Photo courtesy of Yara International

GREAT LAKES ST. LAWRENCE GOVERNORS & PREMIERS

ELECTRIFICATION OPPORTUNITIES

for the Great Lakes St. Lawrence Maritime Transportation System

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INTRODUCTION

Electrification is defined as the process of replacing fossil fuel technologies, such as coal, natural gas, or fuel oil, with other technologies that use electricity as their principal energy source. When renewable sources are used to produce electricity, these technologies can significantly reduce carbon dioxide (CO2) and other emissions from various industrial sectors, buildings and transportation modes.

In the maritime field, electrification mainly applies to ships and port infrastructures. By integrating an electrical solution into a ship's design or by improving its propulsion system, electrification enables the ship's engine to perform at an optimal level and to operate with zero emissions using only the battery's power. To provide their energy supply, electrified ships require the shoreside installation of charging equipment.

This research addresses the electrification potential in the Great Lakes St. Lawrence maritime transportation system. Specifically, the study examines the status of electrification in the region, the issues and challenges surrounding it, and the efforts already being made towards a possible transition. The objective is to target opportunities with high electrification potential and to develop a clear and concrete action plan to promote the electrification of ships and port infrastructure.

The Great Lakes St.-Lawrence Region

The Great Lakes St. Lawrence maritime transportation system includes lakes Ontario, Erie, Huron, Michigan, and Superior, their connecting waters, and the St. Lawrence River upstream of Les Escoumins, Québec. With the opening of the St. Lawrence Seaway, the system provides oceangoing deep-draft vessels access to the great industrial and agricultural heartland of the North American continent.

The Great Lakes St. Lawrence region includes 15 major international ports and some 50 regional ports on both sides of the border. Maritime commerce on the system supports domestic and international trade and provides a competitive advantage to a wide range of industries.

WORLDWIDE ELECTRIFICATION

Climate change has become increasingly important in recent years and public concern has led to a strong desire to find concrete solutions to mitigate its consequences. One of the central elements of climate change is the large-scale emission of greenhouse gases. The will for change is growing, and so is interest in specific strategies to transition to low-GHG emission technologies. Several prominent venues have been instrumental in the development of these strategies.

The Conference of the Parties (COP) is a decision-making body of the Convention on Climate Change. It brings together leaders from several countries once a year to discuss matters central to climate change. At COP26, recently held in Glasgow, the topic of broad electrification of transportation took a prominent place in the discussions. Perceived as one of the main solutions to limit the consequences of global warming in the short term, thirty countries and several car manufacturers signed the COP26 Declaration, which includes a goal of replacing all petroleum-powered vehicles with electric vehicles by 2040.

The Electrification International Conference is a conference organized by the Electric Power Research Institute, a non-profit organization located in Washington D.C.. Established in 2018, the conference aims to bring together stakeholders to accelerate the electrification process and allows for the sharing of ideas from industry leaders and discussion to find sustainable solutions. For the 2021 edition, an entire track focused on the electrification of transportation and solutions to make this transition more affordable.

Norway's Transition

Norway started the process of electrifying its maritime sector several years ago, starting with the electrification of ferries. It is estimated that about 80% of the ferries in Norway will be partially or fully electrified by 2022. To achieve this outcome, the Norwegian government adopted several policies to stimulate the energy transition, such as the Pollution Control Act, which applies to pollution from ports. The pollution control act applies to contaminated sediments, noise, local air quality, and waste reception facilities in ports. Such a law, accompanied by a carbon tax increase of 5% per year until 2025 for all sectors, provides an incentive for ships and ports to reduce their GHG emissions over the long term and thus favor carbon-neutral technologies.

In order to further support the transition, the government introduced a reduced electricity tax rate in 2017, allowing electric propulsion technologies to be more competitive on the market. To ease the financial burden on businesses, there are various programs and agencies to support the development of innovative technologies. These programs and initiatives are the result of a collaboration between several public and private organizations and offer important financial support to companies that take action to fight climate change.

Ferries are an important part of the Norwegian maritime sector. The sector includes more than 30 ferries with electric propulsion, and it is estimated that Norway's largest ferry operator, Fjord1, carries 10.5 million vehicles and 21.5 million passengers a year. Electric ferries have been positively received by many passengers, not least because they emit considerably less sound than their fossil-fuelled counterparts, but also because they have a significantly lower environmental impact.

