GREAT LAKES
ST. LAWRENCE
GOVERNORS
& PREMIERS

Michigan Technological University

GREAT LAKES COMMERCIAL VESSELS THAT OPERATE LIKE FERRIES: A POTENTIAL PATH TO ELECTRIFICATION

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EXECUTIVE SUMMARY

This analysis, conducted by the Advanced Power Systems Research Center, known as APS LABS at Michigan Technological University in collaboration with the Great Lakes St. Lawrence Governors & Premiers, aims to identify potential candidates for plug-in electrification within the Great Lakes fleet. Adopting a methodical approach, 191 vessels were identified for analysis. The research then focused on a subset of 103 vessels for which complete Automatic Identification System (AIS) data was available.

The results suggest that 95 out of these 103 vessels are not suitable for electrification due to factors such as the number of ports visited and the distance traveled. Eight vessels did display potential for some form of plug-in electrification, meaning a battery is charged from the power grid while the vessel is in port, and that energy is used to supplement the onboard combustion fuel. Of these, the **Huron** and **Maple Grove** appear the most promising.

The study's recommendations include conducting further detailed research on these vessels to ascertain the technical feasibility, economic viability and environmental benefits of various degrees of electrification and implementation architecture. A real-world pilot project should also be conducted to validate electrification technology's practicality and performance. As electrification cannot be the sole solution for decarbonizing the region's waterways, exploration and development of other propulsion and fuel technologies should also be pursued. New research on which ferries currently in operation in the region are strong candidates for electrification is also recommended. By implementing these recommendations, the Great Lakes St. Lawrence region can reduce shipping emissions and build a more sustainable and resilient maritime transportation sector.

Photo: ForSea

BACKGROUND

Photo: Knut Brevik Andersen

The global transportation network is moving toward the reduction of carbon emissions across the board, necessitating the participation of every mode of transportation to achieve significant emissions reduction. As part of the revised 2023 International Maritime Organization's Strategy on Reduction of GHG Emissions from Ships, the IMO set a target of reducing global maritime GHG emissions to net zero by 2050, with checkpoints in 2030 and 2040 [1, 2]. To meet the goals established by the IMO and governments around the world, the shipping industry has experienced a significant push toward vessel hybridization and electrification [3, 4]. Among various types of vessels, ferries show the most promise for electrification due to their fixed routes, relatively short distances and predictable time spent at ports.

The Great Lakes contain approximately 20% of the Earth's surface fresh water, and, including the St. Lawrence River, the system has long served as a bi-national waterway for regional and global commerce. Commercial vessels in the U.S. and Canadian Great Lakes fleets are larger than ferries but some share the characteristics that make ferries good candidates for electrification. Great Lakes vessels primarily transport bulk cargo such as iron ore, salt and agricultural goods, which often involve routine, predictable voyages between a small number of ports.

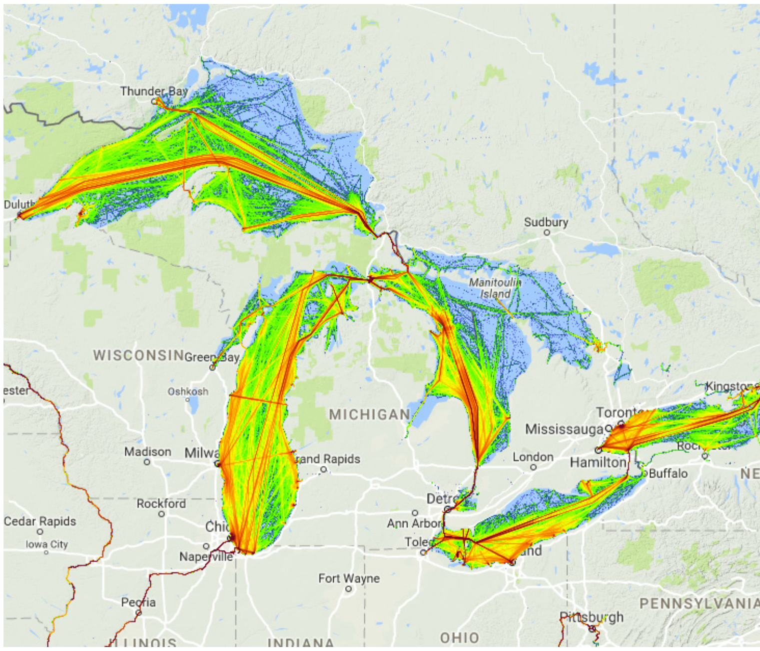
Successful examples like the Yara Birkeland and the MV Ampere in Norway demonstrate the feasibility of electrifying some commercial vessels. The MV Ampere [5], the world's first battery-electric ferry, has been operational since 2014, providing transportation for cars on a 3.6-mile route between Lavik and Oppedal. Similarly, the Yara Birkland, operating in Norway, is a container ship that carries fertilizer approximately 9 miles between the ports of Porsgrunn and Brevik [6].

