
Canadian Port Readiness Shore Power Study

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EXECUTIVE SUMMARY

This study assesses the feasibility of implementing shore power in Canada by analyzing Canadian port readiness through a literature review and interviews with Canadian Port Authorities. The results of this study aim to inform the Government of Canada's efforts to decrease marine emissions on a national scale.

Shore Power Overview

Shore power is the ability to provide electrical land-based power to vessels while dockside to allow them to shut off the auxiliary engines they would typically operate to maintain vessel electronics, accommodation load, and to assist in offloading or loading cargo operations. To use shore power, dockside connections are required, and vessels need to be fitted with electrical systems compatible with the portside system which can be achieved by following shore power international standards.

When clean energy sources are used to supply shore power, local air pollution and greenhouse gas (GHG) emissions can be reduced as well as noise and vibration from auxiliary engines. Using shore power can reduce emissions immediately and it is more efficient than other emission reduction methods.

International Shore Power Implementation

Internationally, shore power has been demonstrated as a feasible emission reduction technology. The EU, China, and the State of California have all implemented shore power regulations. In the EU, European Ports must install shore power facilities on a priority basis by the end of 2025, and container ships and cruise ships over 5,000GT are required to connect to shore power by 2030. Similarly, in China, all domestic ships and shore power-capable Chinese ships are obligated to use shore power as of 2022. Lastly, California mandates vessels to shut down auxiliary diesel engines and connect to shore power while at berth.

In addition to these regulations and standards, the International Maritime Organization (IMO) and the European Maritime Safety Agency (EMSA) have voluntary guidelines and guidance available for shore power connection as well as standardization requirements for most ship types.

The International Electrotechnical Commission (IEC), the Institute of Electrical and Electronics Engineers (IEEE), and the International Organization for Standardization (ISO) created a joint working force to ensure there would be only one international standard for shore power. The standard ensures worldwide interoperability, compatibility, and safe connection between ports and vessels. Standards for cruise ships, container ships, roll-on/roll-off vessels, LNG tankers, and car carriers are developed. However, standards for tankers, bulk carriers and general cargo vessels are still under development. These standards have been implemented in the EU, California, and IMO shore power guidelines.

Canadian Ports and Shore Power

Transport Canada developed ship electrical standards in 2018 that set standards for safety for installation, design, and construction of electrical installation of shore power and operation in Canada. Additionally, Technopole Maritime du Québec (TMQ) has developed key recommendations for a successful shore power project.

Some Canadian ports have already adopted shore power. The ports of Vancouver, Montreal, Halifax, and Prince Rupert have installed standardized high-voltage shore power. Additionally, other Canadian ports have low-voltage shore power for small vessels or have electrical connections for wintering.

Implementing shore power involves several critical factors summarized in this project. Power demand and required infrastructure vary significantly depending on port and vessel type. The Environmental Protection Agency (EPA), California Air Resources Board (CARB) IMO, and ECCC/NRC have conducted studies that estimate the power demand based on vessel type and dockside duration. Additionally, infrastructure requirements have been reviewed, depending on the port, number of berths, and individual vessels. All shore power systems require an electrical substation, a cable management system, data systems and maintenance requirements to effectively convert electricity, meet flexibility needs, and maintain successful operation. Furthermore, successful utility relations are critical in coordinating power demand, grid and infrastructure changes, mitigating power interruptions, and managing peak power. Designated staff, often certified electricians, are also required to manage dangerous and technical aspects of shore power operations including handling high-voltage connections.

Alongside logistical factors, capital costs and funding are significant considerations. Installation costs vary based on terminal configuration, existing infrastructure, grid connectivity, ship type, and coverage type. Additionally, there are ongoing expenses for trained labor, maintenance, and electricity. Despite the potential of shore power enhancing port competitiveness, substantial capital costs highlight the necessity of government funding. Internationally, every mandatory shore power program that has been implemented came with government funding and assistance.

Key Considerations

There are many key factors to consider for a successful shore power project. These include performing initial financial analysis, selecting berths that are good candidates for shore power, considering distance from communities as those ports should be prioritized, ensuring that the technology will be utilized and that there is grid capacity to do so, and engaging with ship owners to increase utilization.

Assessment of Canadian Ports

In this study, ECCC aimed to determine if Canadian ports are shore power ready. This involves a port having a shore power implementation plan and analysis of the environmental, economic, social, and technical aspects of shore power. To assess the readiness of a port, ECCC prepared a

qualitative scoring guide based on six factors associated with more specific criteria derived from the literature review and EMSA guidance. These factors include technical, legal, operational, market/financial, economic, sustainability, social, and safety feasibility as well as external factors including international standardization and certification.

The readiness factors were then incorporated into a framework using qualitative binning (Low-Medium- High). A 'low' score indicates that no relevant work has addressed the specific factor, a 'medium' score suggests that the port has initiated preliminary work to address the factor, and a 'high' score demonstrates that the port has fully addressed the specific factor. Based on this analysis, a global readiness level is assigned to each port: no activity, preliminary activity, intermediate activity, high implementation, and full implementation. These rankings serve as guidance; however, not every factor needs to be 'achieved' to implement shore power.

Using the port readiness framework, ECCC administered a questionnaire and subsequently conducted interviews with 17 Canadian Port Authorities including Nanaimo, Port Alberni, Prince Rupert, Vancouver Fraser, Hamilton-Oshawa, Toronto, Thunder, Windsor, Montreal, Quebec, Saguenay, Sept-Îles, Trois-Rivières, Belledune, Saint John, Halifax, and St. John's Port Authority. Information obtained from the questionnaire and the interviews were then applied to the shore power assessment matrix.

Interview Key Findings

The interviews indicated that the majority of ports are still in the preliminary shore power activity level. This means they have begun exploring shore power and may have some experience with the technology but are not yet providing commercial shore power service for oceangoing vessels. However, there were some disparities in Port Readiness across the country and amongst ship types. Coastal ports on the Pacific and Atlantic oceans are further ahead in terms of 'readiness' than ports in the Great Lakes and St Lawrence region ports. The coastal ports had demonstrated more intermediate level activities such that they are involved in shore power projects compared to inland ports which have only begun investigating shore power's potential. Additionally, the study indicated that cruise terminals are the most shore power ready, followed by Ro-Ro terminals, and bulk carriers' terminals are the least prepared along with tanker terminals.

The interviews highlighted that large-scale implementation of shore power is not likely without government intervention. While Canadian ports are motivated to install shore power to decarbonize port operations, improve quality of life, and protect the environment, numerous barriers are hindering this progress. Consistently, the two largest barriers mentioned by ports are the high cost of shore power and the limitations of the utility grid. Since ports will likely not experience a return on investment the direct cost of shore power is too high for ports to pursue without funding support from the government. Additionally, to expand or implement shore power at some ports enhancements are needed in the electricity infrastructure. The process of improving the grid power capabilities is extremely complicated, long, and costly, making it a large barrier, despite positive relations between ports and utilities. However, since the

technology for the grid and shore power is mature, effort needs to be dedicated to funding support.

Conclusions

This study evaluated the feasibility of implementing shore power at Canadian ports to support the Canadian government’s initiative to reduce national marine emissions. The findings indicate that shore power can be achievable on a national scale. There are well-defined standards for ports and most vessels, successful existing international regulations, and numerous Canadian ports that are already using shore power. Standards have been included in IMO guidelines and international regulations, as well as being utilized in many Canadian ports already. Successful international regulations in China, the EU and California are requiring all ports to install shore power and most vessels to connect at berth by 2030 or earlier. In Canada, despite no regulatory requirements, many ports have proactively implemented shore power, motivated by decarbonizing their port operations and protecting the environment and nearby communities.

The study indicated that most Canadian Port Authorities are still in the preliminary phase, having explored the potential of shore power and understand the technology, but have not yet implemented it in a commercial capacity. However, the results varied by terminal type. The findings revealed that cruise and container terminals are the most ready to implement shore power as over 50% of emissions occur at terminals that have reached an intermediate activity level. Reaching this level means that the port is involved in some commercial shore power projects. In comparison, all tanker, bulk carrier and merchant other terminals remain in the preliminary level. An analysis of each factor’s scoring revealed that, while ports can directly address many factors, some remain beyond their control. Thus, national and international support is necessary to address many of the factors and help ports become more ready to implement shore power.

The interviews and analysis from Canadian Port Authorities illustrated that, as other countries have done, regulations and government incentives are essential in facilitating shore power implementation on a large scale. There are high costs to install shore power, challenges with using existing utility grids, and limited returns on investment. International shore power regulatory have provided substantive funding and assistance to ports when regulations were enforced. Following these regions’ lead, widespread shore power can be possible by administering federal shore power mandates and providing essential monetary support.

The Canadian Government has a number of climate and air pollution priorities under which shore power as a technology will help achieve those goals. “Addressing climate change and ensuring clean air for Canadians is a top priority for the Government of Canada. As Canada begins its journey towards exceeding our 2030 Paris Agreement climate target towards net-zero emissions in 2050, significant reductions in air pollutant emissions are expected as our economy becomes cleaner. For example, recent research suggests particulate matter—one of the most damaging air pollutants—could be reduced by as much as 88 %, with societal health

benefits of about \$7 billion a year” (Canada, 2021). For Canada to meet its climate targets and ensure local emissions are below the Canadian Ambient Air Quality Standards, technologies such as shore power need to be utilized to their maximum potential.

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1.0 INTRODUCTION

The Government of Canada is investigating ways to reduce emissions from the marine sector. One feasible emission reduction technology is shore power for marine vessels at-berth. Shore power technology enables vessels to turn off their auxiliary engines and use shore-based power instead. As a result, using shore power could reduce air pollution and greenhouse gas emissions from vessels at berth especially when clean energy sources such as hydroelectric, solar, wind, natural gas, and nuclear power are used.

In the 2030 Emissions Reduction Plan,¹ the Government of Canada committed to developing an action plan to enable the marine sector to reduce its emissions. The action plan will explore decarbonization pathways for vessels and investigate supporting shore-side measures. Budget 2023 announced funding of \$165.4 million for a new Green Shipping Corridor Program. Some of this funding may support shore power infrastructure on ships and at ports.

This ECCC project intends to better understand the critical issues related to the installation and operation of shore power at Canadian ports. To achieve this objective the ERG/ECCC team evaluated the readiness of individual ports for adopting shore power. To appreciate the critical factors related to shore power the ERG/ECCC team completed a comprehensive review of publicly available literature (Section 2). The product of this review is a compilation of identified factors associated with successful shore power systems (Section 4). These factors were the basis for a series of interviews with 17 port authorities (Section 5). The results from these interviews were assessed and ranked for readiness, with special attention on barriers identified by the ports for which ECCC may help address in the future to encourage use of shore power (Section 6 and 7).

2.0 LITERATURE REVIEW

To better appreciate the issues related to shore power, the ERG/ECCC team identified and summarized the content of documents recently published or posted. The focus of this literature review is to better understand the factors that impact the successful implementation of standardized shore power systems – with special interest in applications appropriate for Canadian ports.

This shore power literature review focused on the following questions.

- What are the current international standards and guidelines for shore power connections at ports?
- Which Canadian ports currently have shore power?
- What level of power demand/local grid connections do ports need to be able to sustain to provide shore power to ships?
- What is the required infrastructure to deliver this power?

¹ Service Canada, “2030 Emissions Reduction Plan – Sector-by-Sector Overview,” July 12, 2022, <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/sector-overview.html>.

- What kinds of partnerships with utility companies are needed?
- What are the capital and running costs required for a successful shore power program?
- How does the provision of shore power impact the competitiveness of a port?
- What are the training requirements/skilled labour needs for shore power management at Canadian ports?

Below is a summary of our findings from this literature review. Appendix A provides completed literature review forms compiled for this effort. Note, this assessment focuses on the port side of high voltage systems, therefore, low voltage and vessel issues were not investigated in depth.

2.1 Current international standards and guidelines for shore power connections at ports

2.1.1 IEC/IEEE/ISO Standards

In the 2000s, the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE) were both working on an international standard for shore power connections and decided to join forces in a joint working group to ensure there would be only one international standard. They also integrated the International Organization for Standardization (ISO) to ensure all the main international standardization organizations would support the same standard. Nowadays, the brute shore power standardization work is mostly done inside of the Joint Working Group 28 (JWG28) of the IEC, and needs to be accepted by IEEE, ISO, and all national standardization committees involved in the IEC.

An international standard reflects a global consensus of technical experts and provides instructions, guidelines, rules, and definitions to design, manufacture, install, maintain, and repair devices and systems and ensure interoperability. An international standard is always voluntary. However, it becomes mandatory when embedded in rules or directives of a national or regional authority.

The international standard on shore power (IEC/ISO/IEEE 80005) initially published in 2012, ensures worldwide interoperability, compatibility, and safe connection between ports and vessels for high-voltage and low-voltage connections. While it is easier to install shore power tailored to specific vessels frequenting the port, it is not always feasible in such a global industry, thus applying international standards are crucial. Since 2012, the standardization requirements have been established for many vessel types; however, some are still not fully defined. As these standards continue to be finalized, the goal is to provide a straightforward connection for any ship in any port. In Canada, many ports with shore power are already following these international standards.

The IEC/ISO/IEEE standards are developed for specific applications based on the type of vessel. Figure and Table 1. provide an overview of the status of each vessel standard.

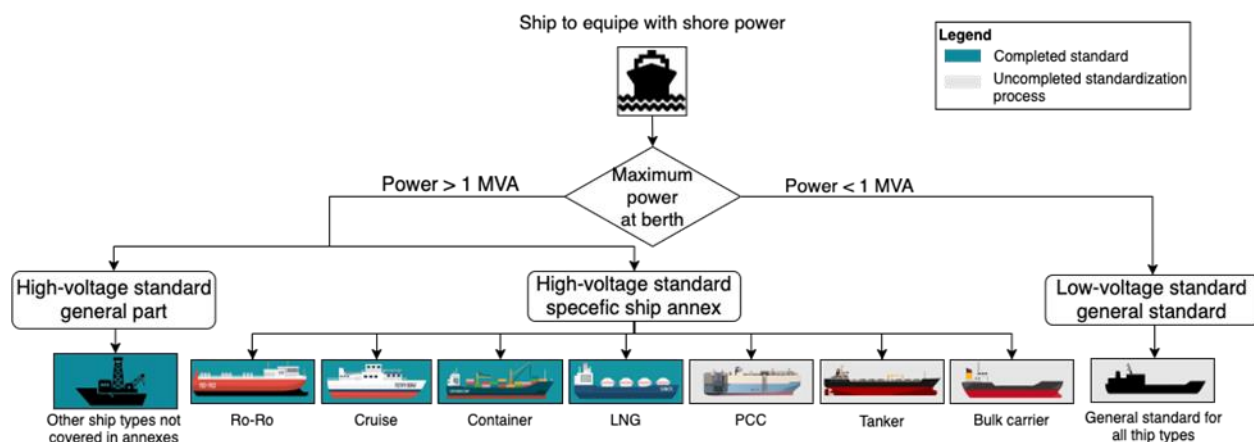


Figure 1. IEC Vessel Standards by Vessel Type

The IEC standards are developed for specific applications based on the type of vessel. Table 1 provides an overview of the status of each vessel standard. Note that standards for cruise ships, container ships, roll-on/roll-off (RORO) vessels, LNG tankers, and Pure Car and Truck Carriers (PCTC) are settled, while standards for tankers, bulk carriers and general cargo vessels are still under development.

Table 1. High Voltage Shore Power Standardization Readiness Based on Ship Type³

Ship type	Applied standard	Status
Cruise	IEC 80005-1	Ready
Container <1000 TEU	IEC 80005-1/IEC 800005-3	Ready/Functional
Container >1000 TEU	IEC 80005-1	Ready
Ro-Ro	IEC 80005-1	Ready
LNG	IEC 80005-1	Ready
Pure Car and Truck Carriers (PCTC)	IEC 80005-1	Ready
Tanker	IEC 80005-1	Standard in redaction
Gearless bulk carriers < 50,000 DWT	IEC 80005-1/IEC 80005-3	Standard in redaction /Functional
Gearless bulk carriers > 50,000 DWT	IEC 80005-1/IEC 80005-3	Standard in redaction /Functional
Geared bulk carriers <25,000 DWT	IEC 80005-1/IEC 80005-3	Standard in redaction /Functional
Geared bulk carriers >25,000 DWT	IEC 80005-1	Standard in redaction
Self-unloaders bulk carriers	IEC 80005-1	Standard in redaction
Gearless general cargo	IEC 80005-1/IEC 80005-3	Standard in redaction /Functional
Geared general cargo <10,000 DWT	IEC 80005-1/IEC 80005-3	Standard in redaction /Functional
Geared general cargo >10,000 DWT	IEC 80005-1	Standard in redaction

Ship type	Applied standard	Status
Heavy lifter general cargo	IEC 80005-1	Standard in redaction

IEC standards related to port operations, including low and high voltage systems and battery storage are noted in the Table 2.

Table 2. International Electrotechnical Commission Shore Power Standard Development²

Shore power type		Interconnectivity	Interoperability	Data communication	International regulation	Enforcement framework
Shore power	High-voltage	IEC 62613-2:2016	IEC/IEEE 80005-1	IEC/IEEE 80005-2	IMO shore power guidelines	IMO shore power guidelines
	Low-voltage	IEC 60309-5	IEC/IEEE 80005-3 (under development, draft ready)	IEC/IEEE 80005-2	IMO shore power guidelines	IMO shore power guidelines
Battery charging	AC charging	IEC 60309-5/ IEC 62613-2	IEC/IEEE 80005-1 or IEC/IEEE 80005-3	Possibility for future development for IEC/IEEE 80005-2 or ISO15118	-	-
	DC charging	(Under development)	IEC 80005-4 (under development)		-	-

All High Voltage Shore Connection (HVSC) installations should meet the requirements of the last revision of IEC/IEEE/ISO 80005-1.³ The current standard applies to systems requiring 1 mega volt-ampere (MVA) of power or more, and more than 1000 V AC. This standard provides significant technical modifications for safety improvements with respect to:

- Grounding requirements
- Procedures for alternative testing
- Specifies the electrical parameters required to ensure safety
- Specifies the connection requirements (number of cables, types of plug, etc.)
- Specifies the required and optional electrical components (transformers, protection relays, etc.)
- Contains specific ship-type annexes integrating additional requirements to the main body of the standard.

² EMSA, “Shore-Side Electricity: Guidance to Port Authorities and Administrations,” EMSA, 2022, <https://emsa.europa.eu/electrification/sse.html#>.

³ International Electrotechnical Commission and Institute of Electrical and Electronics Engineers, Inc, “IEC/IEEE 80005-1:2019(En), Utility Connections in Port — Part 1: High Voltage Shore Connection (HVSC) Systems — General Requirements,” accessed June 20, 2024, <https://www.iso.org/obp/ui/en/#iso:std:iec-ieee:80005-1:ed-2:v1:en>.

Finally, IEC has started to work on the future shore power DC connection 80005-4. DC connections present interesting benefits in terms of cost savings, energy efficiency, and power transfer capability for battery-electric ships or ships with a DC grid. However, the standardization process is still far from any sort of standard and there are not many DC ships yet. Therefore, DC connections are out of scope for this analysis. There is also an online tool to help designers determine the shore power connection type and standard for vessels designed by Sustainable Ships⁴.

2.1.2 European Union Regulations

European Union Directive 2014/94/EU requires the ports in Europe to install shore power facilities on a priority basis by December 31, 2025. In addition, under FuelEU Maritime Initiative, ships over 5,000 GT that berth in an EU port for more than 2 hours will be required to connect to shore power beginning January 1, 2030.⁵ The European Union regulation will enforce ships and ports to comply with the IEC/IEEE/ISO 80005 standard.

2.1.3 CARB Regulations

“In December 2007, California enacted the [Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a California Port](#) Regulation (Existing Regulation).”⁶ This rule was expanded to include a schedule for more vessel types and enhanced administrative structure to implement the program and account for noncompliance. The revised regulation superseded the previous rule effective January 1, 2021,⁷ with implementation being in 2023. The CARB regulation enforces ships and ports to comply with the IEC/IEEE/ISO 80005 standard.