While the overall impact in Norway has been positive from a political point of view, the economic impact has been more nuanced. According to the E-Ferry coordinator, an organization dedicated to designing and building electric ferries, a ferry with an electric propulsion system could have an operating cost of about 25% of that of a similar diesel ferry. Alternatively, these new vessels could be about 40% more expensive than a conventional diesel vessel. Thus, the situation in the field shows that the investment could be profitable after only four or five years in some cases. However, some financing programs exist to reduce the financial risk involved. In 2019 ENOVA, a state-owned enterprise that distributes funds to accelerate the transition to cleaner energy, made new commitments totaling about $638 million, more than double that of the two previous years.

OVERVIEW OF THE ENVIRONMENTAL IMPACT

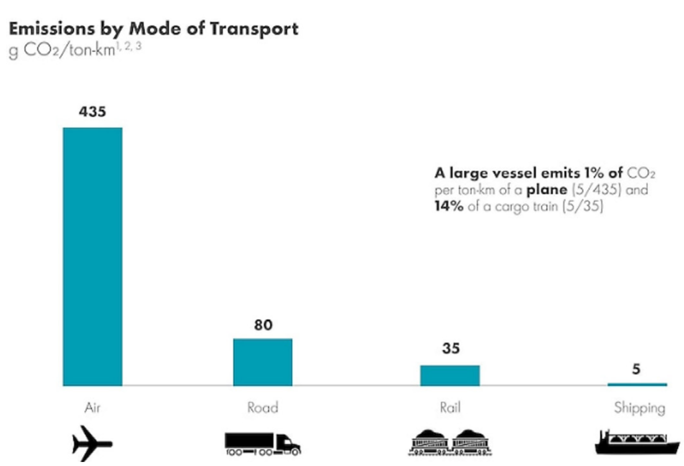
Several factors can influence the GHG emissions produced by vessels operating with fossil fuel propulsion systems. Among them is the size of the vessel and the type of fuel used, as sulfur content can vary among fuels. Below is the estimated carbon dioxide emissions per day for common vessel types operating in the Great Lakes St. Lawrence system.

Estimated Carbon Dioxide Emissions, kg per Day

Vessel	Idle in Port	Seaway Transit		Lock Transit		Open Water Sailing	
		Loaded	In Ballast	Loaded	In Ballast	Loaded	In Ballast
Traditional Laker	6,508	37,703	24,507	26,392	17,155	52,784	34,310
Thousand-Footer	14,812	85,806	55,774	60,064	39,042	120,129	78,084
Next-Gen Laker	10,533	61,021	39,664	42,715	27,765	85,430	55,529
ATB	3,119	18,071	11,746	12,650	8,222	25,300	16,445
Salties	9,569	55,436	51,555	38,806	36,088	77,611	72,177

Source : CPCS Analysis, Vessel Emissions & Operating Cost Estimates for the Great Lakes & St. Lawrence Commercial Navigation, Table 2

A traditional laker can use about 12,000 liters of fuel per day when loaded which represents a carbon dioxide emission of about 37,703 kg per day. In comparison, it takes 8.6 cars to achieve the same level of daily emissions, or the yearly energy use of 6.6 homes. These figures represent far less emissions per ton of freight moved than other transportation methods like trucks or airplanes. Ships continue to be, by far, the most efficient mode of transportation to move large, bulk cargoes.



Source: The International Council on Clean Transportation

According to the International Council on Clean Transportation (ICCT), it is estimated that in 2019 alone 510,000 tons of fuel were consumed by vessels in the Great Lakes St. Lawrence region, emitting approximately 1,625,000 tons of CO2, or the equivalent of 350,000 cars. This is mainly caused by the movement of bulk carriers and liquid bulk tankers, and most of this consumption is in the St. Lawrence Seaway.

Photo courtesy of Algoma Central Corporation

New technologies have had a direct impact on GHG emissions from ships. For example, Algoma Central Corporation's new Equinox Class vessels are expected to emit 45% less GHG than the company's other vessels. Fednav and other carriers are similarly investing in new vessels that are more efficient. But, for a variety of reasons, these new models remain in the minority. Most vessels operating in the Great Lakes St. Lawrence region continue to be older ones, although in many cases these vessels have had engine replacements and other improvements that reduce their emissions.