This analysis aims to identify existing vessels operating within the Great Lakes St. Lawrence maritime transportation system that have the potential to be early candidates for electrification. Similar to other regions around the world, the Great Lakes St. Lawrence region currently lacks the necessary infrastructure to support battery electric cargo vessels. This research serves as an important first step in identifying the vessels that could be electrified. To conduct this analysis, the Advanced Power Systems (APS) Laboratories at Michigan Technological University collaborated with the Great Lakes St. Lawrence Governors & Premiers to survey the routes of vessels within the region's maritime transportation network with the objective of identifying vessels that operate on fixed routes, over a short distance and with predictable time spent at port, as these vessels may be candidates for electrification.

METHODOLOGY

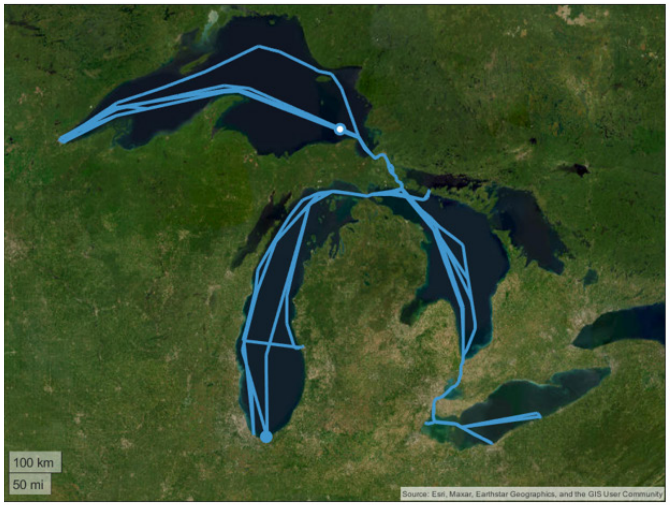
The analysis to identify potential candidate vessels for electrification involved the following steps:

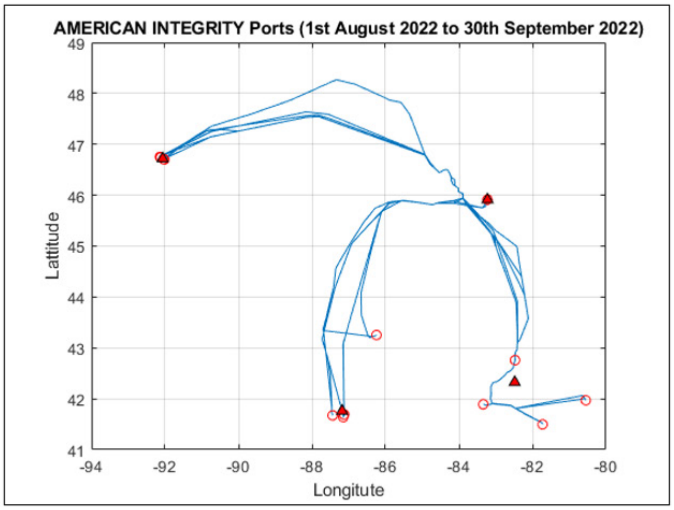
1. **Selection of Ships:** The 2022 Greenwood Guide to Great Lakes Shipping served as the reference to select ships from various categories, including Bulk Freight Vessels, Self-Unloaders, Powered Tankers, American Dry Cargo Barges, Canadian Dry Cargo Barges and Package Freight Vessels. A total of 191 vessels were identified.
2. **AIS Data Acquisition:** Automatic Identification System (AIS) data for the vessels of interest was obtained from Marine Cadastre, a joint initiative of the Bureau of Ocean Energy Management and the National Oceanic and Atmospheric Administration (NOAA) [7].
3. **Timeframe for Data Analysis:** AIS data from June 2022 to September 2022 were used for each vessel. These four months were selected as they represent the middle of the shipping season and exclude the shoulder months when vessels are either starting or slowing down operations close to the seasonal opening and closing of the St. Lawrence Seaway and Soo locks.
4. **AIS Data Extraction:** The vessel name was the primary parameter used to extract AIS data for each vessel. MATLAB code was developed to retrieve the relevant data for the vessel of interest. In cases where the vessel name did not yield an output, either due to a name change or unavailability in the database, International Maritime Organization (IMO) numbers were used as an alternative method for vessel identification.
5. **Data Completeness:** Out of the 191 vessels, AIS data was missing for 61 vessels, and 27 vessels had corrupted data. NOAA was contacted; however, no additional data were available for these vessels. The remaining 103 vessels with complete AIS data were subjected to further analysis. The breakdown of these vessels included 51 self-unloaders, 21 bulk freight vessels, 15 powered tankers, 8 American dry cargo barges, 4 package freight vessels and 3 Canadian dry cargo barges. The complete list of all 191 vessels considered for this project and those 103 vessels with complete AIS data for analysis is provided in Appendix B.



6. **MATLAB Code Development:** A MATLAB code was developed to analyze the AIS data for each vessel. The code processed the data to generate two types of graphs: i) a geo plot illustrating the vessel's route, including the number of Great Lakes visited, and ii) a plot showing all the ports where the vessel made stops.
7. **Geo Plot Analysis:** Geo plots provide insights into the vessel's route. As an example, the geo plot for the bulk freight vessel American Integrity is shown below. The plot reveals that the vessel traveled to four of the five Great Lakes during the analyzed period. Additionally, the plot estimates the vessel's halts based on extended periods of unchanged coordinates. Circles indicate halt locations, and the code aggregates time-averaged halts into four locations represented by triangles on the map. For instance, the halts in the northwestern part of Lake Superior are consistently at Duluth, Minnesota, as indicated by a triangle placed at the port. However, in the southeastern part of Lake Erie, the vessel halts at multiple locations, resulting in the time-averaged location being placed away from the vessel's route. This deviation of triangles from the vessel's route indicates that the American Integrity stops at more than four ports.
8. **Short Route Analysis:** Vessels traveling short routes of less than 500 miles, preferably between two or three ports, were considered potential candidates for future analysis regarding plug-in electrification. This criterion was applied because current battery technology lacks the required energy density for long shipping routes. Furthermore, the implementation of electric vehicle supply equipment (EVSE) for quickly charging large batteries represents a significant capital investment in hardware, infrastructure and grid capacity.

By following this methodology, the research team aimed to identify vessels that could potentially be suitable for plug-in electrification on the Great Lakes.





RESULTS

In the analysis of 103 vessels, 95 were determined to be unsuitable for electrification based on key factors such as the number of ports and the distance traveled. These 95 vessels either had more than three ports or traveled distances greater than 500 miles. However, the research team shortlisted eight vessels for further analysis, as their routes showed potential for electrification. These shortlisted vessels are:

- Huron (package freight vessel)
- Maple Grove (package freight vessel)
- Isle Royale Queen IV (package freight vessel)
- Ranger III (package freight vessel)
- J. S. St. John (bulk freight vessel)
- Sterling Energy (powered tanker)
- Algoma Hansa (powered tanker)
- Damia Desgagnés (powered tanker)

Appendix A includes the route geo plots and port plots for these eight vessels. Among them, the Huron demonstrates the most promise for electrification, as it operates between three ports within a proximity of approximately 10 miles. The Isle Royale Queen IV and Ranger III appear promising at first glance, however, it is important to note that one of the ports they stop at is Isle Royal where most of the electricity is produced from diesel generators and ports in the Keweenaw Peninsula which is among the most carbon intense power grids in the US, thus the carbon benefit of plug-in electrification is questionable on these two vessels. It is worth considering the possibility of partial electrification, wherein only the hotel loads (power needed for crew quarters, etc.) of a vessel are powered using battery energy instead of fuel energy. In this case, all 103 vessels could be seen as potential candidates for electrification.