2.1.4 China Regulations

China also has regulations that require China-flagged ships to use shore power (January 1, 2020 for new builds and January 1, 2022 for existing ships without shore power); and all shore power capable ships except for liquid cargo carriers that berth over three hours to use shore power or equivalent measures.⁸

⁴ “Overview of Shore Power Sockets and Plugs - IEC/IEEE 80005,” Sustainable Ships, accessed June 20, 2024, <https://www.sustainable-ships.org/stories/overview-shore-power-sockets-plugs-2>.

⁵ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” research (Environment and Climate Change Canada, October 26, 2022), <https://www.canada.ca/en/services/environment/cumulative-effect/about/salish-sea-ecosystem/shore-power-feasibility.html>.

⁶ California Air Resources Board, “Proposed Control Measure for Ocean-Going Vessels at Berth” (State of California, August 1, 2019), <https://ww2.arb.ca.gov/rulemaking/2019/ogvatberth2019>.

⁷ California Air Resources Board, “Proposed Control Measure for Ocean-Going Vessels at Berth” (State of California, August 1, 2019), <https://ww2.arb.ca.gov/rulemaking/2019/ogvatberth2019>.

⁸ National Port Standardization Technical Committee, “Shore-to-Ship Power Supply System Technical Conditions -- Part 1: High Voltage Connection” (National Standards of People’s Republic of China, March 15, 2018), <https://www.chinesestandard.net/PDF/English.aspx/GBT36028.1-2018>.

As with other international regulations, the rules require standardization of connecting vessels and shoreside equipment. The Standardization Administration of China (SAC) is a vital governmental organization responsible for the development and management of technical standards in the People's Republic of China; including the development of standards related to shore power, largely based on the IEC shore power standards IEC 80005. However, they also include modifications because some specific ship annexes were not implemented yet when the Chinese government decided to make shore power mandatory for domestic ships and international ships equipped with shore power. Therefore, China developed its own national shore power standard, the GB/T 36028.1 for high-voltage connection, and GB/T 36028.2 for low voltage.⁹

2.1.5 IMO Shore Power Guideline

In addition to regulations and standards, there are voluntary guidelines and guidance available at international and local levels including the new IMO interim guideline for shore power connection.¹⁰ This document details the process of connecting from the ship to the shore, the labor training requirements, the communication, and maintenance to ensure safety.

IMO guidelines support and help propagate the available IEC standards. Additionally, class societies, which develop and apply technical standards for the construction and operation of ships, use these guidelines to write their class rules which could require ships to follow the guidelines if they want a class notation for shore power.

The IMO guideline includes six different sections. The first one covers the general applications of the guideline. Then, the second considers verification and testing of the system for the first connection in a port and for repeated connections. The third section discusses operating aspects of shore power connections regarding the personal protecting equipment to use by seafarers and workers on shore followed by a detailed connection and disconnection procedure. Section five covers the safety precautions before maintenance followed by section six which discusses the required documentation. Lastly, section six covers the personnel familiarization aspects with the system.

2.1.6 EMSA Shore Power Guidance

Additionally, there are guidance documents or guidelines being developed for use at specific locations which are also consistent with the IMO guidelines and IEC standards. For example, the European Maritime Safety Agency (EMSA) shore-side electricity guidance for port authorities and administration is an instrument to support the ports in deploying shore power. The guidance helps ports to access, support, evaluate, and develop control measures for the development of shore power for ships involved in international voyages. The guidance is

⁹ National Port Standardization Technical Committee.

¹⁰ "The IMO Released the Interim Guidelines on Safe Operation of Onshore Power Supply Service in Port for Ships Engaged on International Voyages.," IMO, August 22, 2023, <https://www.marineregulations.news/imo-interim-guidelines-on-safe-operation-of-onshore-power-supply-service-in-port-for-ships-engaged-on-international-voyages/>.

available in two parts with the first being about the equipment and technologies and the second about planning, operation, and safety. This EMSA guidance document includes shore battery charging, shore-side power banks, port generators, shore power risk management tools, etc. While it has been written to be used by European countries, the application of IEC standards is the same no matter the location; that said, national electrical rules should also be reviewed for the specific locations where shore power is being implemented. In summary, the EMSA guidance is a tool that can be used to plan, design, and operate shore power projects in Canada.¹¹

2.1.7 PIANC Shore Power Guideline

Additionally, the World Association for Waterborne Transport Infrastructure (PIANC) recently proposed the creation of a working group to create a guideline for shore power shore installations in port.¹² The guidelines are intended to comprehensively cover various technical aspects of shore power, including planning, design, financing, implementation, operation, and maintenance. They will address issues like electrical and civil engineering requirements, available power supply in ports, technical solutions, safety measures, costs, and integration into port infrastructure and security planning. Additionally, the guidelines will explore future opportunities for shore power, such as its role in port microgrids and its compatibility with emerging technologies like battery-powered vessels and smart grids. While PIANC is considering this study, the committee has not yet initiated the work.

2.1.8 Transport Canada

Transport Canada developed ship electrical standards in 2018 that set standards for safety for installation, design, and construction of electrical installation of shore power and operation in Canada.¹³

2.1.9 TMQ Guidance

Technopole Maritime du Québec (TMQ) has teamed with MERLIN to expand access to research and development expertise, with a focus on facilitating the realization of groundbreaking projects intended to address the multifaceted challenges intrinsic to the maritime industry. The study authored by "Innovation Maritime" is a comprehensive examination of shore power implementation in the maritime industry in Quebec, focusing on the context, current status, challenges, and benefits.¹⁴ It begins with an overview of regulations and the current electrification of docks and merchant vessels. Additionally, the report identifies key factors for the successful implementation of shore power projects, drawing from the experiences of ports worldwide. Annexes of the report, provide detailed information on connection standards, frequency converters, and the market landscape of shore power services providers, making this

¹¹ EMSA, "Shore-Side Electricity Guidance to Port Authorities and Administrations."

¹² PIANC, "Guidelines for Onshore Power Supply (OPS) for Ships" (The World Association for Waterborne Transport Infrastructure, 2023).

¹³ Transport Canada, "Ships Electrical Standards (2018) - TP 127 E," Transport Canada, May 24, 2018, <https://tc.canada.ca/en/marine-transportation/marine-safety/ships-electrical-standards-2018-tp-127-e>.

¹⁴ MMM Merlin, "Étude et État Des Lieux Sur Les Technologies d'électrification Des Quais Au Québec," April 2022.

report a valuable resource for stakeholders interested in the development of shore power infrastructure in Quebec and beyond.

Their key recommendations for a successful shore power project are:

1. Initial analysis: Perform initial analysis on available financial support.
2. Selection of the terminal: Not all berths are good candidates for shore power projects. Maritime traffic requires power and possible berth arrangements need to be analyzed.
3. Terminal utilization and electrical consumption: Perform an analysis of the berth utilization and electrical consumption to determine what will be the return on investment.
4. Distance from local communities: Shore power projects will improve air quality and reduce noise in port. Therefore, projects that are close to local communities should be prioritized.
5. Involvement of shipowners: Verify how many ships already have shore power equipment and involve shipowners in the project so they can coordinate the conversion of their fleet to shore power with the port.
6. Container berths require multiple connection points: While many ship types always berth at the same location, container berths connect to multiple connection points.

2.2 Canadian ports currently using shore power

A variety of online websites were reviewed to identify ports with shore power and where data was available, determine if the shore power system was a standardized low voltage system (less than 1,000 kV), a standardized high voltage system (greater than 1,000 kV), or other. These findings are presented in Table 3 (note ports have been included that have shore power but the system is not standardized).

Table 3. Canadian Ports with Shore Power

Port	Shore Power	Standardized High Voltage
Vancouver ^a	Y	Y
Montreal ^b	Y	Y
Halifax ^c	Y	Y
Prince Rupert ^d	Y	Y
St. John's ^e	Y	N
Hamilton-Oshawa ^f	Y	N
Port de Trois-Riveres ^h	Y	N
Quebec ^h	Y	N
Nanaimo ^g	Y	N

^a <https://www.portvancouver.com/climate-and-air-quality-action>

^b <https://green-marine.org/stayinformed/news/shore-power-for-cruise-ships-at-the-port-of-montreal/>

^c https://aapa.files.cms-plus.com/SeminarPresentations/2015Seminars/2015Cruise/McGrail_Catherine.pdf

- d <https://www.rupertport.com/port-of-prince-rupert-activates-shore-power-to-reduce-ship-emissions/#:~:text=The%20shore%20power%20project%20is,zero%20carbon%20emissions%20by%202050.>
- e <https://sipa-apsj.com/marine-operations/shore-power/>
- f <https://northendbreezes.com/understanding-shore-power-with-hopa-ports/>
- g <https://npa.ca/marina/marina-operations/moorage/>
- h [Information provided by Transport Canada \(12/14/2023\)](#)
- i [Veracity by DNV, interactive map with current availability of alternative fuels and energy](#)

It has been observed that only a few ports have a standardized shore power connection system. However, many ports do offer wintering shore power services. This type of shore power is a non-standardized shore power connection that is generally low power and low voltage. It is generally used to supply ships with power that are not in use during the winter months. For example, vessels that cannot trade when the seaway is closed because of the ice in the lock system and in the St. Lawrence and Great Lakes often used wintering shore power connections. Since these shore power connections are generally not located at commercial berths, are too low in power to supply normal power demand, and are not standardized, they are not the focus of this analysis.

2.3 Level of power demand/local grid connections for ports to provide shore power to ships

Power demand varies by vessel type and duration that a vessel spends dockside. Data documenting the power usage at U.S. ports was compiled for the EPA’s Shore Power Technology Assessment. In summary, U.S. ports have a wide range of shore power capacities, from a maximum capacity of 0.025 MW at smaller ports servicing fishing vessels to 40 MW at larger ports for container ships and cruise liners. Average annual usage also varies, from 1,490 MWh at smaller ports to 32,087 MWh at larger ones. Voltage requirements are typically 6.6 kV and 11 kV for larger ports and vessels, while smaller ports and specific vessels like fishing boats and tugs use 0.48 kV and 0.22 kV. The average annual usage for each port also varies widely depending on the port and the types of vessels it services.¹⁵

In evaluating the shore power energy costs and cost savings of the new CARB shore power regulation, CARB surveyed their ports to compile data on energy demands of shore power connections. For this analysis, typical auxiliary power values were developed by vessel type as noted in Table 4.

Table 4. CARB Assumptions for Auxiliary Power Demand by Vessel Type¹⁶

Vessel Auxiliary Engine Effective Power	Units	Value
Average Container/Reefer Vessel Power	kW/vessel	1,053

¹⁵ OAR US EPA, “Shore Power Technology Assessment at U.S. Ports,” Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

¹⁶ California Air Resources Board, “Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). Proposed Control Measure for Ocean-Going Vessels At Berth,” August 1, 2019, 46.

Average Cruise Vessel Power	kW/vessel	5,620
Average Ro-Ro Vessel Power	kW/vessel	1,159
Average Tanker Vessel Power (Aux. Engines)	kW/vessel	944

In addition to the ports included in the EPA and CARB studies, The ECCC/ National Research Council shore power feasibility study for the Salish Sea estimated power requirements would be 735-1,057 kW/hr per containership and 736-1,000 kW/hr per tanker.”¹⁷ These values are consistent with those presented in Table 4. CARB Assumptions for Auxiliary Power Demand by Vessel Type.

These power values can be applied to hours at dockside, connected to shore power, to estimate total kW hrs. Duration times can vary by port and vessel type as noted in Table 5.

Table 5. Average Time at Berth (hrs) by Port and Vessel Type for Select U.S. Ports in 2020

Vessel Type	POLB	NY/NJ	Seattle	Tacoma	POLA
Container	54.3	31.6	32.0	43.1	61.8
Tanker	36.1	38.1	NA	NA	37.7
RORO	21.5	21.4	NA	18.1	21.5
Cruise	32.1100	16101	8-10102	NA	36.7103

Table 6. Average Time at Berth (Days) Per Port Call Per Vessel Type in the World in 2022¹⁸

Vessel Type	Average time in port
Liquid bulk carriers	0.99
Liquid petroleum gas carriers	1.03
Liquefied natural gas carriers	1.12
Dry bulk carriers	2.18
Break bulk carriers	1.14
Roll-on/roll-off ships	-
Container ships	0.80
Passenger ships	-

Another study that can be used to determine the average power demand of ships in port is the IMO’s Fourth Greenhouse Gas Study¹⁹ which includes power tables for each ship type and size. The power table is available in the annex. However, the power table is based on the average power demand of the ship at berth and not the peak power while connected to shore power.

¹⁷ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” October 26, 2022.

¹⁸ UNCTAD Statistical Portal, “PortCalls,” Port call and performance statistics: time spent in ports, vessel age and size, annual, March 28, 2024, <https://unctadstat.unctad.org/datacentre/dataviewer/US.PortCalls>.

¹⁹ IMO, “Fourth Greenhouse Gas Study 2020,” 2020, accessed June 20, 2024, <https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx>.

This means the maximum level of power a ship may require is not captured in the power table and therefore may result in an underestimation of maximum power needs. Therefore, the power table can be used for emission or electrical demand estimations only and cannot be used for estimations such as capacity planning.

Finally, a TMQ shore power study developed a table presented in Table 7. Power and Electrical Frequencies Per Type of Ships in the World covering the power demand and internal electrical frequency of ships in the world. The table is based on their own data and an ABB study.²⁰

Table 7. Power and Electrical Frequencies Per Type of Ships in the World

Vessel Type	Average power demand	Peak power demand	Peak power demand for 95% of ships	50 Hz	60 Hz
Container ships (<140 m)	0.17	1	0.8	63%	37%
Container ships (>140 m)	1.2	8	5	6%	94%
All container ships	0.8	8	4	26%	74%
Liquid bulk	1.4	2.7	2.5	20%	80%
Cruise ships (<200 m)	4.1	7.8	6.7	36%	64%
Cruise ships (>200 m)	7.5	11	9.5	-	100%
Cruise ships (>300 m)	10	20	12.5	-	100%
All cruise ships	-	-	-	17%	83%
Bulk carriers	0.3	2.1	1.5	30%	70%

The values included above are helpful to roughly approximate power demand without implementing a more detailed port specific assessment that considers the specific vessels visiting the port, the actual power rating of their auxiliary engines they typically operate while dockside, a representative engine load level, and the duration that these engines are operating at the Canadian ports of interest. Additionally, as noted in the Salish Sea Study, when evaluating a ports demand for electricity, it is necessary to also account for expansion of services as more vessels are equipped to connect to shore power systems, and future electrification of port equipment such as cargo handling equipment and truck drayage.²¹

2.4 Required infrastructure to deliver this power

The general arrangement of a shore power installation is presented in Figure .

²⁰ P. Ericsson and I. Fazlagic, "Shore-Side Power Supply - a Feasibility Study and a Technical Solution for an on-Shore Electrical Infrastructure to Supply Vessels with Electrical Power While in Port," 2008, <https://www.semanticscholar.org/paper/Shore-side-power-supply-a-feasibility-study-and-a-Ericsson-Fazlagic/7aa2d75420bb6cc1c83e9c631c652b41766cd4da>.

²¹ Environment and Climate Change Canada and NRC, "Shore Power Feasibility Study in the Salish Sea," October 26, 2022.

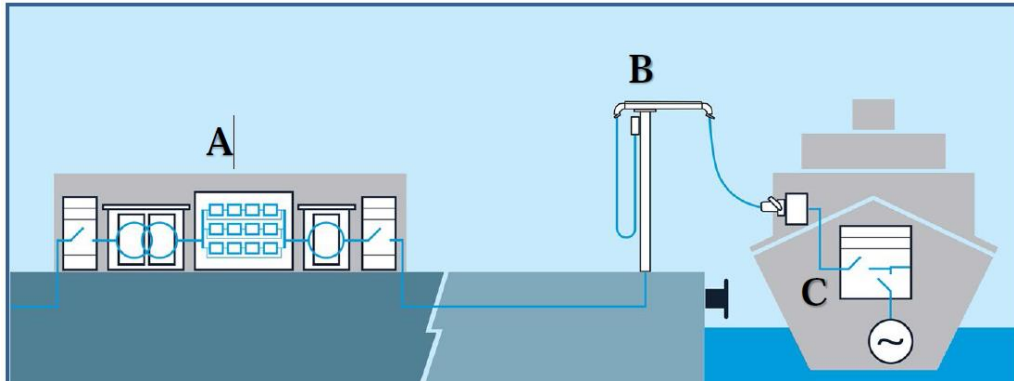


Figure 2. Schematic Showing Example Shore Power Infrastructure, Including the Electrical Substation (A), Cable Interface (B), and Ship’s Electrical Equipment (C)

All shore power systems require an electrical substation that converts the electricity from the grid, or from a local dedicated generator into the right voltage and cycles for the vessels.

Based on IEC 80005-1 high-voltage standard covers the electrical components needed to connect a vessel to a shore power system. Figure presents the electrical diagram of a HVSC system, noting the essential infrastructure elements.²²

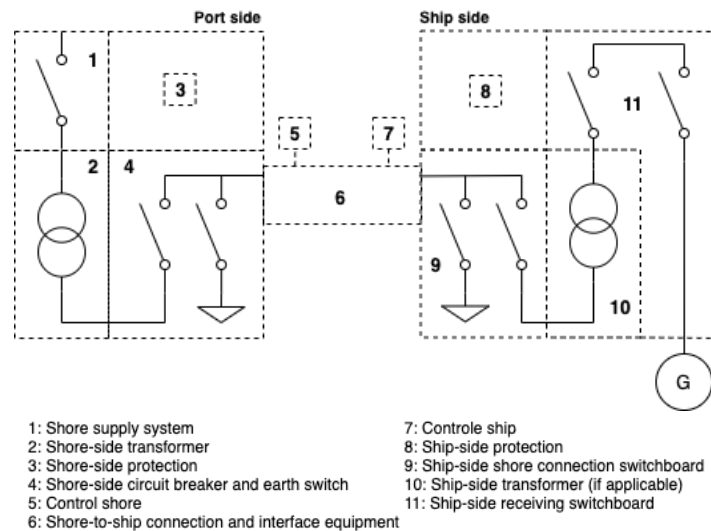


Figure 3. Block Diagram of a High-Voltage Shore Connection

Shore power systems can be dock mounted, containerized, or barge mounted. Dock-mounted systems have transformer equipment and cable-positioning devices to help vessels connect to the system at-berth as noted in Figure . Containerized systems include all the elements found in a dock-mounted system into a standard shipping container. Barge-mounted systems are self-

²² International Electrotechnical Commission and Institute of Electrical and Electronics Engineers, Inc, “IEC/IEEE 80005-1:2019(En), Utility Connections in Port — Part 1: High Voltage Shore Connection (HVSC) Systems — General Requirements.”

contained power plants that typically use alternative fuels or technologies such as liquefied natural gas (LNG) or fuel cells.²³

As previously mentioned, the EMSA guidance details deeply the requirements for infrastructure, electrical distribution layouts, electrical components, civil engineering works, etc.