Focused risk of a transition on a policy level

The energy transition is inherently a risky process and involves many upheavals, particularly at the level of public policy. Challenges include considering and implementing different types of policy-related incentives (e.g., subsidies), cost-related measures (e.g., taxes), performance standards (e.g., battery efficiency standards), production, environment, safety, production standards (e.g., electric vessel sales mandates), and direct regulation (e.g., banning specific technologies).

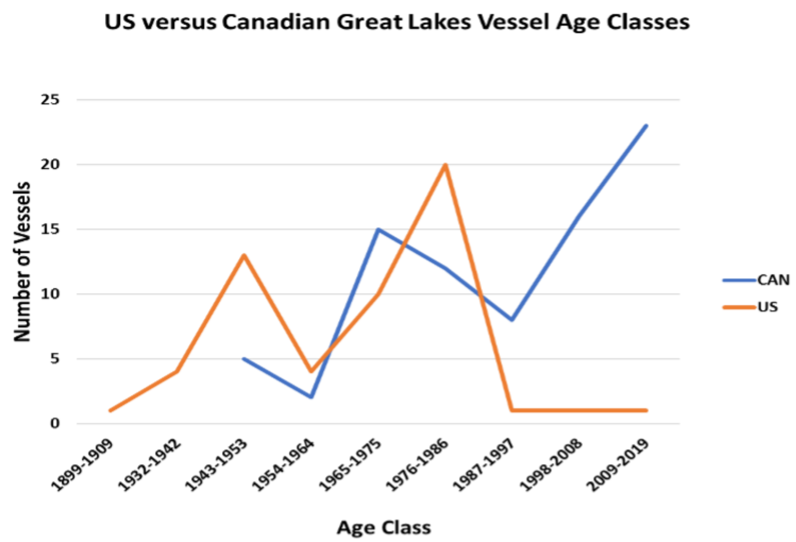
The risk of energy transition manifests itself in various forms including investment and operational decisions by market participants and/or adjustment in the value of companies' assets, among others. Therefore, an overly rapid transition could make it difficult for stakeholders to adequately adapt. Technological and infrastructure realities require a large-scale approach as batteries will require multiple recharging sources in the region if they are to be deployed on a widespread basis.

REGIONAL REALITY

Great Lakes St. Lawrence Fleet

The Great Lakes and St. Lawrence fleet is generally divided into three categories: lakers, salties, and tug-propelled barges. Lakers are vessels built for specific use within the fresh waters of the Great Lakes and St. Lawrence. Salties are vessels built to trade with nations overseas and can navigate freshwater and saltwater. Meanwhile, tug-propelled barges consist of a tug fitted into a specially designed barge.

Typically, lakers are bulk carriers, meaning they carry materials in large contiguous holds, not packed in containers. Examples of typical cargoes include commodities like coal, iron ore or taconite, and grain. Due to the variability of their cargo and the size of their hold, the size of the ship can vary considerably. Typical lakers range in length from 600 to 1000 feet, have an average trip carrying capacity of 25,982 tons, and exert between 6,000 and 8,500 Horsepower (SHP). The 1000-foot lakers have a width of 105 feet and a deadweight tonnage of around 70,000 tons. They have the most power of any of the ships in the region, with power ranging from 14,000 to 19,000 SHP. Lakers also vary considerably in age. On average, lakers are 48 years old, with some built as far back as 1940.



Source: Mike Beaulac, 2018, Michigan Office of the Great Lakes

In the case of recently built ships, their dimensions and performance are often different from older models. For example, the new Algoma Equinox Class and CSL Trillium Class ships are both approximately 700 feet in length, have a deadweight tonnage of 35,000 tons, and a propulsion engine with a power rating of approximately 11,700 SHP. In the US, Interlake Steamship recently constructed the first new US laker to be built in over 35 years.

Policies governing the maritime sector in the region

The Great Lake St. Lawrence marine transportation system cuts across local, state/provincial, and national borders. More than any other mode of transportation, it is a joint private and public sector enterprise. The private sector owns virtually all the vessels and most of the terminals. Governmental agencies are responsible for keeping the waterways open and functioning at optimum efficiency. By its nature and operation, the regional maritime transportation system is intermodal which means it interacts with and depends on access to the other modes.