Overall, these findings provide valuable insights into the vessels that could be prioritized for further electrification studies and pilot projects on the Great Lakes.

CONCLUSIONS & RECOMMENDATIONS


Photo: PortsToronto

This survey of cargo vessel routes on the Great Lakes and St. Lawrence River has identified potential candidates for electrification based on vessels that resemble the operational characteristics of ferries. Although none of the vessels examined appear suited for immediate full electrification (complete elimination of the combustion engine), there are vessels identified that could potentially benefit from supplemental electrification (i.e. hybridization). This research serves as an important initial step toward decarbonizing the Great Lakes St. Lawrence shipping industry. As battery technology continues to advance, more vessels will likely become suitable for electrification in the future. It is also likely that shipping routes may adapt to become shorter as electrification becomes more widespread.

Based on the findings of this study, the following recommendations are proposed:

Conduct Further Research: Additional research should be carried out to explore the potential of the eight selected vessels for electrification in greater detail. This research should delve into the degree of electrification for which there is technical feasibility, economic viability and environmental benefits for these vessels. Additional research should also be conducted on lowering the carbon footprint of vessels' non-propulsion systems. For example, where the hotel loads (power needed for crew quarters, marker lighting, navigation, etc.) of a vessel are powered using battery energy (rechargeable from the grid and through alternatives such as solar) instead of fuel energy. In this case, all 103 vessels could be seen as potential candidates for electrification, and cargo vessels in particular are good candidates due to their relatively high surface area for solar panel mounting.

Implement Real-World Pilot Project: To validate the viability of electrification technology, a pilot project should be conducted on a commercial vessel that operates a route similar to a ferry. This real-world testing will provide valuable insights into the practicality, performance and operational considerations of electrified cargo ships.

Pursue Diverse Propulsion Solutions: While electrification is a promising option, it is important to recognize that it cannot serve as the sole solution for decarbonizing the region's waterways. Continued efforts should be made to explore and develop other propulsion and fuel technologies that are suitable for different use cases within the shipping industry. Achieving emissions reduction goals will almost certainly require a combination of solutions tailored to specific contexts.

Promote Ferry Electrification: The Great Lakes St. Lawrence region is already home to a small but growing number of electrified ferries. To identify other potential candidates for near-term electrification, further research should be conducted to determine which existing ferries have operational profiles suitable for this transition.

By implementing these recommendations, the Great Lakes St. Lawrence region can accelerate the progress towards reducing shipping emissions and contribute to a sustainable and environmentally friendly maritime transportation sector.

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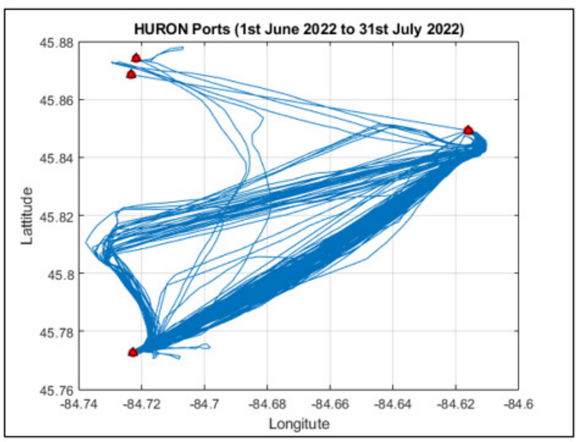
APPENDIX A