The cable management system (CMS) typically safely stores, deploys and recovers the cables and connectors necessary for the shore power connection. Examples of different CMS are shown in Figure . The CMS cables then plug in to a receptacle with sockets or inlets.²⁴ The number of cables to put in parallel to supply the ship’s load vary between the different voltage levels. While a 690 V connection can supply 1 MVA with three cables in parallel, 440 V system requires 4 cables, and 400 V requires 5 cables.²⁵

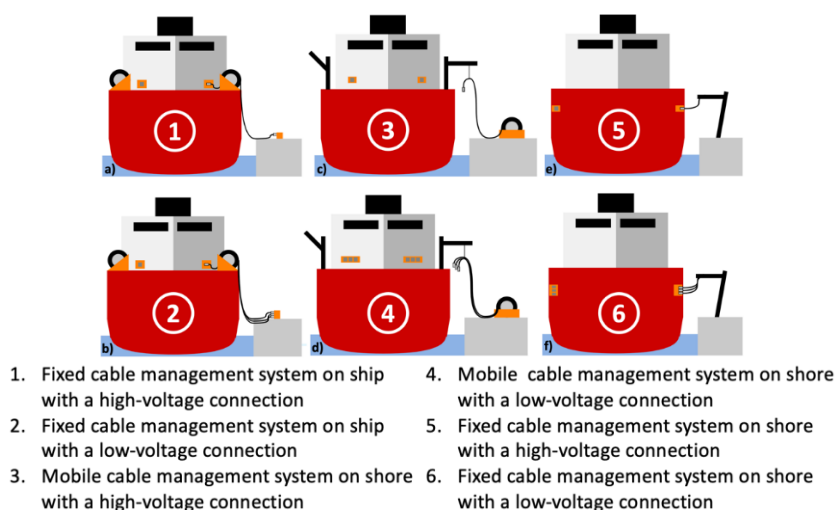


Figure 4. Possible Cable Management Systems^{26,27}

The type and capacity of infrastructure required varies by port and is based on the number of berths with shore power, the individual vessels that are shore power ready that visit the port,

²³ US EPA, “Shore Power Technology Assessment at U.S. Ports,” March 20, 2017.

²⁴ OAR US EPA, “Shore Power Technology Assessment at U.S. Ports,” Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

²⁵ Siamak Karimi, Mehdi Zadeh, and Jon Suul, “Shore Charging for Plug-In Battery-Powered Ships: Power System Architecture, Infrastructure, and Control,” *IEEE Electrification Magazine* 8 (September 1, 2020): 47–61, <https://doi.org/10.1109/MELE.2020.3005699>.

²⁶ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” research (Environment and Climate Change Canada, October 26, 2022), <https://www.canada.ca/en/services/environment/cumulative-effect/about/salish-sea-ecosystem/shore-power-feasibility.html>.

²⁷ Hugo Daniel et al., “A Journey into Electrical Standardization of Shore Power Connections for Bulk Carriers,” n.d.

and the duration they spend dockside loading and unloading cargo. For example, the shore power study for Salish Sea terminals quantified operations by terminal) (Table 8).²⁸

Table 8. Centerm Terminal and Deltaport Vessel Activity

Terminal	Centerm	Deltaport
Vessel type	Containership	
Number of berths with Shore Power	2	1
Annual number of connection	75	0*
Maximum number of vessel that can be serviced concurrently	5	3
Possible additional berths	1	1
Maximum power requirement	6.6kV 7.5 MVA, 60 hz	
Total dockside Duration hours (2018)	7,418	19,447

* Because of the orientation of vessels docking at Deltaport, no vessels could be connected in 2018.

In addition to the physical elements of shore power infrastructure, there are also data systems requirements that should be built into the infrastructure assessment which include data system to:

- Track vessel commissioning,
- Schedule shore power ready vessels to berths with power and,
- Monitoring system to track, control power usage and generate standardized invoicing.²⁹

There are a variety of shore power data systems being developed, for example, the Port of Kiel in conjunction with Siemens is developing a cloud-based power monitoring system.

Lastly, to protect investments in shore power infrastructure; it is necessary to develop and implement a maintenance plan that monitors and replaces high use components prior to breakdown (including stockpiling of critical spare parts).³⁰ These maintenance activities ensure that vessels that are shore power ready can always connect to the ports system, maximizing the anticipated benefits of these initiatives.

Required utility company partnerships Based on the references considered for this report, utility companies are a critical element for the successful implementation of any shore power initiative. For example, a criticism of CARB’s expansion of their shore power regulations was

²⁸ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” (Environment and Climate Change Canada, October 26, 2022), <https://www.canada.ca/en/services/environment/cumulative-effect/about/salish-sea-ecosystem/shore-power-feasibility.html>.

²⁹ International Electrotechnical Commission and Institute of Electrical and Electronics Engineers, Inc, “IEC/IEEE 80005-1:2019(En), Utility Connections in Port — Part 1: High Voltage Shore Connection (HVSC) Systems — General Requirements.”

³⁰ International Electrotechnical Commission and Institute of Electrical and Electronics Engineers, Inc.

that the utilities were unprepared for the impact their new regulations would have on their local infrastructure and need for additional power supplies.³¹ It is critical that ports and utilities jointly implement an infrastructure scoping study as early as possible to assess anticipated power demand and required changes to the power grid and port infrastructure.

From the case studies included in the EPA shore power report, nearly all ports (specifically Hueneme, Seattle, and NY/NJ) noted the importance of engaging with local utilities, early in the planning process and continuing with frequently open dialogue to ensure that the local power grid can be tied into the port system, assessing the need for additional infrastructure such as supplemental power legs into the port and substations and to ensure that the voltage provided is consistent with international standards. Additionally, it is critical to include local communities in these discussions to ensure that the provision of shore power does not have a detrimental impact to local communities' electrical services.³²

The relationship between British Columbia Hydro (BC Hydro) power and Vancouver Fraser Port Authority is an excellent example of the value of a close relationship between ports and utility companies to successfully implement a shore power project. VFPA has an Industrial Energy Manager who acts as a liaison between port terminals, tenants, port authority project teams and BC Hydro. This ensures that BC Hydro has enough power to supply vessels using shore power, while considering options to address future electrification of port equipment such as cargo handling equipment and truck drayage. This included recent plans to upgrade power lines and connections to BC Hydro's grid.³³

Interruptions of power supply is a critical issue to the success of shore power as noted in the EPA study. Several ports (e.g., Los Angeles and NY/NJ) indicated that the utility company has the discretion to interrupt service. These interruptions can be unlimited in frequency and duration when operating reserves are inadequate particularly during periods of peak demand.³⁴ It is also important to work with local utilities to coordinate vessel shore power connections to help the local utility companies manage peak demand. Shore power connections, particularly with regard to cruise ships can be very intermittent and represent significantly large power demands on the local grid. For example, Figure presents typical weekday power demand for the month of July at the Port of Ancona, Italy.

³¹ OAR US EPA, "Shore Power Technology Assessment at U.S. Ports," Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

³² OAR US EPA, "Shore Power Technology Assessment at U.S. Ports," Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

³³ Environment and Climate Change Canada and NRC, "Shore Power Feasibility Study in the Salish Sea," research (Environment and Climate Change Canada, October 26, 2022), <https://www.canada.ca/en/services/environment/cumulative-effect/about/salish-sea-ecosystem/shore-power-feasibility.html>.

³⁴ OAR US EPA, "Shore Power Technology Assessment at U.S. Ports," Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

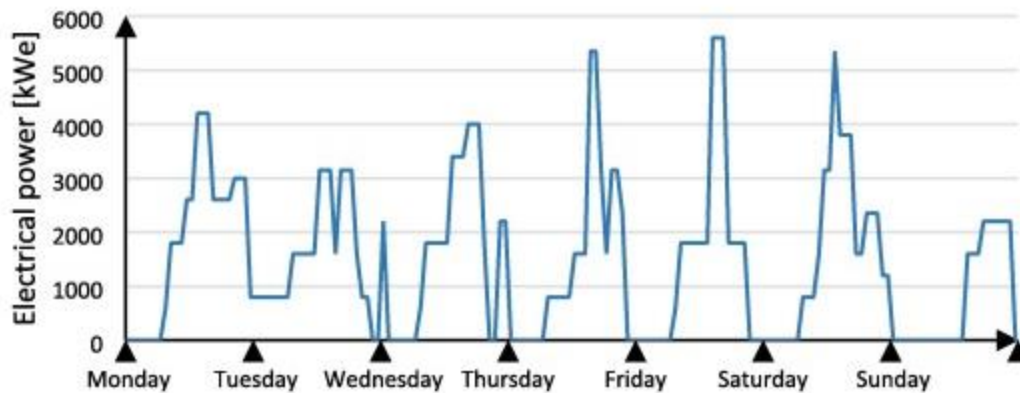


Figure 5. Example Weekday Power Demand for Port of Ancona - July³⁵

In Quebec, only one standardized shore power connection exists and is located in Montreal for cruise ships. Since the Port of Montreal paid for the totality of the electrical installations, Hydro-Quebec offers a special tariff to the Port of Montreal with a low energy cost.

A major issue of future shore power projects in Quebec is the availability of power. With the fast energy transition that is happening, the Hydro-Quebec installations have reached their maximum capacity during the peak power demand periods. Since the available power for new projects is limited, the Government of Quebec has released a form that every organization needs to submit to the government if their project exceeds 5000 kW of power.³⁶ The cruise ship shore power projects are the most affected by this issue since they have an extremely high-power demand. However, this concern is mitigated as the cruise season is not during the winter peak power demand. Hydro-Quebec is also prioritizing interruptibility meaning they have the ability to shut down shore power when the peak power demand occurs. Hydro-Quebec has dedicated representatives for ports who are in charge of all shore power projects and helping ports to better manage their energy and shore power projects.

In Europe, the European On-shore Power Supply Association (EOPSA) has a proactive strategy to accelerate shore power projects. As shore power has existed for more than 30 years in Europe but did not grow as expected, they suggest changing the current shore power mechanism. To do so, they believe electrical operators, much more experienced with electrical installations and

³⁵ Daniele Colarossi and Paolo Principi, "Technical Analysis and Economic Evaluation of a Complex Shore-to-Ship Power Supply System," *Applied Thermal Engineering* 181 (November 1, 2020): 115988, <https://doi.org/10.1016/j.applthermaleng.2020.115988>.

³⁶ Gouvernement du Québec, "Raccordement des projets d'une puissance de 5 MW et plus - Les critères d'analyse pour l'octroi d'un bloc d'électricité rendus publics," Gouvernement du Québec, accessed June 20, 2024, <https://www.quebec.ca/nouvelles/actualites/details/raccordement-des-projets-dune-puissance-de-5-mw-et-plus-les-criteres-danalyse-pour-loctroi-dun-bloc-deelectricite-rendus-publics-47778>.

electrical infrastructure work should be the ones that are in direct contact with the ships to sell the electricity.³⁷

2.5 Capital and running costs required for a successful shore power program

2.5.1 Capital Costs

The Salish Sea study noted that landside shore power installation costs vary based on several factors including terminal configuration, existing infrastructure, and grid connectivity.⁵ One of the better sources of data to assess capital for shore power is the CARB economic data used for the new shore power regulations. This detailed assessment covered one-time equipment capital and installation costs as well as recurring costs for maintenance, labor, fuel, electricity, and administrative costs. The basis for this assessment is a survey of ports conducted in April 2018. A wide range of retrofit costs were reported in the survey, which varied by individual project and vessel type. The majority of California berths contain shore power infrastructure. Port costs to retrofit an existing berth for container or reefer vessels, cruise ships, and tankers are provided in Table 9. Also included is a cost estimate for the installation of a single vault.³⁸

Table 9. CARB Capital Cost Estimates for Shore Power by Vessel Type

Data Input	Value	Basis
Shore power berth retrofit cost per Container/Reefer berth	\$7,010,813 per berth	\$6,316,048 per berth converted from 2012\$ to 2019\$. This is the cost to install shore power at a berth that does not already have shore power. Average of June 2018 survey values ranging from \$3,200,000 to \$11,750,000 total cost per berth (assumed to be in 2012\$). Includes costs to bring additional power to the terminal where survey respondents indicated it would be needed and provided cost estimates.
Shore power berth retrofit cost per Cruise berth	\$83,200,000 per berth (site-specific estimate for Port of San Francisco only)	Estimate provided to staff by the Port of San Francisco in an email to Nicole Light of CARB dated 5/1/19 and discussed on a 5/6/19 phone call. Staff Berth Analysis indicates only the Port of San Francisco would retrofit a Cruise berth for shore power.
Shore power berth retrofit cost per Tanker berth	\$21,983,333 per berth	Average of June 2018 survey values ranging from \$2,250,000 to \$40,000,000 per berth.
Shore power vault Installation	\$1,993,255 per vault	\$1,795,725 per vault converted from 2012\$ to 2019\$. This is the cost to install an additional shore power vault at a berth that already has shore power. Average of June 2018 survey values ranging from \$800,000 to \$3,133,333 total cost per vault (assumed to be in 2012\$).

³⁷ EOPSA, "Port Sustainability and Electrification" (European Onshore Power Supply Association), accessed June 20, 2024, <https://www.eopsa.eu/position-paper>.

³⁸ California Air Resources Board, "Proposed Control Measure for Ocean-Going Vessels at Berth" (State of California, August 1, 2019), <https://ww2.arb.ca.gov/rulemaking/2019/ogvatberth2019>.

For Vancouver Fraser Port, Deltaport reported the cost to equip a single containership terminal for shore power was 6.8 million (CAD) and Centerm reported the cost to be 7.2 million (CAD) which is within the range of values noted in the CARB assessment.³⁹

Several ports included in the EPA study noted the importance to invest in quality, which includes hardware components, scheduling and monitoring systems, and training of technical staff.⁴⁰

In addition to the actual cost to build a shore power system, several studies noted that such construction projects can be disruptive to port activities or the adjacent communities which needs to be taken into consideration as part of the initial planning and system design.⁴¹

Furthermore, the TMQ report cites an Australian shore power feasibility study that was made for the White Bay cruise terminal.⁴² The study aimed to install a 15 MVA shore power connection that also include a frequency converter. Even if most ships in the world work on 60 Hz internal electrical frequency, many also operate on 50 Hz. It is the port duty to supply the different electrical frequencies. The study also includes 21 connection points which is particularly high for a project of this type. The costs are summarized in Table 10.

Table 10. Summary of the Costs for the White Bay Shore Power Project for Cruise Ships Cited in the TMQ Report (in Australian \$)

Items	Cost	Comments
Design cost by Ausgrid	200,000 \$	Electrical supplier
Design of an electrical link between the connection point and the White Bay site	400,000 \$	At this step, the main electrical distribution station is not required to be updated.
Cost and supply of the underground cable of 33 kV.	5-7 M\$	The installation is based on the Ausgrid standard NS168. The cost covers the following design elements: supply of a 2.5 to 3.5 km underground cable at 33 kV depending on the selected trajectory.
Cost of design and installation of the shore power equipment on-site	10-12 M\$	Budgeted cost by Siemens, ABB, and Schneider
Cost of design of the shore power cable management system	2-3 M\$	Budgeted by Siemens and Schneider
Project management	2.9 M\$	Definition of the technical specifications, contract

³⁹ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” October 26, 2022.

⁴⁰ OAR US EPA, “Shore Power Technology Assessment at U.S. Ports,” Reports and Assessments, March 20, 2017, <https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports>.

⁴¹ US EPA.

⁴² Navari Pty Ltd, “Final Report for Shore Power Feasibility Study for White Bay Cruise Terminal,” 2016.

Items	Cost	Comments
		management, and project management
Contingency	10%	Typical for a project of this nature
Total budgeted cost	23 M\$ - 28 M\$	Suggest a +30%/-10% margin.

The British Port Association report on shore power also performed an analysis of investment cost for shore power projects in the world which is detailed in Table 11 and Table 12.⁴³

Table 11. Characteristics and Funding of Shore Power Project at Canadian Ports from the British Association Shore Power Study

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
Halifax	Cruise berth 22	Cruise	2014	USD 10	20	75% Public funding \$10-million cooperative initiative among the Government of Canada, the Province of Nova Scotia and the Port of Halifax. Transport Canada will contribute up to \$5 million to the project. The Province of Nova Scotia and the Port of Halifax will each contribute an additional \$2.5 million.
Montreal	Berth 25,27,29 and M2	Cruise, bulk layup	2017	CAN 11	9.6	C\$5m from SPTP; C\$3m from Quebec Government; C\$3m from the Port
Prince Rupert		Container	2011	CAN 3.6	6	Transport Canada, under the Marine Shore Power Program, will contribute \$1.8 million to the project. This funding is in addition to \$700,000 contributed by Western Economic Diversification Canada, \$200,000 from the Government of British Columbia, and \$900,000 from the PRPA and its partners, CN Rail and Maher Terminals.
Vancouver	Deltaport in Delta, B.C.	Container	2017	CAN 12	7.5	50% public funding Total project funding is \$12 million: \$6 million from Transport Canada's Shore Power Technology for Ports Program

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Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
						and \$6 million from the Vancouver Fraser Port Authority. Both operational by the end of 2018.
Vancouver	Centerm in Vancouver	Container	2019	CAD 6.8	7.5	\$3.55m from Shore Power Technology Programme; other half from Vancouver Fraser Port Authority

Table 12. Characteristics and Funding of Shore Power Project at International Ports from the British Association Shore Power Study

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
Bergen	Skolten/ Montelabo	Cruise	2020	NOK 84	20	Port rec'd 50m NOK from Enova, a state-owned grant scheme BKK (a renewables company) and Bergen Port apply for NOK 50 million in establishment support from Enova. The rest split on the companies themselves, but in the calculus it is that the cruise ships cover the investment over time.
Bergen		OSV	2015	NOK 7.5	0.5	72% public funding Bergen Municipality (NOK 2 million), Hordaland County Municipality (NOK 1.5 million) and Enova (NOK 1.9 million). The rest is paid by the port authority.
Dunkirk		Container	2019	EUR 2.2	8	Co-financed by the Urban Community of Dunkirk, the Hauts-de-France region (via the European Regional Development Fund), and the Port of Dunkirk. The €1.2M installation at Terminal de Flandres was provided for the port authority (GPM de Dunkerque) by ACTEMIUM, part of Vinci Energies.
Genoa	Vado Gateway	Container	2020	EUR 4.5	40	Unknown
Genoa			2020	EUR 8	9.5	Unknown

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
Gothenburg	Quay 46-49	RoPax	2010	SEK 7	2.5	Estimated 40% from Kilmatklivet fund
Hamburg	Altona cruise Terminal	Cruise	2016	EUR 10	12	The ten-million-euro shore power system in Altona was funded by the federal government and the EU with 7.2 million euros.
Hamburg	Container	Container	2022	EUR 76	33.5	Under discussion
Juneau (Alaska)	Princess Cruise-berth		2002	USD 5.5	11	Princess spent approximately \$5.5 million to construct the shore side facilities and to retrofit the vessels (about \$500,000 each)
Kiel	Norwegenkai terminal (ferries - color line)	Ferry; Cruise	2019	EUR 1.5	4.5	30% (€400k) from state of Schleswig-Holstein from a fund that supports port infrastructure. The rest was from the Port of Kiel
Kiel	Ostseekai (cruise) and Stena's Schwedenkai (ferry) berth	Ferry; Cruise	2020	EUR 15	12.8	Funding from EU CEF (TEN-T), and federal state of Schleswig-Holstein (the same fund as the Norwegenkai project)
Kristiansand		Cruise	2014	NOK 4.2	0.5	Funded by the port, although the ferry company Color Line also made separate significant investment made possible by the NOx fund
Kristiansand		Ferries and cruise	2018	Nok 38	16	The plant costs close to NOK 40 million and is paid for by the EU Innovation Fund Horizon. The port itself pays the infrastructure, which amounts to NOK 3-4 million
Livorno			2015	EUR 3.5	12	Livorno Port Authority received specific cofinancing from the Italian Ministry of Environment (60%) and from the Region of Tuscany (20%)
Long Beach		Tanker, cruise, container	2008	USD 185	60	~70% grant funded. Remainder recouped from tenants (terminals)

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
Los Angeles		Container, cruise	2004	USD 23.7	60	\$25.5m
Marseille	Quai de la Méridionale	Ropax	2015	EUR 4.4	1.5	Part financed by national and regional government aid: funding by the GPMM , La Méridionale, the State, the Feder, l 'Ademe and the Provence-Alpes-Côte d'Azur Region
Marseille	Eastern Harbour		2022	EUR 20	25	80% public grant funding: 4.5 million ERDF(FEDER) funds; Port of Marseille (GPMM) has signed a objectives and financing agreement with the Departmental Council of Bouches-du-Rhône. The latter undertook to finance up to 41%, up to a limit of € 6M, for the electrification of four berths
New York	Brooklyn cruise terminal (1 berth)		2011	USD 21	20	PA/NY/NJ voted to spend \$12.1 million to build a shore power station. EPA granted another \$2.9 million for the project, and the Empire State Development Corporation allocated \$4.3 million to the project, for a total of \$19.3 million.
Oakland		Container	2013	USD 70	8	The Bay Area Air Quality Management District and U.S. Maritime Administration (MARAD) contributed \$12.8 million to the Port's shore power project; up to an additional approximate \$20 million were awarded to the Port by the California Air Resources Board (CARB) and the Metropolitan Transportation Commission (MTC)/Federal Highway Administration.
Oslo		Cruise	2011	NOK 7.8	4.5	Port of Oslo NOK 2 million Color line NOK 15.2 million Support Transnova NOK 2 million Support Enova NOK 3.7 million
Osle	Utstikker 2		2019	NOK 17	3	NOK 9m from Enova.