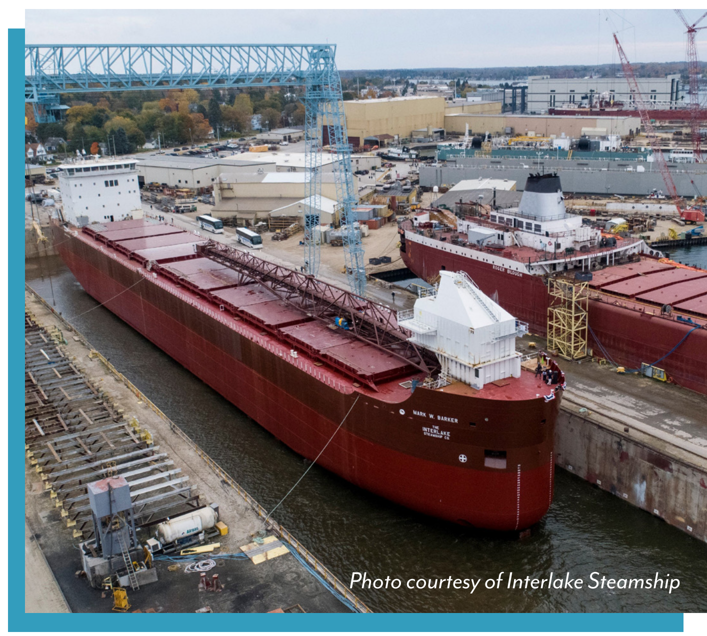


Photo courtesy of Interlake Steamship

A vessel that carries freight from one Great Lakes U.S. port to another U.S. port without stopping in Canada must fulfill the requirements of the 1920 Jones Act which requires that the vessel be built in the U.S., that it be registered in the U.S., and that it is crewed by U.S. citizens.

The service life of a steel ship in freshwater is decades longer than a similar ocean vessel resulting in 60 plus-year-old ships operating efficiently and safely. This longevity and the high cost of U.S. shipbuilding makes the prospect of replacing a large portion of U.S.-flag Great Lakes ships unlikely. By contrast, as of 2011, the (Canadian) Coasting Trade Act allows foreign-built vessels to be purchased and flown under the Canadian flag without paying high duties.

Regional specific challenges and current energy transition constraints

Operation on the Great Lakes and St. Lawrence is restricted during the height of winter due to ice conditions and the closure of the locks. Vessels that elect to operate during this period need an ice-strengthened hull, rudder, and propeller, and would be limited to operational areas not requiring locking. Air temperatures can go as low as –50 degrees F (–46 degrees C) with ice covering a large portion of the northern Great Lakes and most of the harbors. This is a central matter in connection with a possible energy transition since new technologies must be able to offer the same level of performance in this harsh climate.

The second challenge to electrification is one of economics. Like most new technologies, electric or hybrid engines are more expensive to purchase than traditional fossil fuel models. A new high-cost ship would be competing with a decades-old ship that has long since paid off its capital cost. If the vessels were competing for the same cargo, it would be difficult to justify the additional capital costs incurred in new builds. To alleviate this problem, it is possible to consider the creation of incentives or assistance programs to help reduce the financial burden of companies wishing to modernize their fleet.

Finally, the last constraint is technical. Heavy battery arrays typically require significant space in the vessels. It is not possible to increase the size of the vessels to accommodate the space demands of this technology since the vessels must not exceed the maximum dimensions allowed by the locks. As a practical matter, therefore, battery arrays may displace cargo capacity with negative consequences for economic competitiveness.

Electrification Potential

Ferries

The size and routes of Great Lakes St. Lawrence ferries vary greatly. Ferry trips can be as short as a few minutes (e.g. crossing a river) to as long as seven hours (e.g. crossing Lake Superior). These routes are all closed in the winter when the rivers and lakes are iced over, and these closures can be as long as four months each year. Ferries can vary in length from 50 to 250 feet and in width from about 35 feet or greater. Ferries primarily carry passengers, and they can also carry vehicles and sometimes cargo. Passenger capacity is highly dependent on the size of the vessel; thus some ferries can carry only 150 passengers while others have a capacity of 620 passengers plus 180 vehicles. Because of their smaller size and predictable routes, ferries are already being targeted for electrification. The energy demand of ferries varies depending on their size. While the Mary Ann Market requires 1.8 MW of propulsion, the SS Badger, because of its larger dimensions, requires 5.22 MW. This represents an energy demand that can be fully met by an electric propulsion engine and explains why several electrically powered ferries have been built in recent years, with more on the way.