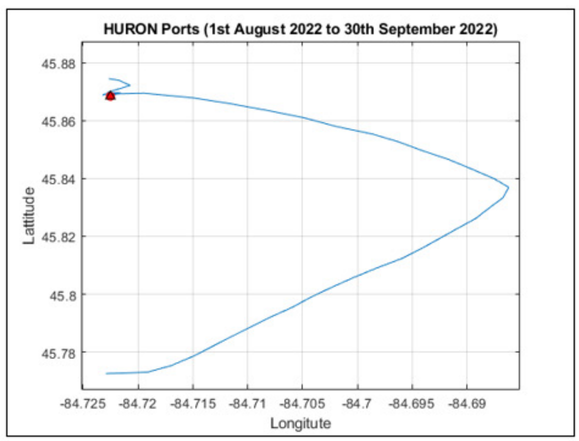
Details regarding the eight vessels showing potential for electrification that have been identified for further analysis in descending order of potential for electrification.

HURON (PACKAGE FREIGHT VESSEL)

Operating ports: St. Ignace, MI; Mackinaw City, MI; Mackinac Island, MI
Approximate shipping distance between farthest ports: 8 miles
Great Lakes or rivers the vessel travels: 1 (Lake Huron)

The Huron is a strong candidate for electrification. It serves three ports in close proximity to the highly popular summer tourist destination of Mackinac Island. However, it is worth noting that the vessel experienced lower utilization during the months of August and September, which could be attributed to the decline in tourist traffic to Mackinac Island during that period.

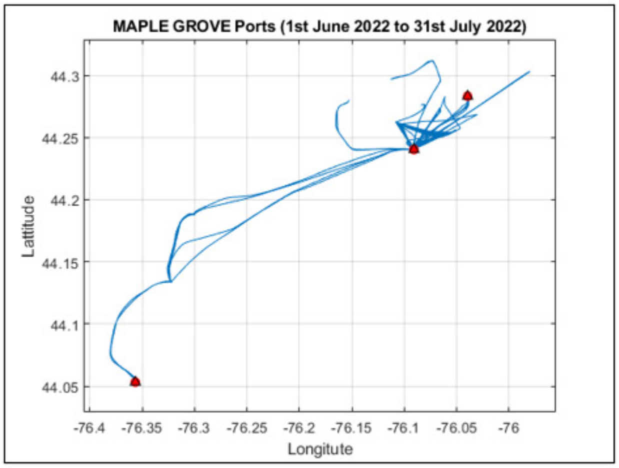


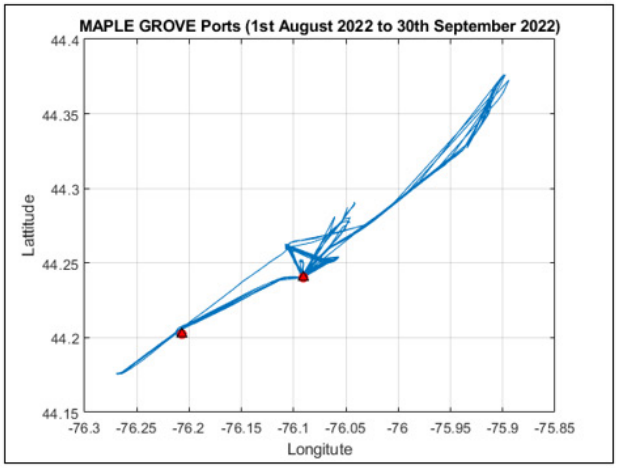


MAPLE GROVE (PACKAGE FREIGHT VESSEL)

Operating ports: Clayton, NY; Grenadier Island, NY; Grenell Island, NY
Approximate shipping distance between farthest ports: 28 miles
Great Lakes or rivers the vessel travels: 1 (St. Lawrence River)

The Maple Grove has a route on the U.S. side of the St. Lawrence River, where it travels between three ports close to one another.