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
	Vippetangen					
Oslo	Sjursøykai		2020	NOK 18	4	NOK 9.1m from Enova.
Palma de Mallorca	Muelles Paraires – Norte	Ferries	2020	EUR 2.1	1.6	20% financed by the CEF European funding instrument
Rotterdam	Parkkade		2020	EUR 1.5	0	€500,000 mainly coming from the government via the Dutch National Collaboration Programme on Air Quality, will aim to find the best way to improve air quality, particularly in urban areas. A second €1,500,000 trial is scheduled for 2020 focusing on innovative shore power concepts for larger sea-going vessels.
San Francisco	Pier 27	Cruise reefers	2010	USD 5.2	16	\$1.9 million – Bay Area Air Quality Management District (Carl Moyer Program); \$1.3 million – San Francisco Public Utilities Commission (capital funds); \$1.0 million – US Environmental Protection Agency (Diesel Emission Reduction Act Program); \$1.0 million – Port of San Francisco (capital funds); San Francisco Public Utilities Commission budgeted \$500,000 for “upstream” improvements to its electrical infrastructure.
Seattle		Cruise	2005	USD 1.8	16	Grid upgrade costs helped with a \$50k grant from EPA
Toulon	Toulon Côte d’Azur (TCA) terminal	Ferries	2021	EUR 15	7	Zero Fumee plan Region (CRET + FEDER): 6.13 million € Métropole TPM: 4.39 million € Var Departmental Council: 3.6 million € State: 0.87 million €
Valencia			2023	EUR 8.5	30	The two projects are expected to be launched during 2020 (April in the case of the substation and June in the case of legislative homogenization) and that they have grants from the European Union. However, the president of

Port	Terminal	Vessel Types	Date	Cost (millions)	Capacity (MW)	Funding
						the APV has defended that, given the relevance of both projects, "Valenciaport will continue with or without European grants."

The cost analysis shows that shore power projects vary tremendously based on the capacity delivered, ship type, and coverage type. Often, cruise and container berths are targeted as they present the best emission reduction opportunities, and they were the first ship types to benefit from the international standard on shore power (IEC/ISO/IEEE 80005) as described in section 2.1.1 IEC/IEEE/ISO Standards.

2.5.2 Running Costs

Cost to operate shore power includes multiple components:

- Labor cost to commission a vessel, connect and disconnect during each visit,
- Ongoing maintenance costs, and
- Electrical charges for the power used.

2.5.3 Labor

The CARB study estimated the average labor cost to connect and disconnect a vessel to a shore power system was \$2,355 for each shore power visit. This estimate was based on conversations with terminal. Note this value does not represent the labor associated with connecting and disconnecting tankers.⁴⁴

2.5.4 Maintenance

Shore power systems are designed for an operating life of 20 years. However, during that period there is ongoing monitoring of the system to ensure it is functioning correctly, and high use components are replaced prior to a malfunction event.

CARB estimated that the annual shore power terminal equipment maintenance for containership/reefer terminal costs \$24,285 annually per berth. The basis for this analysis is the average of 2018 survey or ports which provided estimates from \$4,000 to \$44,571 annually. Conversations with terminal operators at the port of Long Beach indicated an average cost around \$20,000/year.

They also estimate that equipment maintenance costs for cruise ship terminals was estimated to be \$50,000 annually per berth. The basis for this value is information provided from the Port of San Francisco; an estimate of \$40,000 for one terminal and \$60,000 at the other.⁴⁵

⁴⁴ California Air Resources Board, "Proposed Control Measure for Ocean-Going Vessels at Berth" (State of California, August 1, 2019), <https://ww2.arb.ca.gov/rulemaking/2019/ogvatberth2019>.

⁴⁵ California Air Resources Board.

2.5.5 Electricity Rates

Electricity rates for shore power at Canadian ports can vary depending on the location and the specific agreements in place. Additionally, the actual charges to the vessel can vary by port or terminal as terminal operators can add on service charges or utilities including surcharges for periods of peak demand. For example, electric power from BC Hydro for Salish Sea ports is currently set at 4.889¢/kWh plus \$150/month administration fee. Additionally, BC Hydro’s shore power rate has no peak demand charge.⁴⁶ On the other hand, ports such as Brooklyn provide rates that are partially subsidized as an incentive to connect.⁴⁷

Data documenting the electrical rates at U.S. ports was compiled for the EPA’s Shore Power Technology Assessment and presented in Table 13 for different vessel type voltage systems.

Table 13. Port Electrical Rates⁴⁸

Port Name		Service Price
Juneau		Peak: \$0.0592/kWh Off Peak: \$0.0555/kWh
Seattle		Peak: \$0.0867/kWh Off Peak: \$0.0572/kWh
San Francisco		Peak Summer Rate: \$58.304/meter-day + \$17.39/kW demand +\$0.1333/kWh energy
Brooklyn		\$0.12/kWh (\$0.26/kWh to deliver)
Los Angeles	Container	AMP \$150 service charge + \$1.43/kW facilities charge + \$0.07511/kWh energy charge (additional charges may be applied—see the source)
	Cruise	AMP-B: AMP + \$10,000 minimum monthly charge (additional charges may be—see the source; no facilities charge)

⁴⁶ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” research (Environment and Climate Change Canada, October 26, 2022), <https://www.canada.ca/en/services/environment/cumulative-effect/about/salish-sea-ecosystem/shore-power-feasibility.html>.

⁴⁷ US EPA, “Shore Power Technology Assessment at U.S. Ports,” March 20, 2017.

⁴⁸ US EPA.

Port Name	Service Price
Long Beach	Varies; each terminal equipped with shore power has its own account and rate structure with Southern California Edison
Oakland	\$267/hour ^[12] + \$31/hour maintenance rate
Tacoma	\$83.25 per month + \$0.11944/kWh

Some of the data in Table 13 was obtained from CARB’s assessment of terminal electricity bills provided by Californian ports to determine the \$/kilowatt-hour rate. They found that costs range from 15 to 25 cents per kilowatt-hour which align with commercial electricity rates averaged for the four largest utilities that serve ports (Southern California Edison, Los Angeles Department of Water and Power, Pacific Gas and Electric, and San Diego Gas & Electric).⁴⁹

CARB estimated future electricity rates for California to be \$0.18 per kilowatt-hour (kWh) through 2030, \$0.19 per kWh in 2031 and 2032. The basis for this analysis was California Energy Commission Mid Case Revised Demand Forecast (CEC, updated February 21, 2018). Projected rates for PG&E, LADWP, SDG&E, and SCE were averaged to produce an average statewide rate.

2.5.6 Government funding

Government funding is generally supplied when shore power regulations are implemented. In California, CARB estimated that the potential health benefits surpass the shore power implementation cost of 2.23 billion \$US for cruises, tankers, containers, PCTCs (passenger and truck carriers), RoRos (roll-on roll-offs), and reefers (refrigerated cargo ship). Additionally, reducing air pollution through shore power could alleviate costs on California’s legal and governmental systems.⁵⁰ Numerous lawsuits have been filed against the EPA for failing to meet air pollution targets, including a recent case in 2021, in which the federal appeals court ruled the EPA erred.⁵¹ CARB believes the cost per freight transport is reasonable in the end with \$1.14 per TEU, \$4.65 per cruise passenger, \$7.66 per automobile, and less than \$0.01 per gallon of finished oil product.⁵²

The EU has supplied 1.1 million euros to the TEN-T (Trans-European Transport Network) for preliminary shore power studies and early deployment of shore power.⁵³ With the new FUEL EU FIT 55 package, shore power will be mandatory in Europe among all the TEN-T ports by 2030

⁴⁹ US EPA.

⁵⁰ “Several Groups Sue EPA over Unhealthy San Joaquin Valley Air | Fresno Bee,” accessed June 20, 2024, <https://www.fresnobee.com/news/local/article255711601.html>.

⁵¹ “Federal Court Rules EPA Wrongly Approved CA Valley Air Plan | Fresno Bee,” accessed June 20, 2024, <https://www.fresnobee.com/fresnoland/article260637012.html>.

⁵² US EPA, “Shore Power Technology Assessment at U.S. Ports,” March 20, 2017.

⁵³ Asad Tariq, “Onshore Power Supply in Europe – An Overview,” *PTR Inc.* (blog), July 16, 2021, <https://ptr.inc/onshore-power-supply-in-europe-an-overview/>.

and all European ports by 2035 for cruises, containers, tankers, PCTCs, RoRos and reefers. To enable this project, the EU has released a 25.8-billion-euro program between 2021 and 2027, the Alternative Fuels Infrastructure Facility (AFIF).⁵⁴

Finally, the Chinese shore power program covers more than 80% of commercial and specialized berths of containers, RoRos, cruises, passenger transport above 3,000 tons, and dry bulk cargo above 50,000 tons. The subsidy program implemented by China covered 40%-60% of equipment costs for domestic ships and the costs for land facility construction, power capacity increase, electricity price difference, and maintenance of land facilities.⁵⁵ The experience of these three programs demonstrates that large-scale shore power regulations implemented worldwide came with government funding programs.

2.6 The provision of shore power's impact on port competitiveness

The Salish Sea study noted that for Pacific ports, traffic patterns in 2018 showed that tankers and containerships sailed mainly to Asia and the United States. Among the countries that are most frequently visited by these vessels, China and the United States and have shore power connections. As noted, several U.S. ports have shore power connections for containerships, including Los Angeles, Long Beach, Oakland, San Diego, San Francisco, Seattle, Tacoma, and Hueneme. Containership operations have been targeted in the past for shore power resulting in much of the Pacific fleet being shore power ready. In order to be competitive in this market, Canadian ports such as Port of Vancouver are strengthening eco-partnerships with ports in the United States and China to allow shore power equipped vessels to fully realize their investment in this technology and to enable Green Shipping corridors between ports offering shore power services.⁵⁶ For example, the Port of Vancouver is already leading an International Collaboration on Ship Emission Reductions (ICSER) and is a member of Environmental Ship Index (ESI).⁵⁷

“Form Eco-partnerships with sister ports to provide guarantees for shipping lines that vessel could hook up at either the originator or destination ports. Coordination with Eco-partners could also help in the planning stage to address any lessons learned from them about the carriers that operate from their location.”⁵⁸

⁵⁴ European Commission, “Connecting Europe Facility – Transport.”

⁵⁵ Ming Yin, Yi Wang, and Qiang Zhang, “Policy Implementation Barriers and Economic Analysis of Shore Power Promotion in China,” *Transportation Research Part D: Transport and Environment* 87 (October 1, 2020): 102506, <https://doi.org/10.1016/j.trd.2020.102506>.

⁵⁶ Jingwen Qi, Shuaian Wang, and Chuansheng Peng, “Shore Power Management for Maritime Transportation: Status and Perspectives,” *Maritime Transport Research* 1, no. 0 (2020), <https://trid.trb.org/View/1878471>.

⁵⁷ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” October 26, 2022.

⁵⁸ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” October 26, 2022.

Growing interest in decarbonization by shippers is another factor driving competitive aspects of shore power. Maersk and others have made public commitments to support shore power initiatives that support their customers efforts to decarbonize their supply chain.⁵⁹

Shore power might also have an important impact on cruise port competitiveness, as more and more cruise terminals are electrified. The ports equipped with shore power will attract more clients as the public perception of their environmental footprint is growing. Therefore, ports without shore power may be disadvantaged. This is an important consideration for coastal cities in Canada as the cruise industry is a vital industry. For example, in 2019, it was estimated that the cruise industry in Quebec had a total output economic impact of \$712 million and a business and welcome tax of \$66.5 million.⁶⁰

Another element for consideration to help in this competitive market is the possible implementation of incentives that promote use of shore power by terminals and vessel operators. These programs could attract more clean vessels that are equipped with shore power, enhancing utilization rates.⁶¹ Incentives do not need to be just monetary; China's system prioritizes ships with shore power in berthing.⁶²

The impact a shore power program has on adjacent communities, is also important to consider, specifically in attaining environmental goals.⁶³ Not only do such systems provide improvements to local air quality but also eliminate engine noise from the vessels. Local communities perceive such initiatives as improvements since they can notice disparities in noise and particulate emissions when malfunctions occur in the system and vessels are unable to connect.⁶⁴

Some ports are concerned about the risk of shore power becoming a stranded asset. They expect that as ships transition to clean alternative fuels, shore power will no longer be necessary to reduce emissions at berth. However, the World Ports Climate Action Program (WPCAP) commissioned CE Delft to investigate and assess the long-term viability of OPS facilities. This study was mentioned in an IMO paper (MEPC 70/7/6) submitted by the International Chamber of Shipping (ICS), the International Association of Ports and Harbors (IAPH), the International Cruise Line Association (CLIA), and INTERFERRY.⁶⁵ The three main conclusions from the CE Delft study are:

⁵⁹ "Maersk," Sustainable Ships, accessed June 20, 2024, <https://www.sustainable-ships.org/rules-regulations/maersk>.

⁶⁰ Croisières sur le fleuve Saint-Laurent au Québec, "Études et documents - Qui sommes-nous -," accessed June 20, 2024, <https://www.cruisesaintlawrence.com/FR/Qui-sommes-nous/10021/Etudes-et-documents.aspx>.

⁶¹ Environment and Climate Change Canada and NRC, "Shore Power Feasibility Study in the Salish Sea," October 26, 2022.

⁶² Qi, Wang, and Peng, "Shore Power Management for Maritime Transportation."

⁶³ Kyunghwan Kim, "Characteristics of Economic and Environmental Benefits of Shore Power Use by Container-Ship Size," *Journal of Marine Science and Engineering* 10, no. 5 (May 2022): 622, <https://doi.org/10.3390/jmse10050622>.

⁶⁴ US EPA, "Shore Power Technology Assessment at U.S. Ports," March 20, 2017.

⁶⁵ Marine Environmental Protection Committee, "The Role of Onshore Power Supply (OPS) in the Future Maritime Energy Mix," April 28, 2023, I:\MEPC\80\MEPC 80-7-6.docx.

1. The variable costs of shore power are projected to be lower than electricity generated on board with a decarbonized fuel.
2. Ships operating on fully renewable fuels may still have air pollutant emissions, especially when the renewable fuels are used in an internal combustion engine with a pilot fuel. In such cases, the use of OPS while at berth will still make sense and, in the parts of the world where mandates already apply, these may remain also in the future.
3. In all decarbonization scenarios, a significant proportion of maritime fuels will still be fossil-based by 2040. For ships sailing on such fossil fuels, onshore power supply (OPS) will remain a viable solution while at berth.

Therefore, investing in shore power is an investment for the future and not a stranded asset.

2.7 Training requirements/skilled labour needs for shore power management at Canadian ports

It is important to ensure appropriate labour requirements are met in managing shore power. To connect and disconnect vessels from shore power systems, dedicated staff are required to complete specialized training to perform these tasks at the port.⁶⁶ Many ports also require a certified electrician who specializes in these activities to oversee the process.

The biggest issue is the high-voltage connections. The handling of high-voltage cables is dangerous and can only be done by properly trained staff. It will require that all shipowners and all ports train workers with Canadian programs and/or international training. In some countries, the staff from international ships are not allowed to work, i.e. connect a cable, on the port side since the formation of the international ship workers is not recognized in Canada. This means that in the case of container ships where the connection is performed on the dockside, a team of electrical engineers must always be on stand-by to perform the connections.

Example: Connecting a Vessel to a Shore Power System.

- Safety checks to ensure that the system is not powered prior to connecting.
- Inspection of cables for cracks, bulges or indications of over heating
- Check all splices for cleanliness, tightness and good surface contacts
- Check cables for insulation resistance
- Check resistance between each phase and ground
- Check terminal or receptor for moisture
- Lay out enough cable to account for vessel movement during tidal changes, but not too much that the cable is in the water or caught between the vessel and the pier.
- Connect the cable to the ships terminal
- Connect the cable to the shore-side terminal
- Check phased rotation on the ships indicator on the vessels switch board.
- Energize shore power system
- Monitor usage

⁶⁶ Robert Schluter, "Ports Without the Right Infrastructure Need a New Shore Power Solution," The Maritime Executive, accessed June 20, 2024, <https://maritime-executive.com/editorials/ports-without-the-right-infrastructure-need-a-new-shore-power-solution>.

The level of technical skill required is indicated in the adjacent box that show the steps needed to connect a vessel to a shore power system.

Given the international nature of marine freight movements, it is important that port technical staff are able to communicate critical information about how to connect and disconnect the shore power system in multiple languages as vessel staff may not always be fluent in English or French.”⁶⁷

Additionally, trained staff are required to monitor the shore power infrastructure system and be able to troubleshoot issues that occur during connection, disconnection, and while providing power to the vessel.

2.8 Existing shore power policies

Shore power is now used in many parts of the world to reduce GHG and emission emissions. Different types of policies and actions have helped to improve its utilization such as voluntary programs, market-based incentives, funding programs, regulations, and more. However, only regulatory measures have enabled serious uptakes in the installation of shore power. California was the first state to mandate the use of shore power in 2007 for cruise and container ships. China also recently electrified most of its commercial berths and is mandating shore power for containers, cruises, bulk carriers, tankers, PCTCs, and RoRo ships. Additionally, the EU has a phased plan to regulate shore power ship type by ship type by 2030 and 2035 starting with the biggest ports. Table 14 presents the list of shore power policies in these three organizations.

Table 14. Main shore power policies in California, China and the EU

Policy	Type	Region	Target	Description
California Air Resources Board (CARB) Shore Power Regulation (2020)	Regulation	California	Cruise, container, reefers cargo, ro-ro (2025), tanker (2025-2027)	<ul style="list-style-type: none"> Ships are required to use shore power or alternative compliance methods. Ports are required to provide shore power infrastructure for ships to use. Funding available If vessel equipped with shore power, it is required to use it. Vessels must connect within 2 hours after successfully docking.
Port and Freight Infrastructure Program (2022)	Program	California	Ports	Funding program

⁶⁷ Environment and Climate Change Canada and NRC, “Shore Power Feasibility Study in the Salish Sea,” October 26, 2022.