Photo courtesy of Interlake Steamship

The first all-electric car ferries made their debut in North America in September 2021. Intended to operate on Lake Ontario, the 68-meter Amherst Islander II has a capacity for 40 cars, and the Wolfe Islander IV, which measures nearly 100 meters, can carry 75 cars. Originally commissioned in 2018 by the Ontario government, both ferries have been designed to sail in 60 cm thick ice and to be fully operational at -25°C to withstand Canada's harsh winter conditions.

The batteries of these two ferries are charged via direct current (DC) charging stations, which offer protected and heated charging that, in conjunction with extra energy storage, allows the batteries to be charged on board in 10 minutes, delivering 6MW of power. In case of

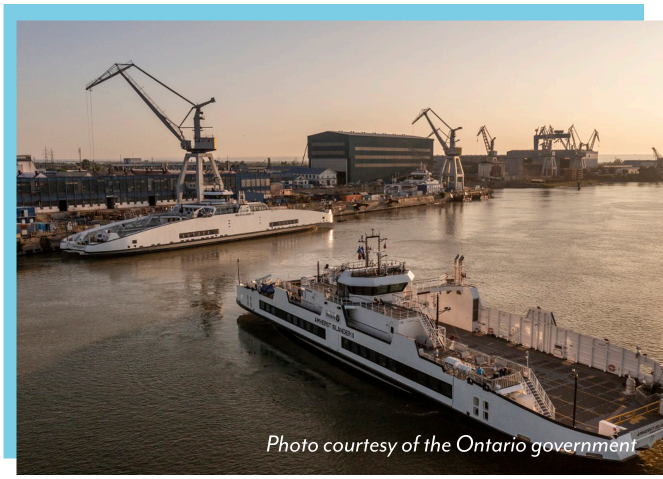


Photo courtesy of the Ontario government

heavy ice conditions over either route, the company building the ship also installed standard diesel-powered backup generators aboard the ships.

Ontario Power Generation (OPG) is working on the construction and design of onshore power to recharge electric ferries . To accomplish this, several terminals will be installed, such as the Kingston terminal, which will have 64 battery strings, holding 5.9megawatt-hours of energy, enough to power nearly 1,950 homes for an hour. The onshore batteries will be charged during off-peak hours when electricity demand and prices are lower. In addition to charging the ferries, they will also be able to power other parts of the terminals. Based on their life expectancy, the ferries are expected to reduce greenhouse gas emissions by the equivalent of 446 million kilograms of carbon. Several other recharging infrastructures will be installed to charge the ferries on their way, including in Marysville, Millhaven, and Stella.

Potential for bulk carrier

Because of their wide variety, the potential for electrification is highly dependent on the type of bulk carrier, especially in terms of its energy demand. Currently, some electric propulsion suppliers can offer an engine with a power approaching 10,000kW (10MW), assuming the ships have the necessary space on board. Unfortunately, such a battery cannot have a long period of operation which prevents the vessels from traveling long distances.

Table 9. Vessel Characteristics

Vessel Characteristics	Traditional Lakers	Next-Gen Lakers	1,000 Footers	Articulated Tug Barges	Salties
Deadweight Tonnage (DWT)	25,000 - 40,000	35,000	~70,000	20,000 - 40,000	~30,000
Horsepower (SHP)	6,000 - 8,500	11,700	14,000 - 19,000	2,150 - 4,500	5,250 - 8,650
Crew Type	Domestic	Domestic	Domestic	Domestic	Domestic
Crew Size	18 - 21 people	18 - 21 people	23 people	11 - 12 people	22 - 23 people
Vessel Age	40 - 75 years	~0 - 5 years	~40 - 50 years	~20 years	~0 - 30 years
Geographic Range	All system	All system	Superior, Michigan, Huron, Erie	All system, primarily US	All system