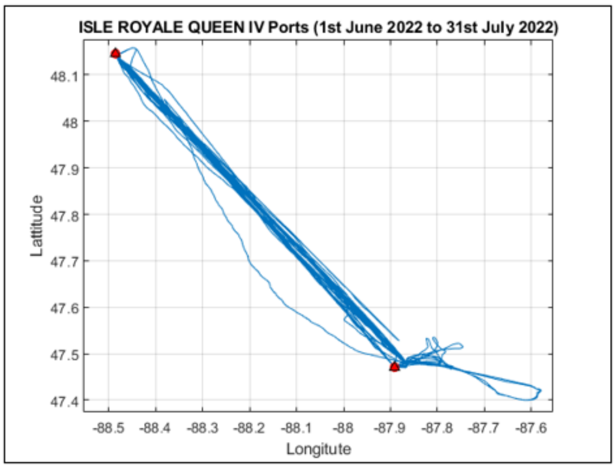


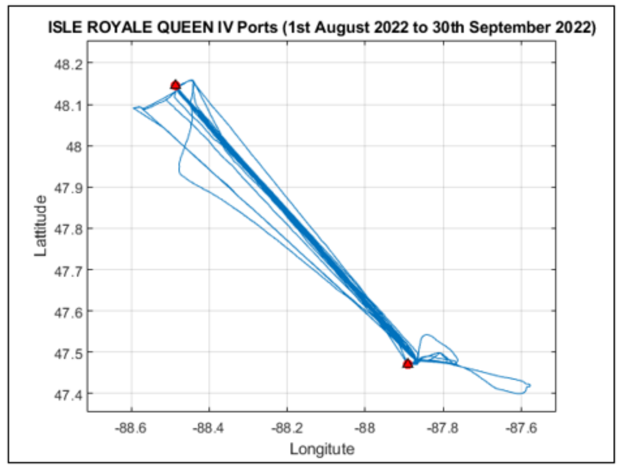


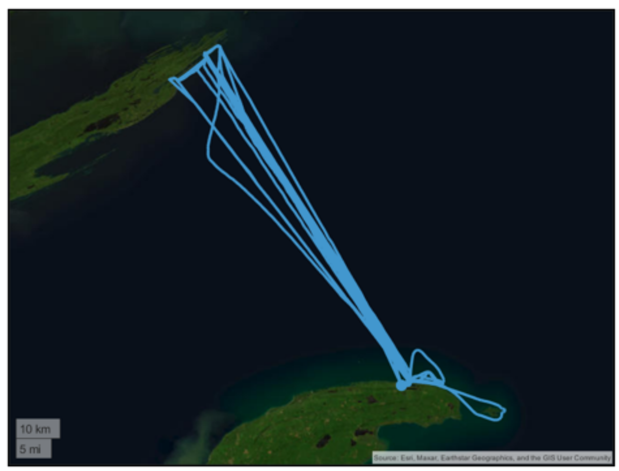
ISLE ROYALE QUEEN IV (PACKAGE FREIGHT VESSEL)

Operating ports: Copper Harbor, MI; Rock Harbor, MI
Approximate shipping distance between farthest ports: 54 miles
Great Lakes or rivers the vessel travels: 1 (Lake Superior)

The Isle Royale Queen IV travels from Copper Harbor to Rock Harbor on Isle Royale National Park during the summer. This vessel has a quick turnaround time as it goes to the island and back every day.