European Union (EU) Directive on the deployment of alternative fuels infrastructure (2025)	Regulation	EU	Ports	Shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025.
Alternative Fuels Infrastructure Regulation (AFIR) (2030)	Regulation	EU	Container (2030), passenger (2030), other ship types (2035)	Port will provide a minimum number of shore power connections.
Alternative Fuels Infrastructure Facility (AFIF) (2024)	Program	EU	Ports	Funding program
FuelEU Maritime Regulation (2030)	Regulation	EU	Container (2030), passenger (2030), other ship types (2035)	<ul style="list-style-type: none"> • Vessels must use shore power at berth for all energy needs. • Vessels must connect within 2 hours after successfully docking.
Proposal for a Revised Energy Taxation Directive (ETD) (2030)	Regulation	EU	All ships	Member states have the possibility to introduce tax exemptions or lower tax rates for electricity provided to ships at berth.
Implementation Scheme for Ship and Port Pollution Prevention and Control (2015–2020): Part A	Regulation	China	Ports	Harbour working ships and public service ships shall use SP during berthing.
Implementation Scheme for Ship and Port Pollution Prevention and Control (2015–2020): Part B	Regulation	China	Ports	50% of specialized terminals, e.g., container, ro-ro passenger and cruise ship terminals, shall be enabled to provide SP.
Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution (2016)	Regulation	China	Ports and ships	<ul style="list-style-type: none"> • Management policies for emission control areas (ECAs) shall be implemented in key waters. • The use of SP shall be prioritized by berthed ships.
Guide of Application for Shore-based Power Supply Project Award Funds for Berthed Ships in 2016–2018	Program	China	Ports	SP facilities established in 2016, in 2017 and before March 31, 2018 are entitled to apply for subsidies to cover respectively 60%, 50% and 40% of equipment costs.
Ecological Environment Protection Plan for the	Regulation	China	Ships	<ul style="list-style-type: none"> • Management policies for emission control areas

13th Five-year Plan Period (2016)				<p>(ECAs) shall be implemented in key waters.</p> <ul style="list-style-type: none"> The use of SP shall be prioritized by berthed ships.
Shore Power Layout Plan of Ports (2017)	Regulation	China	Container, passenger, ro-ro, cruise, tanker, bulk	<ul style="list-style-type: none"> More than 50% of established container, ro-ro passenger, and cruise ship terminals as well as specialized berths shall be enabled to provide SP to ships at major ports as well as ports in ECAs by 2020. Ports should provide shore power at berth visited by container, passenger, ro-ro, and cruise of more than 3000 DWT and bulk of more than 50,000 DWT.
Three-year Action Plan to Protect Against Air Pollution	Regulation	China	Ports	<ul style="list-style-type: none"> Rapid construction and improved utilization rate of SP facilities at ports are urged. More than 50% of specialized berths shall be enabled to provide SP by the end of 2020. Newly built terminals shall have SP facilities planned, designed and constructed synchronously.
Notice on Jointly Promoting Shore Power Use among Berthed Ships at Ports	Program	China	Shore power operators	SP operators that implement two-part tariff systems are exempted from electrical demand (capacity) charges by the end of 2025.
Port and Ship Shore Power Management Measures	Program	China	Ports and shore power operators	<ul style="list-style-type: none"> Terminals and other SP operators are allowed to collect electricity charges from ships. SP operators that implement industrial electrical tariffs are exempted from electrical demand (capacity) charges.
Notice on Jointly Promoting Shore Power	Regulation	China	Ports	<ul style="list-style-type: none"> SP shall be used by phase, by region and by type in ECAs.

Use among Berthed Ships at Ports				<ul style="list-style-type: none"> • Port energy consumption statistical systems and related standards should be optimized.
Port and Ship Shore Power Management Measures	Regulation	China	Ships	<ul style="list-style-type: none"> • Ships with receiving facilities shall use SP in case their berthing time at ports capable of providing SP is longer than the stipulated hours. • SP is encouraged to be used when ships' berthing time is shorter than the stipulated hours. • Domestic vessels should install shore power for container, passenger, ro-ro, and cruise of more than 3000 DWT and bulk of more than 50,000 DWT. • Vessels with shore power capabilities must connect within 3 hours after successfully docking.

Based on successful existing international shore power regulations, different components are required to ensure an effective shore power policy in Canada:

1. The policy must include a phased implementation of shore power making it mandatory for different ports and/or terminal types that have better shore power potential to install the technology.
2. The port must ensure that if both the terminal and the vessel have shore power then it is required to plug-in. This ensures that the shore power connection is used.
3. There must be funding programs to support the shore power program and objectives.
4. Measures and rules aimed at reducing the operational cost of shore power must be adopted.

3.0 ENVIRONMENTAL ANALYSIS

The environmental analysis was performed with data from the Marine Emission Inventory Tool (MEIT).⁶⁸ The MEIT is a web-based tool that provides an inventory of shipping activity, energy use, air pollutants and greenhouse gas emissions from commercial marine ships operating in Canadian waters. The MEIT uses actual ship movement data and information on ships engines/machinery to model marine emissions in Canada, assuming compliance with regulations in effect during an inventory year.

The goal of the environmental analysis was to determine the quantity of ships' emissions at berth in Canada, specifically in the 17 Canadian Port Authorities. To perform the estimation, domestic and international cruise (not including ferries), container, bulk carrier, tanker, and other vessels in Canadian waters were considered with a size greater than 5,000 DWT. The yearly emissions were calculated based on the total equivalent emissions of carbon dioxide from 2020 to 2023. From March 2020 until the end of February 2022, cruise vessels were restricted in Canadian waters, slowing the recovery of the sector.⁶⁹ Therefore, cruise data from 2020 and 2021 were excluded from this analysis. Finally, because shore power is not mandatory in Canada, estimating the actual usage of current shore power systems is challenging. Consequently, this study does not account for the emission reductions already achieved by existing shore power systems.

3.1 Emissions of ships at berth in Canada

Overall, a total of 726,000 t of CO₂e is emitted by domestic and international merchant ships at berth in Canada annually. Of all these at-berth emissions, 96.7% can be eliminated by shore power if the connection and disconnection time are taken into consideration. However, the remainder of the analysis will focus solely on total emissions, excluding the connection and disconnection times. Additionally, the emissions presented in section 3.1 and 3.2 are a four-year average of the 2020 to 2023 period. Figure 6 highlights the breakdown of marine at-berth emissions in Canada.

⁶⁸ Government of Canada, "Marine Emission Inventory Tool," accessed June 20, 2024, <https://ec-meit.ca/app.html#>.

⁶⁹ Transport Canada. (2022a, June 10). Ban on cruise ships and pleasure craft due to Covid-19. <https://tc.canada.ca/en/binder/ban-cruise-ships-pleasure-craft-due-covid-19>



Figure 6. Average annual estimation of carbon dioxide equivalent emissions at berth of merchant ships in Canada per province

British Columbia and Quebec are the two provinces with the highest potential emissions reductions by using shore power with 252,000 t of CO₂e and 220,000 t of CO₂e respectively. Followed by Ontario, Newfoundland-Labrador, and Nova Scotia with a reduction potential of 133,000 t of CO₂e, 49,000 t of CO₂e, and 46,000 t of CO₂e respectively. Finally, New Brunswick and Prince Edward have a reduction potential of 23,000 t of CO₂e and 2,000 t of CO₂e annually. The other provinces have negligible emissions reduction potential by using shore power. Bulk carriers are the ships with the highest total shore power potential in Canada as they are responsible for 44% of the emissions at berth. Figure presents the share of emissions by ship type.

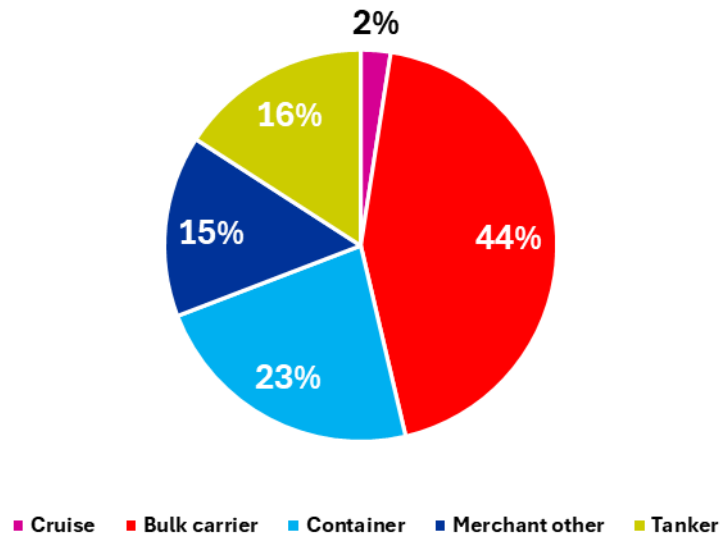


Figure 7. Share of emissions at berth per ship type

However, the total number of ships in each ship type category impacts the shore power potential. When fewer ships are responsible for more emissions, there is a smaller relative cost and complexity. Figure presents the approximative ratio of emissions per ship type. To obtain this ratio, the total quantity of emissions of each ship type is divided by the number of individual ships that are responsible of these emissions. The x-axis is the ship types, and the y-axis is the averaged quantity of emissions per ships, i.e., the ratio. While this ratio is not realistic since it is only based on the total emissions and total number of ships, it is a good indication of which ship type could be easier to address. While this ratio doesn't consider all factors needed for successful shore power connections, a high ratio means that less shore power conversions and retrofits, and lower costs are needed to achieve a greater emissions reduction.

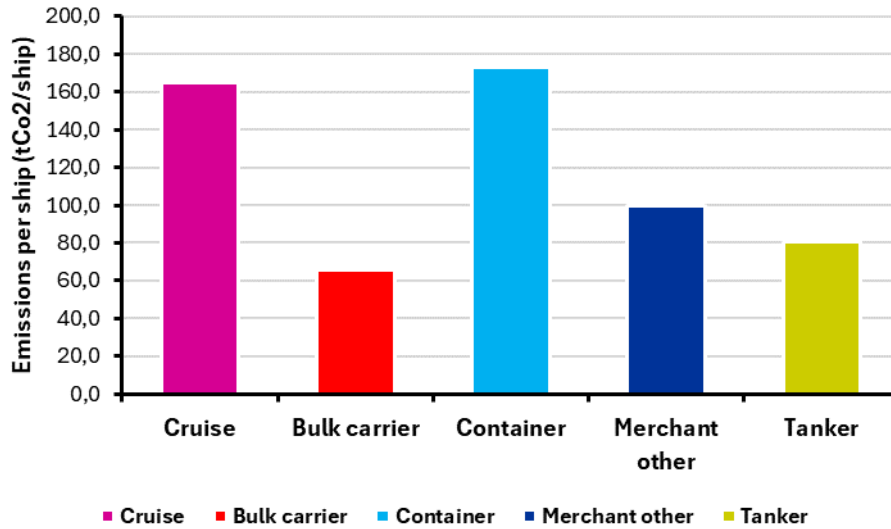


Figure 8. Approximative ratio of emissions at berth per ship type

The result indicates that for cruise, each ship equipped with a shore power system can reduce on average about 170 t of CO₂ while each bulk carrier only reduces 60 t of CO₂. In terms of general tendencies, the ratio analysis of Figure 8 shows that container ships and cruise ships have the best ratio, i.e. have a smaller number of ships to equip with shore power compared to the quantity of emissions they cover. Even if they are responsible for only 23% and 2% of the total emissions, they still have a better ratio than other ship types. In the 2020-2023 data set there were a total of 959 container ships and 108 cruise ships compared to 4,825 different bulk carriers, 1,431 tankers, and 1,090 merchant others. Additionally, the number of container and cruise terminals that would need to be equipped with shore power is much smaller than the number of bulk and tanker berths. Therefore, when shore power is compared on a project basis, it can be argued that cruise and container ships are good candidates as there would be fewer retrofits required that could reduce more emissions than other ship types.

Finally, Figure presents the emissions per province and ship type. The y-axis is the emissions in tons of CO₂e emissions.

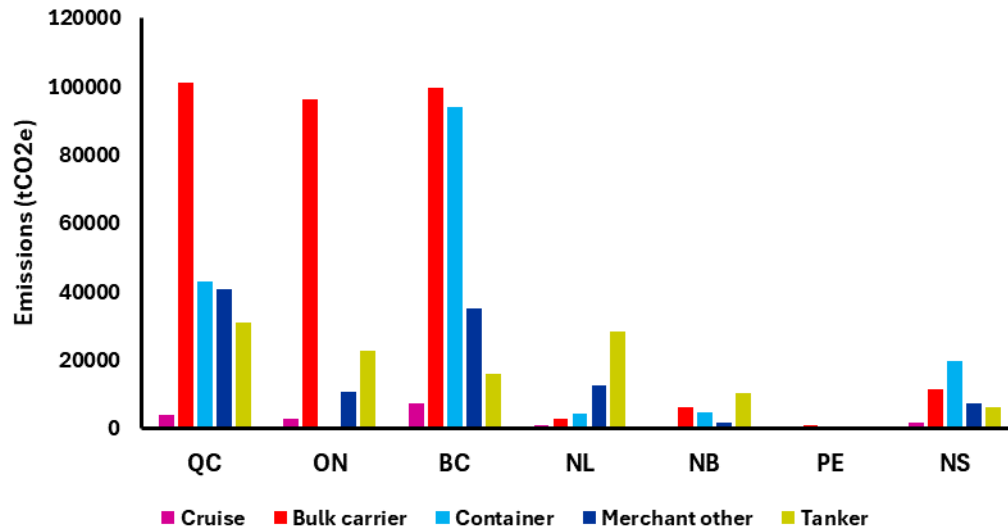


Figure 9. Emissions at berth of ships per province and ship type

The results indicate that Quebec, Ontario and British Columbia have a similar amount of at-berth bulk carrier emissions. However, at-berth container and merchant other emissions are mostly located in British Columbia and Quebec. Tanker emissions at berth are relatively consistent across the different provinces.

3.2 Emissions of ships at berth in the Canadian Port Authorities

Together, the 17 Canadian Port Authorities cover 508,000 t of CO₂e of at-berth marine emissions which is 70% of the at-berth emissions for all ports across Canada. Figure presents the emissions of merchant ships at berth by each Canadian Port Authority.

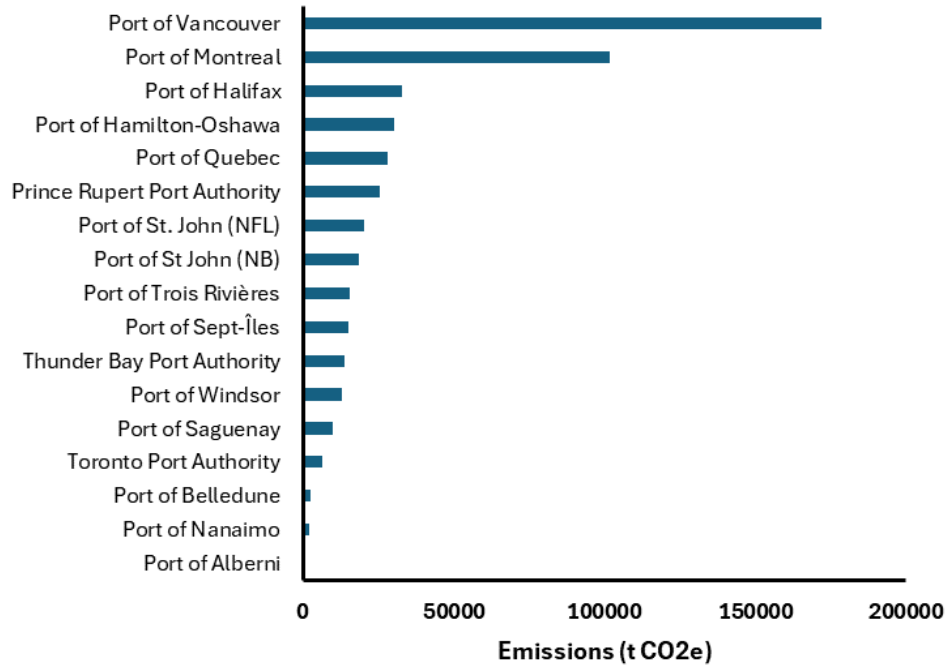


Figure 10. Average annual estimation of emissions of ships at berth in the Canadian Port Authorities

The Port of Vancouver and the Port of Montreal have the largest emission reduction potential by using shore power with 171,980 t of CO₂e and 101,710 t of CO₂e respectively. The other ports have an average annual emission reduction potential by using shore power of about 20,000 t of CO₂e. Figure details the distribution of the emissions between the different ship types and geographic areas. The y-axis is the emissions in tons of CO₂e emissions.

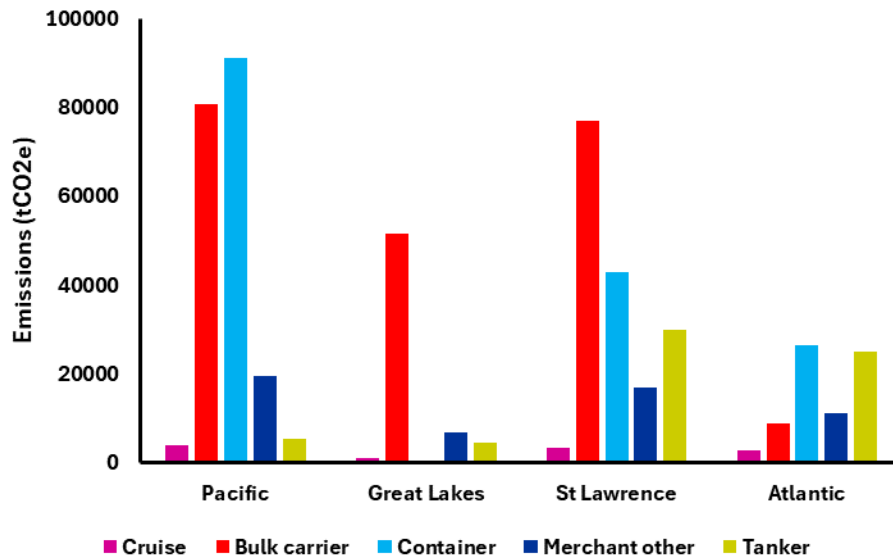


Figure 11. Average annual estimation of emissions of ships at berth per ship type and area

Within Canada, 39% of the emissions occurred in the Pacific area with an equal share of bulk and container ship emissions. The St. Lawrence Seaway is second with 33% of the emissions. However, in the St. Lawrence, a significant portion of the emissions come from bulk carriers. In this region, tanker, container, and merchant other emissions are more evenly distributed. The Great Lakes area is also dominated by bulk carrier emissions. Finally, emissions in the Atlantic region are primarily from containers and tankers.

Finally, Figure 12 presents the NO_x, SO_x, and PM_{2.5} emissions at berth in tonnes (x-axis) per province (y-axis).

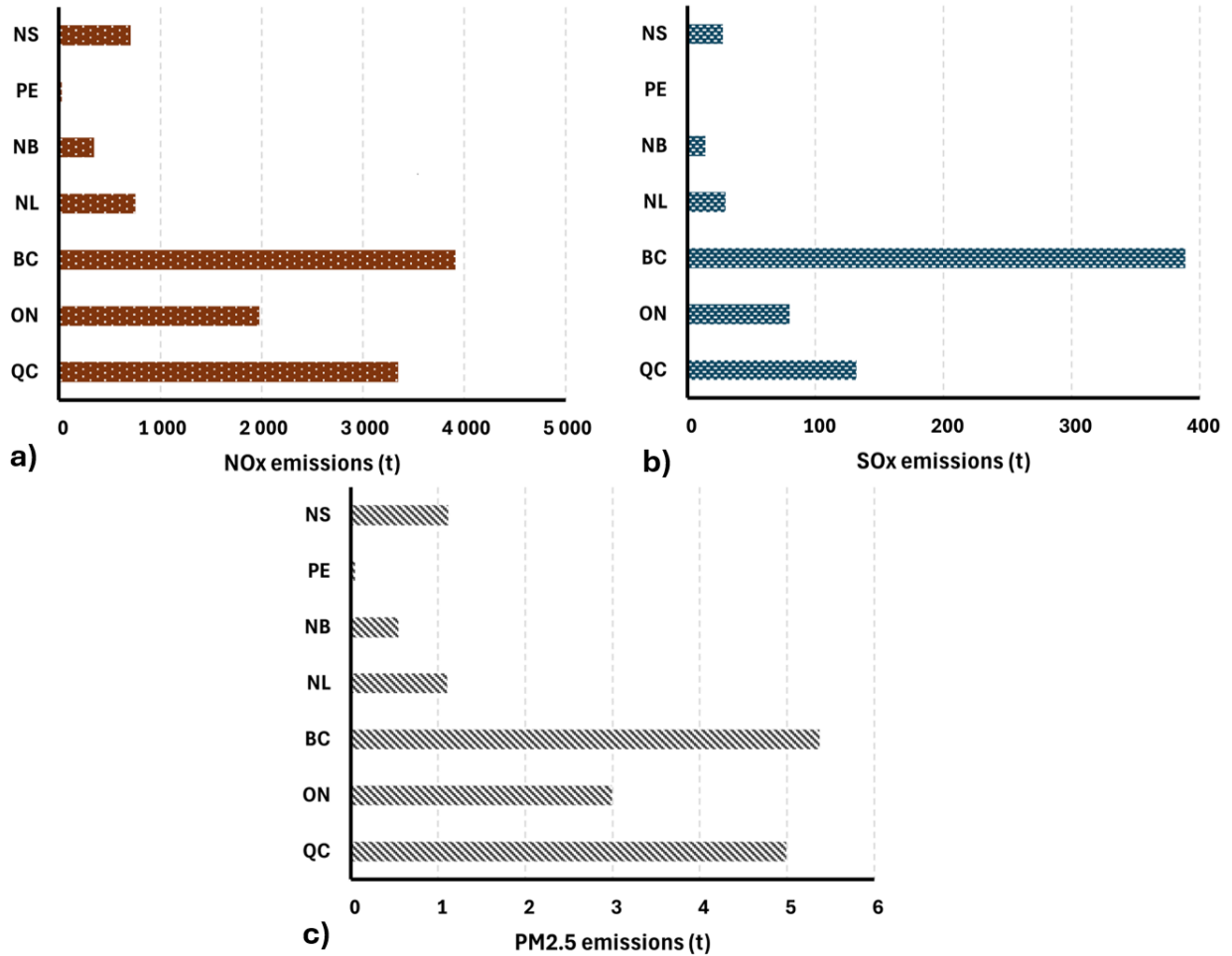


Figure 12: Annual averaged estimation of air pollutant emissions at berth for a) Nitrogen oxides, b) Sulfur oxides, c) Particulate matter less than 2.5 micrometers in diameter

Shipping contributes an important share of air pollutant emissions in Canada, and shore power can help to reduce these emissions. Based on Figure 12, commercial ships at berth emit annually 11.1 kt of NO_x, 0.67 kt of SO_x, and 16 t of PM_{2.5}. When compared to the total annual emissions of air pollutant in Canada,⁷⁰ shore power for commercial ships has the potential to reduce about 0.9% of the total Canadian NO_x emissions and 1% of the total Canadian SO_x emissions. While the marine PM_{2.5} emissions is relatively small compared to the total annual emissions of 1.3 Mt of PM_{2.5} Mt for all sectors in Canada, it still represents a significant part of the ports PM emissions.

