the inefficiencies of these groups and result in fewer regional transmission projects that emerge from these processes. In Canada, the Federal government can play an active role in convening these groups and potentially providing funding during the project development process or perhaps even for a portion of the projects themselves if they are seen to address a national interest. These planning groups would ideally agree amongst themselves, though discussion and analysis, what the next steps are in developing any identified projects. As part of this regional planning process, it is important to keep updating the net-zero analysis work to be able to provide the most up-to-date information on new transmission needs.

2. **Outline a fair and reasonable cost allocation framework:**
   To overcome the cost allocation barrier of inter-provincial transmission it is important to establish a fair and reasonable cost allocation framework that compliments the transmission planning process discussed previously. Having a means through which costs can be allocated can help bypass some of the more significant barriers to inter-regional transmission development. The contrasting effects of a cost allocation framework can currently be seen in the U.S. within regional planning groups and within ISOs and RTOs. Under the current design of the regional planning groups in the U.S. there is no clear cost allocation framework. This is left to the members to agree on, which can prove difficult in a group that has entities with very different system sizes and cost expectations. Ultimately, this disincentivizes entities from coordinating through the regional planning process in the U.S. and instead, leads to utilities building projects through their own channels where projects are decided by the state Public Utilities Commission. On the other hand, coordinated planning has been successful in ISOs and RTOs that cover large areas of the U.S. and have established cost allocation methodologies allowing for the development of inter-utility and inter-regional transmission. Examples of large inter-regional transmission projects include MISO's Multi Value Projects, or SPP's Priority Projects. Having one independent entity that coordinates planning over large areas is able to establish a clear cost sharing methodology.

   Canada's current regulatory structure does not currently lend itself to this same construct since provinces are responsible for their own electricity sectors there is no larger governing body that oversees all provinces like an ISO or RTO as those are province specific. However, cost allocation frameworks could be a subject of discussion and/or negotiation among the regional planning groups described above.

3. **Continue to explore international trade opportunities for mutual benefit:**
   Though there are certainly instances of inter-provincial transmission, as discussed in the barriers to transmission in Canada, provincial systems and geography have made it somewhat challenging and rare to develop inter-provincial transmission. While new technology may help increase the use of existing transmission, long inter-provincial transmission lines are relatively expensive and may not be warranted unless there is federal support or an established cost allocation framework. A continued focus on transmission development between Canada and the US can yield mutual trade benefits and improved reliability for both countries.

While the geographic extent of Canada is one of the largest barriers to transmission development, it is also a source of significant benefits when pursuing decarbonization and net-zero. Abundant hydro resources are found across many jurisdictions, and those without generally have access to outstanding wind and/or solar opportunities. Core to the successful achievement of net-zero is using transmission to leverage the benefits provided by the vastness of Canadian geography and resource potential. Examples of beneficial transmission projects exist across all the use cases described in this report and a thoughtful, objective, cost-benefit pursuit of these projects is the in the best interests of Canada and decarbonization.

In addition to domestic opportunities, it is important that Canada continue to look for opportunities of mutual benefit with its largest trading partner, the United States. Diversity of load and resources can provide opportunities for Canadian energy projects, as well as revenue opportunities for Canadian load service entities with a view to reducing the cost of domestic electricity.

Finally, the recent Federal budget sets aside roughly $3 billion over the next seven years in the area of clear electricity including regional coordination, transmission planning, net-zero energy plans, and investment in clean energy or carbon reducing technologies.[14] Specific items within this portion of the budget include $250 million over four years to support pre-development of inter-provincial transmission projects and Small Modular Reactors, $25 million to establish Regional Strategic Initiatives to develop net-zero energy plans by working with provinces, territories, and with relevant stakeholders, and $2.4 million in 2022-2023 to establish a Pan-Canadian Grid Council "which would provide external advice in support of national and regional electricity planning".[15] The alignment of this investment with the key conclusions of this reports evidences the importance of transmission as an enabling factor for Canada's net-zero goals.

[14] https://budget.gc.ca/2022/report-rapport/chap3-en.html#2022-2
[15] https://budget.gc.ca/2022/report-rapport/chap3-en.html#2022-2