Source : CPCS Analysis, Vessel Emissions & Operating Cost Estimates for the Great Lakes & St. Lawrence Commercial Navigation, Table 9

As shown in this table, an old US or Canadian Laker has a power range of 6000 to 8500 SHP. This is a power that can be matched by an electric propulsion system, therefore the feasibility of electrifying the vessel will depend mainly on the distance it has to travel and the predictability of its route in order to reliably access charging equipment. Since the battery would be drained quickly during use, it would be possible to electrify these ships if they traveled short distances and recharged their batteries regularly. Far from having an impact only on the ship, this type of use will also entail considerable adaptation on the part of the port authorities, since charging installations would have to be built in the ports to allow for the numerous stops of electric ships.

One example of a successful bulk carrier electrification is the Yara Birkeland, which entered service in 2021 in Norway. 262 feet in length, the ship has a battery with a power output of 7MW, equivalent to nearly 100 Tesla Model 3s cars. Despite this, the battery storage capacity only allows the ship to transport goods to nearby cities. Nevertheless, the Yara Birkeland could reduce the number of truck transports by 40,000 in a single year.

Opportunities for action

i. **Promote research and development.** Technologies surrounding the electrification of ships are advancing rapidly but currently struggle to meet the needs of the maritime sector. Research and development, therefore,

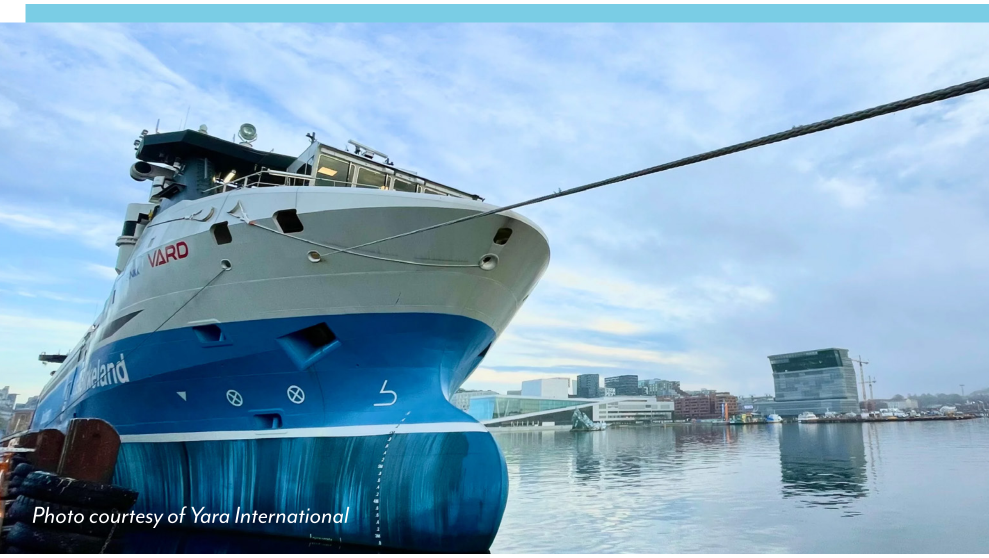


Photo courtesy of Yara International

represents a good opportunity to bring new systems to market. In the near term, regionally based organizations could test the implementation of new technologies on ships.

ii. **Coordinate the energy transition.** Long-term planning, prioritization, and the identification of particular ships and port facilities for electrification represents another promising opportunity. Industry stakeholders could benefit from coordinated policies that could lead to standardized practices in the region.

iii. **Provide funding for electrification projects and promote the Impact Investment Platform.** Expand the Great Lakes Impact Investment Platform to include a maritime transportation theme. Identify opportunities to financially support initiatives and pilot projects to implement electric propulsion technologies.

CONCLUSION

The electrification of maritime transportation could be one of the most important challenges of the decade ahead and a viable solution to combat climate change. Significant progress has been made in recent years to reduce GHG emissions from the regional fleet, and stakeholders are undoubtedly looking for sustainable and innovative solutions to address future climate change issues. The upcoming years will be crucial for the development of a regional strategy to accelerate the electrification of the maritime sector, and it will be critical to ensure collaboration with stakeholders from all sectors in order to benefit the entire population and the regional economy.