⁷⁰ Public Services and Procurement Canada Government of Canada, "Canada's Air Pollutant Emissions Inventory Report. : En81-30E-PDF - Government of Canada Publications - Canada.Ca," July 1, 2002, <https://publications.gc.ca/site/eng/9.869731/publication.html>.

4.0 COMPILATION OF FACTORS FOR DETERMINING READINESS OF A PORT TO IMPLEMENT A SHORE POWER PROGRAM

One of the objectives of this project is to determine the feasibility of implementing shore power in Canada through an analysis of Canadian port readiness. For this report, a shore power-ready port is defined as a port that has done work to analyze the environmental, economic, social, and technical aspects of shore power. The port has a plan to implement shore power and services it in an organized, safe, and economical manner for its different terminals when feasible.

Shore power readiness can be viewed in multiple ways. Figure 13 presents the shore power readiness general landscape with the red circles being readiness components, the dark blue circles are different types of shore power readiness, and the arrows are the flow of readiness from low-level components to high-level components.

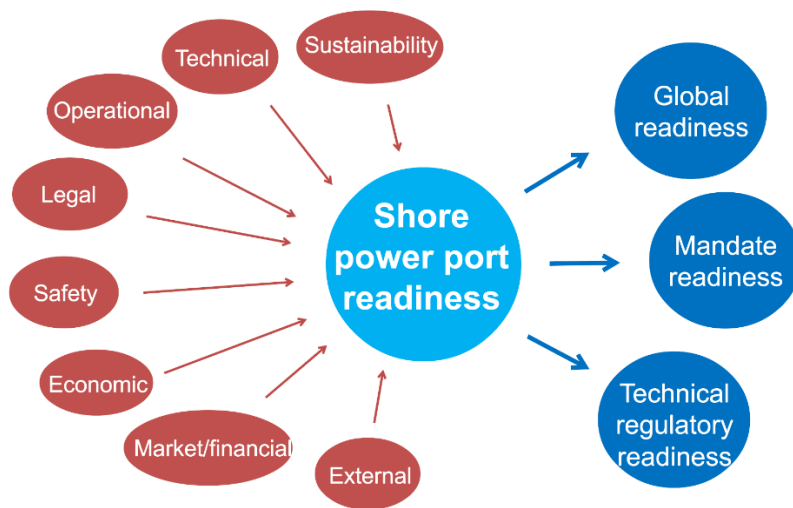


Figure 13. Shore power readiness landscape

The landscape shows that many different components influence a port's readiness for shore power, and this readiness can be viewed in multiple ways. Therefore, this study is addressing shore power readiness as a whole and intends to encompass all of the high-level components of shore power.

4.1 Shore Power Readiness Factors

Assessing the readiness of a port requires the development of a qualitative score based on the factors derived from the literature review and the EMSA guidance on shore power projects. The list of components and the identified factors that feed into them are presented in Table 15. A description of each factor follows Table 15.

Table 15. Shore Power Readiness Factors.

Scope	Component	Factors
Internal	Technical feasibility	<ul style="list-style-type: none"> • Communication with local utilities to verify the electricity source and availability of power; • Electrical infrastructure is sufficient for current and future capacity evaluation; • Communication procedure and availability for operations (system able to coordinate with ship operators and the group that schedules berth assignments and monitors energy usage); • Design, management, and certification are based on existing standards; • Meeting all certification requirements • Technical maturity of the selected solution • Definition of the level of automation and manning requirements
	Legal feasibility	<ul style="list-style-type: none"> • Assessment of the national and port regulations (regulatory vs voluntary) • Detailing the permitting requirements and timeline
	Operational feasibility	<ul style="list-style-type: none"> • Expertise with shore power system operation • Engage ship owners in planning and implementation phases. • Ship energy and power demand profile evaluation (including concurrent vessel charging and charging of electrified non-vessel equipment such as vehicles and cargo handling equipment) • Measurement system for energy and power consumption • Competencies and training identified/required • Training for communication in multiple languages • Operational resources availability (manning and replacement components) • Operational restrictions and alternative options should be expressed in the port regulation • Operational envelopes considering local weather restrictions are also to be covered in port regulations and procedures • Available dock space for equipment • Flexible design that allows vessels to connect regardless of the location on the vessel of the connection port.
	Market/Financial feasibility	<ul style="list-style-type: none"> • Vessel traffic and demand evaluation • Electricity pricing agreements/strategy (including charges during high demand periods) • Customized/tailored contract • Competitiveness evaluation • Market incentives for participation improvement • Capital funding and financial evaluation
	Economic feasibility	<ul style="list-style-type: none"> • Operational cost difference with current situation evaluation • Economic cost-benefit analysis • Cost recovery evaluation and risk management • Impact assessment in port/local economies • Evaluation of options competing with shore power and stranded assets

Scope	Component	Factors
	Social consideration	<ul style="list-style-type: none"> • Social impact evaluation • Public consultation and social acceptance • Prioritization of projects benefiting local communities the most
	Safety	<ul style="list-style-type: none"> • Qualitative or quantitative risk assessment and mitigation • Safety distance and zone identification • Safety procedures and culture • Special considerations for connecting tankers to shore power systems
	Sustainability	<ul style="list-style-type: none"> • Life-cycle environmental impact evaluation • Sustainability of the project • Socio-Economic-Environmental balance • Multiple stakeholder involvement and collaborative effort
External	International standardization and certification	<ul style="list-style-type: none"> • Standardization readiness of terminals visited specific vessel types: <ul style="list-style-type: none"> ○ Container vessels ○ Cruise vessels ○ Tanker vessels ○ Passenger Roll-on/Roll-off vessels ○ Pure Cars and Trucks Carriers vessels ○ Bulk carrier vessels • Compliance with international guidance on shore power operations • Compliance with national or international guidance on shore power infrastructure design

Technical feasibility

Communication with local utilities to verify that electricity source and availability of power -

The Port must show that they have made sufficient effort to contact their local electrical provider to ensure power will be available for their shore power expenses, that the energy will be available, and that they have analyzed the source of the energy to determine the fossil content of the provided energy. The Port has a mapping of the existing electrical distribution infrastructures, storages, and sources.

Electrical infrastructure is sufficient for current and future capacity evaluation - The Port must show that the electrical infrastructures will be designed according to the current and future electrical needs of shore power. Alternatively, a plan for the deployment of the shore power electrical infrastructures is developed by the port to show that the future electrical installations will be able to cope with the future demand.

Communication procedure and availability for operations (system able to coordinate with ship operators and group that schedules berth assignments and monitors energy usage) - The communication aspects of shore power operations and procedures are critical. The Port must show that communication means (Radio frequencies, encrypted data, digital, web-based communications, emergency communications, etc.) will be available for shore power operations.

Design, management, and certification are based on existing standards - The Port must show that the design of the shore power system ensures interoperability and practical feasibility of the shore power connection between the ship and the shore. The solution is based on existing standards. Other aspects of shore power equipment, operations, certifications, training, or infrastructure must also follow international and national standards.

The Port identifies the different standards that it should comply with. The Port should make clear reference to the relevant standards for shore power in their plan. Legally binding requirements for standardization must be inscribed either in the national legislation of port-specific regulations.

Meeting all certification requirements - When applicable, the port must show that the training of the personnel involved in shore power operations, the shore power infrastructures, the shore power procedures and management follow established certifications.

Technical maturity of the selected solution - The Port has selected a shore power technical solution on the system level (infrastructure, automation, etc.) that has a proven maturity to guarantee that operations will be successful. Reference to existing technologies/projects is provided by the Port.

Definition of the level of automation and manning requirements - In cases where automation will be present, the Port must identify the minimal manning requirements for the shore power system and operations. Furthermore, automated operations must be provided with an override option to enable manual operations.

Legal feasibility

Assessment of the national and port regulations (regulatory vs voluntary) - The Port should provide a comprehensive information package to potential shore power operators, including relevant legal references for defining the project concept. For early consultations, the Port must assess specific details of the proposed shore power project and provide applicable legal references. Additionally, based on early project evaluation, the Port may offer an initial feasibility indication along with relevant legal references.

Detailing the permitting requirements and timeline - The Port identifies the different permits related to shore power projects and operations and provides all elements of permitting to the operators if needed. The Port assumes the position of a facilitator for the permitting process.

Operational feasibility

Expertise with shore power system operation - The port must show its ability to handle shore power operations. Existing shore power infrastructures that are not standardized are considered to be a minimum. Expertise with large-scale and/or standardized shore power system show that the port has sufficient expertise with shore power.

Engage ship owners in planning and implementation phases - The Port has engaged with the shipowners that are related to its shore power expansion to align with the planning process and implementation phases.

Ship energy and power demand profile evaluation (including concurrent vessel charging and charging of electrified non-vessel equipment such as vehicles and cargo handling equipment) - The Port has analyzed the typical energy demand of the different vessels at berth and can predict the power and energy demand of the ships using its shore power installations.

Measurement system for energy and power consumption - The Port must show that a system will be in place to measure and record the energy and power consumption of each vessel using the shore power installations.

Competencies and training identified/required - The Port has identified the training and certification that will be required for shore power operations and intends to integrate them into its Port regulations.

Training for communication in multiple languages - The Port acknowledges the complexity of shore power operation and shows its intent to have a multi-language shore power communication stream to enable safe and effective operations of shore power operations.

Operational resources availability (manning and replacement components) - As operational resources are critical for shore power operation, the Port must show its ability to provide adequate manning resources for safe and effective operations of its shore power facilities. Also, The Port must prepare for replacement components to improve its flexibility and resiliency when facing technical issues.

Operational restrictions and alternative options should be expressed in the port regulation - The Port must identify the different operational restrictions related to shore power operation and the alternative options. A risk-based approach may be considered by the port in the latter. The Port must show its intention to include the operational restrictions of shore power in the Port regulations.

Operational envelopes considering local weather restrictions are also to be covered in port regulations and procedures - The Port must have analyzed the environmental conditions that could affect shore power operations and characterize them. When ready for implementation, the Port must show its intent to share with operators any relevant information related to new shore power projects. In cases where operations will need to be realized during critical environmental conditions, a risk-based approach may be considered.

Available dock space for equipment - The Port must analyze the available dock space for the selected shore power system, how it will affect its operation, and have a plan to ensure the safety of the shore power personnel and equipment.

Flexible design that allows vessels to connect regardless of the location on the vessel of the connection port. - The Port must show that the operations will not be affected by the connection system selected in the design phase.

Market/Financial feasibility

Vessel traffic and demand evaluation - The Port must have performed a study on the vessel traffic that is visiting the port and evaluate the future demand for shore power based on the existing shore power compliant vessels, the vessels that intend to be shore power compliant, and, if applicable, future regulations. The objective is that the Port can identify the short-term and medium-term shore power demand for its shore power projects.

Electricity pricing agreements/strategy (including charges during high-demand periods) - The Port has established electrical pricing or service pricing for the vessels using its shore power facilities. The pricing also includes the charges during high-demand periods and any other special particularities if applicable.

Customized/tailored contract - The Port is ready and able to implement contracts for the shore power services.

Competitiveness evaluation - The Port has analyzed the impact of shore power on the competitiveness of its activities and the impact on the external activities related to the port such as the impact on the local economy or the greening of the supply chain.

Market incentives for participation improvement - The Port must identify the possible market incentives that could be used to encourage shore power usage in the case where shore power is less competitive than the current solutions used by the vessels and not regulated. The analysis should be integrated into the business plan.

Capital funding and financial evaluation - The Port has listed and identified the possible capital funding for its shore power expansion and is aware of the different opportunities. The Port has addressed the financial implications of the implementation of shore power in a detailed business plan covering capital expenditure and operational expenditure, funding, etc.

Economic feasibility

Operational cost difference with current situation evaluation - The Port has determined the operational cost of shore power and can compare it with its own current operational cost.

Economic cost-benefit analysis - The Port has analyzed the economic cost-benefit of shore power in terms of revenues, expenses, and opportunities.

Cost recovery evaluation and risk management - The business plan of the Port shore power deployment project includes a cost recovery evaluation and is supported by a risk management strategy.

Impact assessment in port/local economies - The Port can quantify the expected benefits for the port and local economies resulting from the shore power project.

Evaluation of options competing with shore power and stranded assets - The Port has listed and identified the options competing with shore power and analyzed their costs for comparison with the shore power solution.

Social considerations

Social impact evaluation - The Port has evaluated the social impacts of the shore power deployment on local communities and intends to communicate the impacts with them.

Public consultation and social acceptance - The Port is involved in public consultation considering the shore power implementation and has gained social acceptance for its project.

Prioritization of projects benefiting local communities the most - Based on the consultations with the public and the evaluation of the social impacts of the shore power projects the Port goal is to prioritize the projects that have are benefiting local communities.

Safety

Qualitative or quantitative risk assessment and mitigation - The risk assessment is critical to show that the port will be in measure to service shore power safely and that the port will be able to obtain permits and certifications.

At this stage, the Port must present its risk analysis listing the possible risks related to shore power operation safety and the measures that will be taken to mitigate the risks. The risk assessment and mitigation measures must be shared with the operators.

Safety distance and zone identification - The evaluation of the safety zones is crucial, the Port has examined the compatibility of the intended location, adjacent infrastructure, and proposed safety distance. If potential ignition sources, gas trapping spots, or conflicting activities cannot be entirely eliminated within the safety zone, project feasibility will be impacted, requiring continuous review. The safety zone should be designed to eliminate potential ignition sources and conflicting activities, necessitating careful management to avoid conflicts and ensure project feasibility.

In the end, the Port has identified the safety zones associated with the operation of shore power and has determined the safety distance and measures to ensure safe operation.

Safety procedures and culture - The Port has established safety procedures for shore power operations and has a plan to establish a safety culture for shore power operations. The Port is

sharing the safety procedure with the shore power operators and is including all the stakeholders in the safety culture plan.

Special considerations for connecting tankers to shore power systems - Regarding liquid cargo vessels transporting cargo that is sensitive to ignition and explosion, the Port is aware of these risks and is taking extra considerations to ensure safety in these cases.

Sustainability

Life-cycle environmental impact evaluation - The Port has analyzed the life-cycle impact of the shore power project on the environment. This includes the benefits of emission reductions, but also the impact of component transportation, manufacturing, and installation.

Sustainability of the project - The Port has evaluated the sustainability of the shore power project based on the social, environmental, and economic aspects. The Port can determine its impact on the sustainability profile of the port.

Socio-Economic-Environmental balance - The Port can find a balance between the social and economic aspects of the shore power deployment.

Multiple stakeholder involvement and collaborative effort - As shore power projects are complex and require the involvement of many different stakeholders, the Port must identify and make contact with the different stakeholders directly or indirectly involved in the shore power projects. The more a Port can show that a collaborative effort is taking place, the more the chances that the project will be a success.

4.2 Readiness Assessment

For this project, the port's readiness to implement shore power was assessed at a factor-by-factor level, as well as for each port as a whole. To do so, a framework was created which was inspired by the methodology used in the *Port Readiness Level For Marine Fuels (PRL-MF) Assessment tool*⁷¹ developed by the International Association of Ports and Harbors (IAPH) which classifies a port's alternative fuel project readiness into three general phases of implementation: the research phase, the development phase and the deployment phase. During the research phase, the port evaluates the technology relative to the specific port and its stakeholders. This involves identifying informational gaps and assessing the implementation's preliminary pros and cons. In the development phase, strategic decisions are made to proceed. Finally, in the deployment phase, the system has been constructed and implemented and the technology has become a regular port operation. This phased-implementation framework can be adapted to assess shore power readiness, using the identified factors.

The port shore power readiness framework was developed using five readiness phases. These phases follow a similar pattern as those used in the *Port Readiness Level For Marine Fuels (PRL-*

⁷¹ "WG 4 – World Port Sustainability Program," <https://sustainableworldports.org/wpcap/wg-4/>.

MF) *Assessment tool*. Specific to the shore power framework, the readiness phases are as follows:

- **No activity:** The port has not started any work or any considerations about shore power.
- **Preliminary activities:** The port has initiated some work on shore power.
- **Intermediate activities:** The port is involved in shore power projects.
- **High implementation:** The port has a high level of control over its shore power operations and offers regular shore power services.
- **Full implementation:** The port achieves a perfect grading on all shore power factors

Each port was assigned a readiness phase for each factor (a specific criterion of shore power implementation). Each factor was assessed based on a qualitative score to establish the appropriate phase. Depending on the work done by the port, each factor was scored either low, medium, or high. The qualitative scores are defined as follows:

- **Low:** The Port has not initiated any relevant work to clearly address the issues and objectives related to the factor.
- **Medium:** The port has initiated work to address the factor and has preliminary studies, procedures, plans, supporting documents, etc. to support its decisions.
- **High:** The Port has fully addressed the factor through the development of comprehensive studies, plans, procedures, support letters, and other relevant measures.

Table 16. presents the quantitative evaluation matrix with the qualitative scoring associated with each readiness phase. As outlined in this matrix, Table 16. the qualitative score to achieve a particular readiness phase will vary from factor to factor. For example, factor 1 (Communication with local utilities to verify that electricity source and availability of power) needs to score medium to achieve “Intermediate activities” while factor 6 (Technical maturity of the selected solution) only needs to achieve a low score. Since the definition of “Intermediate activities” only requires involvement in shore power, a ‘low’ score is sufficient to achieve the intermediate activity phase for Factor 6. However, the port must at least have had some sort of communication with the grid utility, i.e., factor 1, in order to use power from the grid, resulting in a medium score at the minimum for factor 1 to reach the intermediate activity phase.

In reality, all 50 of these factors do not need to be achieved to successfully implement shore power. Some of the factors are external and are not in the control of the port. The matrix and factors are intended to be a guide to assess the feasibility of implementing shore power in Canada. Table 16 illustrates the minimum score needed for each factor under each readiness phase.

Table 16. Qualitative Binning Matrix for Shore Power Port Readiness Evaluation

#	Component	Factor	No Activity	Preliminary Activities	Intermediate Activities	High implementation	Fully implemented
1	Technical feasibility	Communication with local utilities to verify that electricity source and availability of power	NA	Low	Medium	High	High
2		Electrical infrastructure is sufficient for current and future capacity evaluation	NA	Low	Medium	High	High
3		Communication procedure and availability for operations (system able to coordinate with ship operators and group that schedules berth assignments and monitors energy usage)	NA	Low	Low	Medium	High
4		Design, management, and certification are based on existing standards	NA	Low	Medium	High	High
5		Meeting all certification requirements	NA	Low	Low	Medium	High
6		Technical maturity of the selected solution	NA	Low	Low	Medium	High
7		Definition of the level of automation and manning requirements	NA	Low	Low	Medium	High
8	Legal feasibility	Assessment of the national and port regulations (regulatory vs voluntary)	NA	Low	Low	Medium	High
9		Detailing the permitting requirements and timeline	NA	Low	Low	Medium	High

#	Component	Factor	No Activity	Preliminary Activities	Intermediate Activities	High implementation	Fully implemented
10	Operational feasibility	Expertise with shore power system operation	NA	Low	Medium	High	High
11		Engage ship owners in planning and implementation phases.	NA	Low	Medium	High	High
12		Ship energy and power demand profile evaluation (including concurrent vessel charging and charging of electrified non-vessel equipment such as vehicles and cargo handling equipment)	NA	Low	Medium	High	High
13		Measurement system for energy and power consumption	NA	Low	Low	Medium	High
14		Competencies and training identified/required	NA	Low	Medium	High	High
15		Training for communication in multiple languages	NA	Low	Low	Medium	High
16		Operational resources availability (manning and replacement components)	NA	Low	Low	Medium	High
17		Operational restrictions and alternative options should be expressed in the port regulation	NA	Low	Low	Medium	High
18		Operational envelopes considering local weather restrictions are also to be	NA	Low	Low	Medium	High

#	Component	Factor	No Activity	Preliminary Activities	Intermediate Activities	High implementation	Fully implemented
		covered in port regulations and procedures					
19		Available dock space for equipment	NA	Low	Medium	High	High
20		Flexible design that allows vessels to connect regardless of the location on the vessel of the connection port.	NA	Low	Medium	High	High
21	Market & Financial feasibility	Vessel traffic and demand evaluation	NA	Low	Medium	High	High
22		Electricity pricing agreements/strategy (including charges during high demand periods)	NA	Low	Medium	Medium	High
23		Customized/tailored contract	NA	Low	Low	Medium	High
24		Competitiveness evaluation	NA	Low	Medium	Medium	High
25		Market incentives for participation improvement	NA	Low	Low	Medium	High
26		Capital funding and financial evaluation	NA	Low	Medium	High	High
27		Operational cost difference with current situation evaluation	NA	Low	Low	Medium	High
28	Economic feasibility	Economic cost-benefit analysis	NA	Low	Medium	High	High
29		Cost recovery evaluation and risk management	NA	Low	Medium	High	High
30		Impact assessment in port/local economies	NA	Low	Medium	Medium	High
31		Evaluation of options competing with shore power and stranded assets	NA	Low	Medium	High	High
32		Social consideration	Social impact evaluation	NA	Low	Medium	High

#	Component	Factor	No Activity	Preliminary Activities	Intermediate Activities	High implementation	Fully implemented
33		Public consultation and social acceptance	NA	Low	Low	Medium	High
34		Prioritization of projects benefiting local communities the most	NA	Low	Low	Medium	High
35		Qualitative or quantitative risk assessment and mitigation	NA	Low	Low	Medium	High
36		Safety distance and zone identification	NA	Low	Low	Medium	High
37		Safety procedures and culture	NA	Low	Low	Medium	High
38		Special considerations for connecting tankers to shore power systems	NA	Low	Low	Medium	High
39		Sustainability	Life-cycle environmental impact evaluation	NA	Low	Medium	High
40	Sustainability of the project		NA	Low	Medium	High	High
41	Socio-Economic-Environmental balance		NA	Low	Low	Medium	High
42	Multiple stakeholder involvement and collaborative effort		NA	Low	Medium	High	High
43	International standardization and certification	Standardization readiness of terminals visited by Container vessels	NA	Low	Low	High	High
44		Standardization readiness of terminals visited by Cruise vessels	NA	Low	Low	High	High
45		Standardization readiness of terminals visited by Tanker vessels	NA	Low	Low	High	High
46		Standardization readiness of	NA	Low	Low	High	High

#	Component	Factor	No Activity	Preliminary Activities	Intermediate Activities	High implementation	Fully implemented
		terminals visited by Passenger Roll-on/Roll-off vessels					
47		Standardization readiness of terminals visited by Pure Cars and Trucks Carriers vessels	NA	Low	Low	High	High
48		Standardization readiness of terminals visited by Bulk carrier vessels	NA	Low	Low	High	High
49		Compliance with international guidance on shore power operations	NA	Low	Low	Medium	High
50		Compliance with national or international guidance on shore power infrastructure design	NA	Low	Low	Medium	High

5.0 PORT AUTHORITY INTERVIEWS

The factors compiled in Section 4.0 were evaluated to determine how best to obtain information from the ports to evaluate their readiness for shore power. It was determined that the most effective approach would be to provide each port with a simple short answer questionnaire that covered the main topics followed up with a more detailed interview with port officials who were familiar with the ports' shore power initiatives. Two sets of questionnaires were developed, one for ports with shore power and another for those who did not have shore power. The questionnaire was available in both English and French and posted as a Qualtrics survey form. A copy of the questionnaire is provided in Appendix B. Results from the questionnaires were used by the team's interviewers to focus the interviews on the most important issues from the ports perspective. A copy of the interview form developed from the identified readiness factors is provided in Appendix C.

The team worked with the Associations of Canadian Port Authorities/Association des Administrations Portuaires Canadiennes to identify the best contacts at each port authority.

As questionnaires were completed and submitted, arrangements were quickly made for the interviews. Prior to the interview, the questions were tailored to the specific port, using the questionnaire responses to do so.

It was noted that shore power projects are highly ship-type dependent. To the extent possible, this analysis attempted to obtain information from the ports pertaining to the specific types of terminals that offer or are planning to offer shore power.

Information obtained from the questionnaire and the interviews were applied to the shore power assessment matrix. It is recognized that assignments made for the matrix are inherently subjective. To mitigate bias in populating the matrix, an uninvolved, external, staff member reviewed the initial ranking confirming the initial assignments or recommending changes. Completed matrix are provided in Appendix D.

6.0 INTERVIEW FINDINGS

The interviews implemented for this project helped convey each port's history and current position on shore power, highlighting several key issues that are informative for encouraging further adoption of shore power.

Economic Considerations

- As funding for capital investment for shore power was generally provided by other government agencies, not from existing port resources, there was a consensus that return-on-investment was not the primary motivation for the installation of the system but for the greater good of decarbonizing port operations and improving quality of life and environmental protection.
- Installation of shore power systems at ports would require additional resources, likely from government agencies.
- Some ports have developed an incentive program to encourage the use of shore power. An example of this is Vancouver which offers reduced in harbor fees for shore power connecting vessels.
- Multiple ports noted that their current agreements with the local utilities prohibited them from marking up the electricity costs to cover capital investments or ongoing maintenance. This is an important option, especially where the differential between local electricity prices and North America Emission Control Area (NA ECA) compliant fuels is large; by increasing electricity charges, ports may be able to cover some capital or operational costs, while still being able to provide energy at a price point below expensive NA ECA compliant fuel.
- For ports where terminal operators provide trained staff for shore power, these operators have their own connection fees. Ports encourage terminal operators to keep their fees low to facilitate increased utilization of shore power.

Utilities

- Some ports noted that for shore power to work in their area, enhancements are need in the electricity infrastructure; sometimes the utilities pick up these costs or they may be shared with the port, municipality, provincial or federal governmental agencies.

- Most of the ports had excellent relations with local utilities, generally including them early in their shore power planning activities.

Design and Maintenance

- Most ports noted that the most challenging aspect in providing shore power to a port is the construction period, where proposed time schedules are often extended, and original budgets are typically exceeded.
- Vessel alignment was an issue for several ports that negatively impacted utilization.
- Some ports had limited dock space or there was high traffic of cargo handling equipment, limiting the available space for installation or expansion of shore power.
- Ongoing maintenance activities require resources and careful planning; for example, obtaining replacement parts can take months to receive. Some ports try to address this by keeping in stock common maintenance supplies.
- Some ports have older infrastructure that poses a challenge. In order to implement a large-scale shore power system, additional costs would be incurred to retrofit the existing infrastructure.
- Some ports were early introducers of shore power which has created unanticipated problems now. For example, some of these older systems were initiated prior to international standards and they are not equipped to use new plug designs, such that to use these systems, electricity needs to be hardwired directly onto the vessel. To convert to the new standards can be costly both for the port and the vessel operators. Additionally, some ports are holding back on shore power, waiting for new standards to be issued as to avoid future connection issues and associated cost to upgrade their system to meet international standards.

General

- Many of the ports included in this project were smaller ports around the Great Lakes whose primary shore power activities were the provision of low voltage energy for vessels hoteling during the winter seasons. Expansion of these systems focused on better utilization of existing infrastructure rather than transitioning to higher voltage systems.
- For ports which have seasonal traffic such as cruise ships or fishing, critical maintenance or system updates are implemented during periods when the terminal is off-season.

Table 17. Studied Canadian Ports’ Shore Power Status

Port	Shore Power	Standardized High Voltage	Low Voltage ⁱ	Low Voltage Wintering
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Vancouver	Y	Y	N	N
Montreal	Y	Y	N	Y
Halifax	Y	Y	N	N
Prince Rupert	Y	Y	N	N
Saint John	N	N	N	N
St. John's	Y	N	Y	Y
Hamilton-Oshawa	Y	N	N	Y
Trois-Riveres	Y	N	Y (Ferries and Small Ships)	N
Quebec	Y	N	Y	Y
Nanaimo	Y	Y (for Fast Ferries only)	N	N
Port Alberni	Y	N	Y (fishing vessels)	N
Thunder Bay	Y	N	N	Y
Toronto	Y	Y (electric ferry)	N	Y
Windsor	Y	N	N	Y
Saguenay	N	N	N	N
Sept-Iles	N	N	N	N
Belledune	y	N	Y	N

In summary, the two largest barriers mentioned by ports are the high cost of shore power and the limitations of the utility grid. Since ports will likely not experience a return on investment the direct cost of shore power is too high for ports to pursue without funding support from the government. Additionally, to expand or implement shore power at some ports, enhancements are needed in the electricity infrastructure. The process of improving the grid power capabilities is extremely complicated, long, and costly, making it a large barrier. However, since the technology for the grid and shore power is mature, effort needs to be dedicated to funding support.

Belledune Port Authority

The Port of Belledune is a cargo and bulk shipping port offering one of the shortest routes between Europe and North America. They have low voltage shore power for electric tugboats at

their facility but no high voltage shore power. In 2020, while expanding their port they tried to implement shore power for larger vessels; however, the shipping companies did not seem interested (no demand), so they did not follow through with implementing it. They would be interested in installing high-voltage shore power as they are positioned as a green energy hub and part of Green Marine. It is just about ironing out the details, getting the shipping companies involved, and receiving some funding to install the required shore power infrastructure.

Halifax Port Authority

Port profile: The shore power system at the Halifax Port Authority is configured to provide shore power to cruise ships specifically. Challenges faced when implementing shore power include delays from utility reviewing the rate structure, a lack of available dock space at a congested port, vessel alignment issues, and delays when replacing maintenance parts. Electricity is passed through with no mark-up, only the costs for commissioning and decommissioning are passed through to the vessel. There are no on-demand peak charges to electricity use due to the tariff set up using an interruptible ride rate. There is a strong relationship between the port and utility with open communication and idea exchange. To ensure safety, the shore power system was designed and installed per international codes for high voltage, including training on certain procedures for connection. The port considered sustainability and health impacts when implementing the system but acknowledged that the largest hindrance to putting in place these systems is cost.

Hamilton-Oshawa Port Authority

Port profile: The Hamilton-Oshawa Port supports vessel traffic operating along the Saint Lawrence Seaway. The port has provided power to vessels that winter at the port for over 50 years. Currently there are sufficient connections to meet the needs of the winter hoteling vessels. The port is interested in expanding its shore power offering, but it is also considering whether alternative fuel options would be a more cost-effective option to provide similar air quality benefits. Additionally, the port is waiting on standards for bulkers to more accurately assess cost for the expansion.

Montreal Port Authority

Port profile: The Port of Montreal has strategic objectives to be a green and clean port, as well as to be a recognized and valued corporate citizen within local communities, which are particularly concerned about noise, light, or air pollution. It is committed to maintaining good relations with the community. The Port of Montreal has a docking facility with shore power, exclusively used by cruise ships. This project, completed in 2017, was funded by Transport Canada, the Government of Quebec, and the Montreal Port Authority. The port has also installed over forty low-voltage connections distributed across the various docks. While the current electrical infrastructure supports the existing shore power, greater coordination with the electric distributor Hydro-Québec will necessarily be required to facilitate the eventual implementation of large projects as they multiply in the future.

Nanaimo Port Authority

Port profile: The Nanaimo Port Authority has an older shore power system used for their fast ferries. They are expanding a containership terminal and considering plans for a shore power system that can berth and connect two containerships to shore power. There have been preliminary conversations with BC Hydro on feasibility of electricity capacity. The primary driver for adding shore power to this terminal is to reduce greenhouse gases and other emissions.

Quebec Port Authority

Port profile: The Quebec Port Authority currently is using shore power for wintering and low voltage connections but plans to expand to reach cruise ships and some cargo ships. They are an urban port that hopes to reduce greenhouse gas emissions, and work towards carbon neutrality. On the operational side they feel prepared to implement shore power and plan for port officials to manage the system. The greatest challenge and barrier to a wider scale implementation of shore power is cost. They cannot afford to fund this themselves and the funding streams they are eligible to apply for can provide a maximum of 4 million CAD when the minimum need for one berth would be 20 million. Additionally, the electrical infrastructure would need to be redone, as Hydro Quebec would need to provide them with 15-18 megawatts of power for cruise ships. They are looking at flexible technology given their 6–7-meter tides. They are consistently communicating with ship owners and cruise lines to assess the needs and smaller cargo companies for other projects to reduce emissions.

Port Alberni Port Authority

Port profile: The Port Alberni Port Authority currently has shore power at one of their three berths. The shore power was purchased by the port in 2014, but the ship owners reimbursed the port as they are the primary users (for their fishing vessels). The port would like to expand shore power for medium sized vessels, but their greatest challenges are funding, and a lack of knowledge regarding the available power infrastructure from BC Hydro.

Prince Rupert Port Authority

Port profile: The Prince Rupert port has a shore power system at Fairview container terminal dating back to 2010. At that time there were very, few vessels using shore power, but there is now a greater demand from shipping lines in the Pacific to reduce their carbon footprint. The system is available for containerships, but the port is exploring expanding shore power. Issues with alignment have arisen where ships that are too large are out of alignment with the shore power pits on the dock. The port authority made a commitment to Indigenous and community partners to reduce their carbon footprint, and it is continuing to work towards those goals. There is significant demand on the electrical system in BC including in the north. Investments in infrastructure would be required to meet the demands to fulfill the requirements for projects

across the north over the next 5-10 years. The port provides discounts on harbor dues when vessels use shore power, to incentivize use.

Saint John Port Authority

Port profile: Saint John Port Authority does not currently have shore power. The port authority is interested in putting in place shore power largely for cruise ships. The greatest barriers to this work include cost, the electrical power infrastructure, and the operational feasibility given their 28-foot tides, twice a day.

Saguenay Port Authority

Port profile: The Port of Saguenay is the only public port in the Saguenay-Lac-Saint-Jean region of Quebec and one of the 17 official Canadian port authorities, recognized as the Saguenay Port Authority (SPA). The deep-water marine terminal of the Port of Saguenay is accessible year-round. The SPA is known for its operational efficiency and its high capacity for receiving and shipping bulk goods, making it the largest cruise port of call in the Saguenay-Saint-Laurent corridor. Through its initiatives and strategic vision for sustainable development, the Port of Saguenay is committed to decarbonization and participates in the Sustainable Electric Mobility Table, and is a founding member of the Green Alliance. However, the Port of Saguenay faces challenges regarding the distribution capacity of the electrical network, as new distribution lines need to be installed and there is limited electricity available by Hydro-Québec.

Sept-Îles Port Authority

Port profile: The Port of Sept-Îles is well involved in shore power. They have performed economic and technical studies to integrate shore power at their cruise and bulk terminals. They are also a member of Green Marine and have a good relationship with the local communities. For the port, the main driver to install shore power is the benefits in terms of GHG reductions. However, there are some important barriers to shore power deployment and adoption, starting with the demand from the ship owners. Currently bulk ships are not equipped with shore power systems and there is a lack of shore power connection standardization for bulk carriers. Nevertheless, the port is committed to moving forward and is involved in the standardization process of shore power connections for bulkers. Funding and grid capacity are also other barriers to shore power in general, but the Port of Sept-Îles these are less important.

St. John's Port Authority

Port profile: The port has multiple variations of shore power systems that differ from one another. These systems range in size and connection styles from physical hardware connection of 600V/100A up to a maximum of 600v/400A pin/sleeve connection. Generally speaking, the work to connect the ships to the shore power systems is contracted out but vessels do have the ability to connect themselves to the smaller connections which are twist lock receptacles.

Additionally, some vessels have electricians on board who are certified to connect/ disconnect the vessels. The larger shore power systems are generally used by offshore vessels but during the winter months, the port sees a large influx of small fishing boats which tie up for the winter season. The St. John's Port Authority has investigated the use of larger shore power systems for one of the container terminals located on its property but would seek additional funding should this be deemed prudent. Other challenges include long lead times, the cost of replacement materials, and standardization. Power can be marked up by the port of St. John's, but they are not able to sell power and continue to pass on power charges to vessel operators at their current rate structure. The port employs a financial strategy to reinvest money into the current infrastructure to provide reliable services. Due to the electrical system being adjacent to a large body of water, there is a lot of necessary repair and maintenance done.

Thunder Bay Port Authority

Port profile: The Thunder Bay Port Authority has shore power at two berths which is solely used for wintering of ships (any ships). The system is about 30 years old, however the wire and connection boxes were recently replaced. These connection/disconnection boxes are by the docks, and it takes about an hour on average, to connect. To reach larger vessels, the port is looking into combining two 200 amps to a 400amp. In terms of expansion, they plan to extend power to more berths for short-term high voltage systems. Decarbonization and pollution reduction are the major drivers behind the port's shore power expansion. The port plans to do a feasibility study that will also consider environmental impacts. Because the shore power system is old, it is not standardized.

Toronto Port Authority

Port profile: The Toronto Port Authority does not have a full-fledged shore power system, rather they've pulled existing cables from their electrical system for winter layups of general cargo ships in the Great Lakes. Their shore power is a low voltage system and takes in about 2-3 ships in the winter. Costs were low to implement this system since it was developed from an existing system. The available power infrastructure is limited. Cost is one of the biggest barriers to expansion, paired with the reality that the electrical infrastructure available is not sufficient for future large-scale projects.

Trois-Rivières Port Authority

Port profile: Trois-Rivières Port Authority in the Quebec region of Canada has had shore power in place for 10 years at 3 of their berths. They are providing low voltage shore power to primarily ferries and smaller ships. The shore power was not an entirely new system as it was integrated into their existing infrastructure. The port would like to provide shore power to their bulk carriers but are awaiting the results from an international convention on shore power to better assess the recommended standards. Trois Rivières would like to expand their shore power as they see a need for it, but this would require funding and to ensure they have a sufficient electrical infrastructure, which is not currently the case.

Vancouver Fraser Port Authority

Port profile: The Vancouver Fraser Port Authority has shore power for cruise ships and container ships (at 2/4 container terminals) through a project funded by the federal government, provincial government, the Vancouver Fraser Port Authority and the cruise lines (industry). Maintenance costs are shared amongst the users of the system. Watts Marine installed and currently manages the system. EcoAction offers incentives via discounts on harbour dues to vessels calling into the port based on their environmental performance (bronze- 25% off vs platinum- 75% off), this makes it more attractive, in 2024 vessels connecting to shore power received a 75% discount (Platinum). BC Hydro has a set shore power rate for the non-firm electric service, the shore power users are charged only for electricity usage and no demand charges. There is a strong relationship with utility, they have a liaison between port authority and utility. The port emphasized the prioritization of air pollution and noise pollution reduction and has worked with indigenous groups with no pushback from any local communities.

Windsor Port Authority

Port profile: The Port of Windsor is an important bulk port in the Great Lakes. The port believes that the key shore power driver is decarbonization. For the Port of Windsor to introduce shore power they would need to be influenced by governmental policies and funding as they have no demand from shipping companies- the business need would only be in reducing GHG. While the grid capacity would be sufficient to cover the power demand of cargo ships at berth, recharging battery-electric ships would require extra grid capacity. At the Port of Windsor vessels are in port for very short times (often 2-4 hours) and are often moving while at berth to load/ deload ships, which would make shore power connection difficult.

Non-CPA Ports

Canada has over 550 port facilities. Of those, the seventeen Canada Port Authorities (CPAs) were interviewed for this study as it allowed for a clearly defined scope and because of their strategic, regional, national, continental and international importance. However, the experiences of the other port facilities are important. Two non-CPAs, Greater Victoria Harbour Authority and Port of Sydney expressed interest in the study. Therefore, they were also interviewed, and their insights have been summarized below.

Greater Victoria Harbour Authority

Port profile: The Greater Victoria Harbour Authority does not currently have shore power; however, they have been analyzing the potential to implement it for several years. Shore power at their port would mainly be intended to be used for cruise ships (2-3 berths), as well as cargo ships waiting to get into Vancouver during the off season. The biggest barrier to this work is cost. They have access to power through BC Hydro, but they would need to bring the power (28MW) over 7KM or 4.3 Miles to the terminal. Despite substantive investment in preliminary

engineering, geotechnical, economic, and shipping demand-based assessments, they are unable, at this juncture, to proceed without extensive funding to install and maintain infrastructure. They are currently working on updating a previous business case to present to the Board of Directors in 2025. The port plays a vital role in regional cruise programs, as well as being the perfect stop off route for vessels in the Pacific Northwest. They are also a part of the Pacific Northwest to Alaska Green Corridor.

Port of Sydney

Port profile: The Port of Sydney does not have shore power at this time; however, they are currently assessing the opportunity to implement shore power for cruise lines as well as other vessels. Many of the port's regular cruise customers are shore power ready so adding in shore power would be competitively advantageous, especially in an altered market post-covid. The port is near the Port of Halifax which has already implemented shore power. They are also adjacent to a residential area making this transition increasingly beneficial. The port is currently inquiring with Nova Scotia Power; however, they are yet to perform an economic analysis as well as lead formal discussions with shippers and cruise lines. The largest barriers to implementing shore power at the Port of Sydney are the cost and utilities. As a port, despite decarbonization motivations, they cannot invest in shore power independently and would require external funding.

7.0 FACTOR ANALYSIS FINDINGS

Using the data collected from the port's preliminary questionnaires and the interviews conducted with each port authority, their readiness was evaluated using the matrix described in Section 4.0. Port's readiness to implement shore power was assessed at a factor-by-factor level, as well as for the port as a whole. The shore power factor analysis enabled the cross-linking of data from the port interviews, environmental analysis, and literature review to provide a detailed overview of shore power readiness across the Canadian Port Authorities. Figure 14 presents the readiness level achieved by Canadian Port Authorities, displayed regionally. The x-axis presents the readiness level while the y-axis is the number of Canadian Port Authorities. The ports are grouped by regions across Canada.

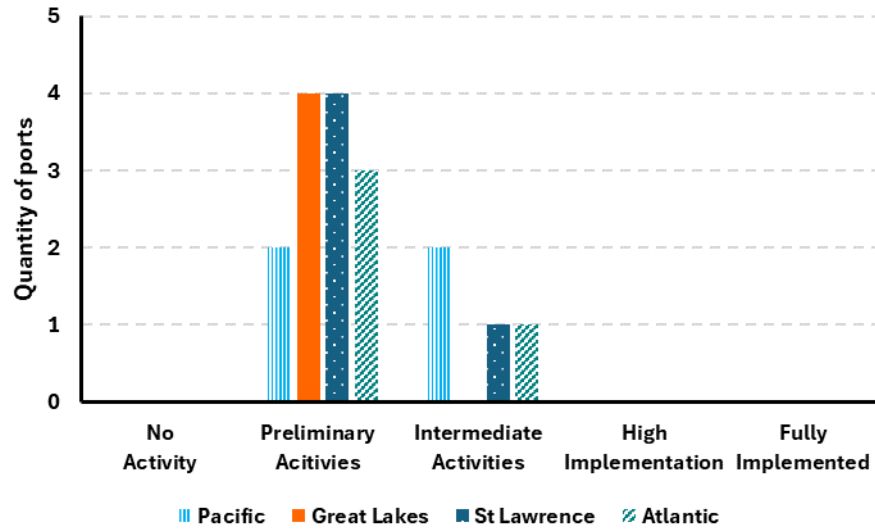


Figure 14. Number of ports per readiness level and region.

The results indicated that the majority of ports are still at the preliminary shore power activity level. This means they have begun exploring shore power and may have some experience with the technology but are not yet providing commercial shore power service for oceangoing vessels. Figure 14 **Error! Reference source not found.** also shows that about one quarter of the ports have reached the intermediate activities level, such that they are involved in some commercial shore power projects. The Great Lakes is the only region where all the ports are in the preliminary activities level with no ports in the intermediate activities level.

Figure **Error! Reference source not found.** shows the percentage of achieved factors met by the ports at each readiness level. The goal of this representation is to see how much work needs to be done to improve the ports shore power readiness. The x-axis represents the readiness level, and the y-axis is the average percentage of factors met by the ports.

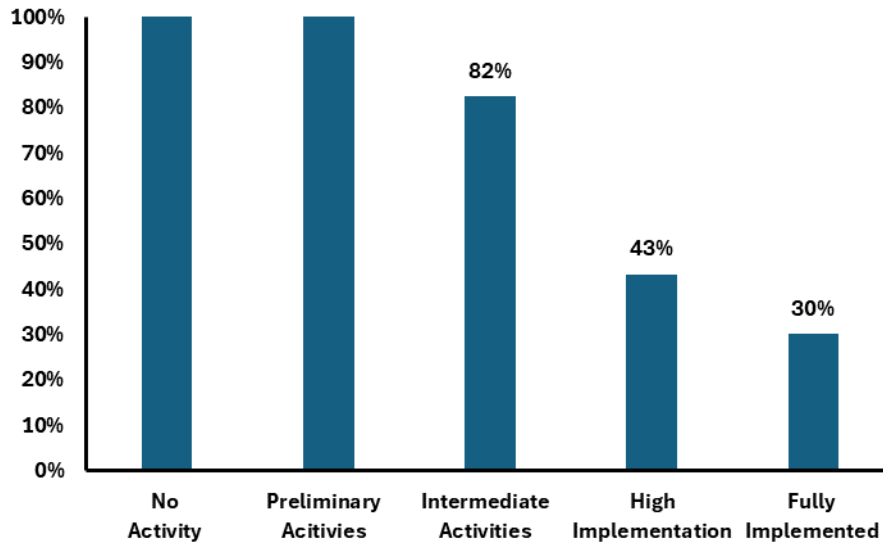


Figure 15. Average shared of achieved factors per readiness level

Based on the results in Figure , all ports have achieved the preliminary activity level for all factors. This means that all Canadian Port Authorities have explored the potential of shore power and understand the technology in some capacity. Furthermore, ports on average have meet 82% of the criteria required to reach the intermediate activities level. This indicated that most ports at the preliminary activities level are very close to reaching the intermediate activities level since they only have 18% of the criteria to address. However, the average of achieved criteria drops to 43% for the intermediate activities level, which involves achieving factors consistent with operating basic shore power services. Moreover, the average achieved criteria is only 30% for the high implementation level, indicating that, in general, more work is needed by ports to reach the high implementation level.

Figure 19 illustrates the readiness of various terminal types in Canada to implement shore power. It shows the proportion of emissions at terminals based on their shore power readiness levels and the type of terminal. Emissions are used as a metric for assessing shore power readiness because they an effective representation of the level of shipping activity occurring at each terminal type. Since ports vary in size and capacity, the percentage of emissions for each terminal type reflects the differing contributions of emissions. This percentage is determined by considering the emissions at each port and their corresponding readiness scores. The goal is to identify where ports and governments should focus their efforts to optimize results. The emissions used to generate this analysis are from the Environmental Analysis of Section **Error! Reference source not found.**

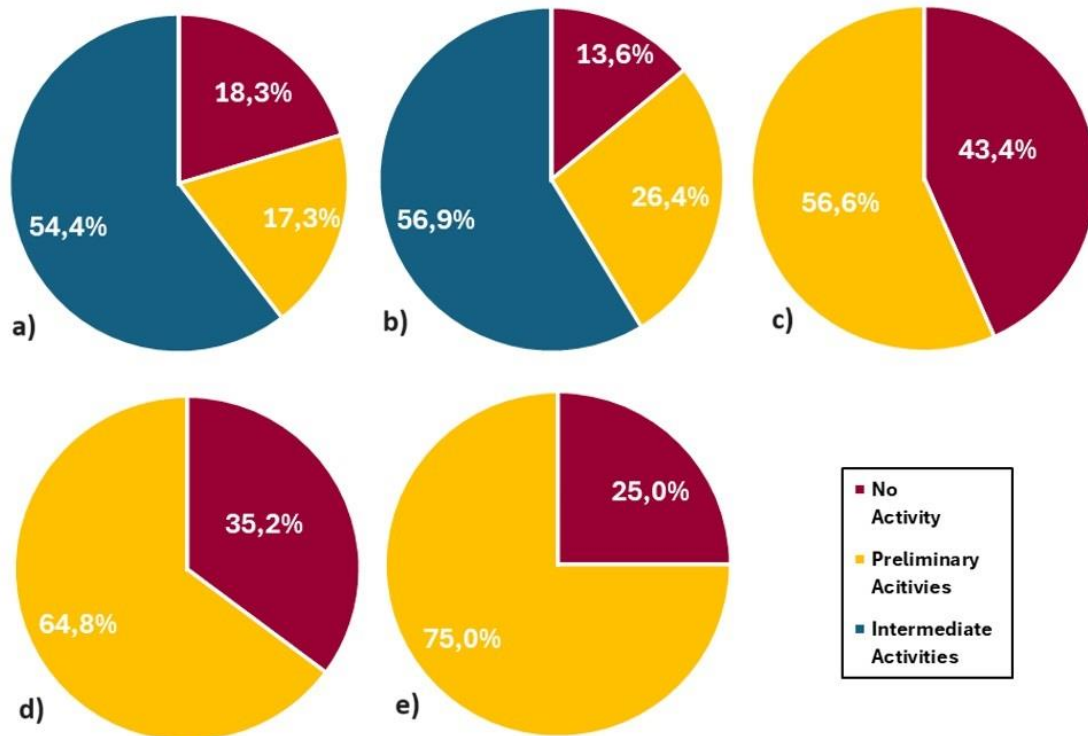


Figure 16. Share of emissions happening in each readiness level and per terminal type: a) Cruise b) Container c) Tanker d) Bulk carrier) Merchant other

Cruise and container terminals are the most ready for shore power implementation. As Figure 19 shows, 54% and 57% of the emissions for these vessel types occur at cruise and container ship terminals that have reached the intermediate readiness level. Therefore, over 50% of the emissions for each of these vessel types are occurring at terminals that already have some involvement in shore power. As a result, only a few actions could be taken to enable the cruise and container ports to reach higher levels of readiness and offer better systematic shore power services.

Comparatively, Figure 19 shows that terminals for tankers, bulk carriers, and other merchant ships require more substantial efforts to prepare for shore power operation. Currently, 57%, 65%, and 75% of emissions for these terminal types occur at ports with preliminary activities level of readiness. Since 82% of the criteria have already been met at these terminals (as shown in Figure), only an additional 18% of the criteria need to be fulfilled to advance these ports to the next level of readiness. Achieving this would improve the share of emissions handled at shore power-ready ports, as depicted in Figure .

To determine which factors require more attention by ports, Figure presents the share of ports achieving each readiness level. The x-axis represents the identification number of each factor, and the y-axis represents the percentage of ports achieving the factor. Then, each line represents the share of ports achieving a factor but based on different readiness level.

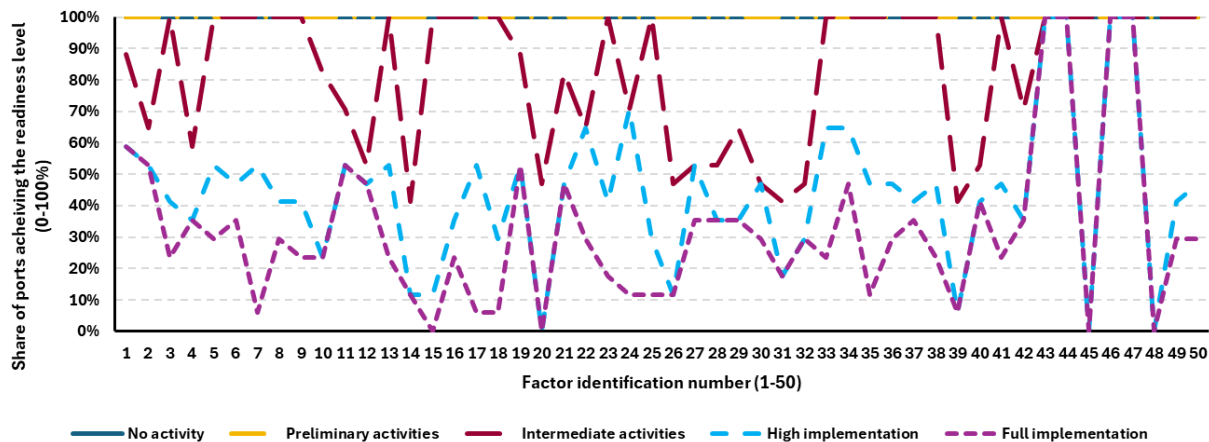


Figure 17. Shared of ports per factor and readiness level

For example, Figure shows that factor 28, Economic cost-benefit analysis, is only achieved at an intermediate readiness level by about 55% of the ports. This indicates that 45% of the ports need to address this criterion to reach the intermediate readiness level. Additionally, only 35% of the ports have reached a high implementation level for this factor, meaning 65% of ports need to improve in this area to achieve the next level. The same analysis was conducted for all factors to identify, on average, the areas where ports have the lowest readiness levels. The factors requiring the most improvement are summarized in Table 18, along with the scope level. The scope is for guidance only and is intended to indicate the level that likely would address the factor.

Table 18. Factors requiring significant improvements by ports and related scope

Factor No	Description	Category	Scope
2	Electrical infrastructure is sufficient for current and future capacity evaluation.	Technical	Provincial/National
4	Design, management, and certification are based on existing standards.		International
12	Ship energy and power demand profile evaluation (including concurrent vessel charging and charging of electrified non-vessel equipment such as vehicles and cargo handling equipment)	Operational	Port
14	Competencies and training identified/required.		Port
20	Flexible design that allows vessels to connect regardless of the location on the vessel of the connection port.		Port

22	Market incentives\regulation for guaranteeing use of shore power	Market/Financial	Provincial/National
26	Capital funding and financial evaluation.		Provincial/National
27	Operational cost difference with current situation evaluation.		Port
28	Economic cost-benefit analysis.		Port
29	Cost recovery evaluation and risk management.		National/Port
30	Impact assessment in port/local economies.		Port
31	Evaluation of options competing with shore power and stranded assets.		Port
32	Social impact evaluation.	Social considerations	Port
39	Life-cycle environmental impact evaluation	Sustainability	Port
40	Sustainability of the project		Port
45	Standardization readiness of terminals visited by Tanker vessels.	International standardization	International
48	Standardization readiness of terminals visited by Bulk carrier vessels.		International

Table 18 reveals that while improving most of the factors can be addressed directly by the ports, some factors are outside of their control. Thus, national and international support is necessary to address many of the factors and help ports increase their shore power readiness.

8.0 CONCLUSIONS

To support the Canadian government’s initiative to reduce national marine emissions, this study evaluated the feasibility of implementing shore power at Canadian ports. The assessment included a literature review and interviews with Canadian Port Authorities to determine port readiness.

The findings indicated that shore power can be achievable on a national scale. There are well-defined standards for ports and most vessels, there are successful existing international regulations, and numerous Canadian ports that are already using shore power.

One international standard, IEC-80005, has been developed by the IEC, IEEE, and ISO to ensure shore power connections are safe, compatible, and operational for all ports and vessels worldwide. These standards have been finalized for cruise ships, container ships, roll-on/roll-off vessels, LNG tankers, and car carriers and are under development for tankers, bulk carriers, and general cargo vessels. These standards support national and global implementation, already reflected in international regulations and the IMO guidelines. Most Canadian ports with shore power, including the Port of Vancouver and the Port of Prince Rupert, are already following the

IEC-80005 standards. Transport Canada also developed ship electrical standards in 2018; however, these do not directly connect to the IEC-80005 guidelines.

In addition to well defined standards and guidelines, the success of international regulations mandating shore power highlights Canada's capability to do the same. While the specific directives varied in the EU, China, and the State of California, the regulations consistently require all ports to install shore power and most vessels to connect at berth by 2030 or earlier.

In Canada, despite no regulatory requirements, many ports have proactively implemented shore power, motivated by decarbonizing their port operations, protecting the environment and nearby communities, and maintaining their competitiveness as a port. 1/3 of Canadian Port Authorities have installed standardized high-voltage shore power including the Port of Vancouver, Montreal, Halifax, Prince Rupert, Nanaimo, and Toronto while other Canadian ports offer standardized low-voltage shore power for small vessels or have electrical connections for wintering.

Shore Power Port Readiness in Canada was evaluated by applying the questionnaire and interview findings through the Qualitative Binning Matrix. The results indicated that most Canadian Port Authorities are still in the preliminary phase, having explored the potential of shore power and understand the technology, but have not yet implemented it in a commercial capacity. However, the results varied by terminal type. The findings revealed that cruise and container terminals are the most ready to implement shore power as over 50% of emissions occur at terminals that have reached an intermediate activity level. Reaching this level means that the port is involved in some commercial shore power projects. In comparison, all tanker, bulk carrier and merchant other terminals remain in the preliminary level. An analysis of each factor's scoring revealed that, while ports can directly address many factors, some remain beyond their control. Thus, national and international support is necessary to address many of the factors and help ports become more ready to implement shore power.

The interviews and analysis from Canadian Port Authorities illustrated that, as other countries have done, regulations and government incentives are essential in facilitating shore power implementation on a large scale. Despite the aspirations of Canadian ports towards climate action and environmental protection, several obstacles limit these efforts. Consistently, the most significant barriers communicated by ports were the high cost of shore power and the limitations of existing utility grids. Due to the high direct cost of shore power, ports do not anticipate a return on investment. Furthermore, expanding or implementing shore power often requires electrical infrastructure enhancements, which can be expensive, complex, and timely. Despite these challenges, ports remain engaged in implementing shore power. International shore power regulatory leaders like the EU, China, and California have provided funding and assistance to ports when regulations were enforced. Following these regions' lead, widespread shore power could be possible by administering federal shore power mandates and providing essential monetary support.

Shore power technology can help the Canadian Government achieve its climate and air pollution priorities. “Addressing climate change and ensuring clean air for Canadians is a top priority for the Government of Canada. As Canada begins its journey towards exceeding our 2030 Paris Agreement climate target towards net-zero emissions in 2050, significant reductions in air pollutant emissions are expected as our economy becomes cleaner” ⁷². For Canada to meet its climate targets and ensure local emissions are below the Canadian Ambient Air Quality Standards, technologies such as shore power need to be utilized to their maximum potential. This study can guide future assessments of large-scale implementation of shore power and contribute to achieving Canada’s climate commitments.

⁷² Service Canada, “Net-Zero Emissions by 2050,” November 19, 2020, <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html>.