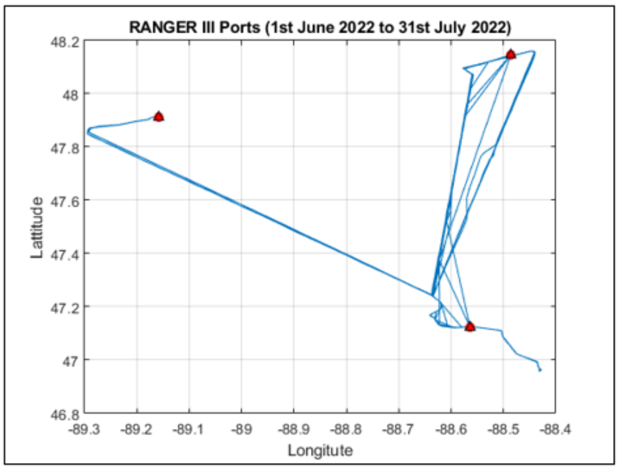


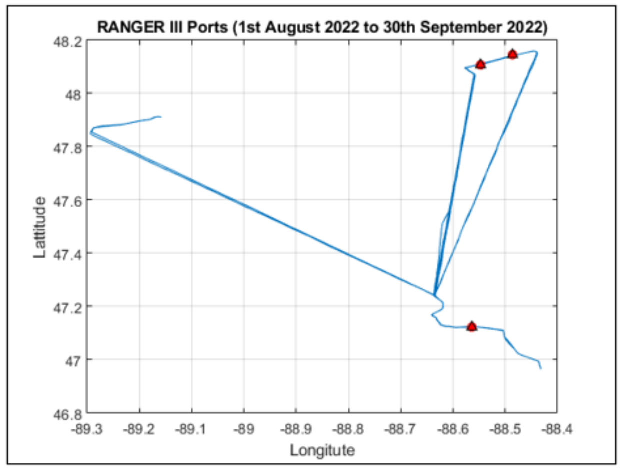


RANGER III (PACKAGE FREIGHT VESSEL)

Operating ports: Houghton, MI; Rock Harbor, MI
Approximate shipping distance between farthest ports: 72 miles
Great Lakes or rivers the vessel travels: 1 (Lake Superior)

The Ranger III operates between Houghton and Rock Harbor in Isle Royale National Park during the summer. The majority of its trips are to Rock Harbor, located at the northeast port of the island, while occasionally it also travels to Windigo, the port at the southwestern end. The vessel completes two round trips to the island per week, with travel in only one direction on a given day. This schedule allows ample time for the vessel to charge at both ends, making it a compelling candidate for electrification.

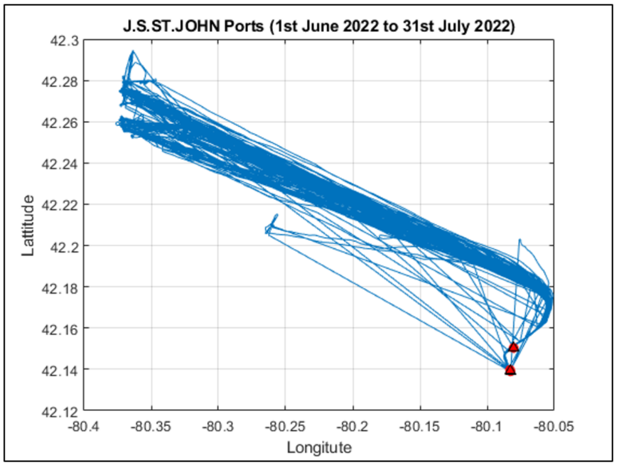


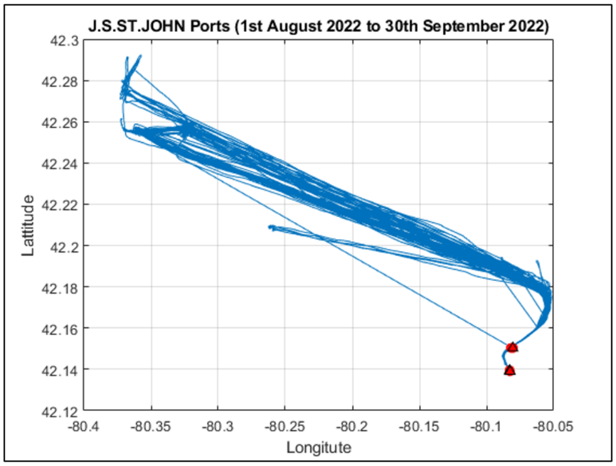


J. S. ST. JOHN (BULK FREIGHT VESSEL)

Operating ports: Erie, PA
Approximate shipping distance between farthest ports: N/A
Great Lakes or rivers the vessel travels: 1 (Lake Erie)

The J. S. St. John has just one port at Erie, PA. It is a dredging vessel that travels ~20 miles into the Lake and returns to the same port. Further investigation is needed to ascertain if battery technology could be appropriate for dredging vessels.

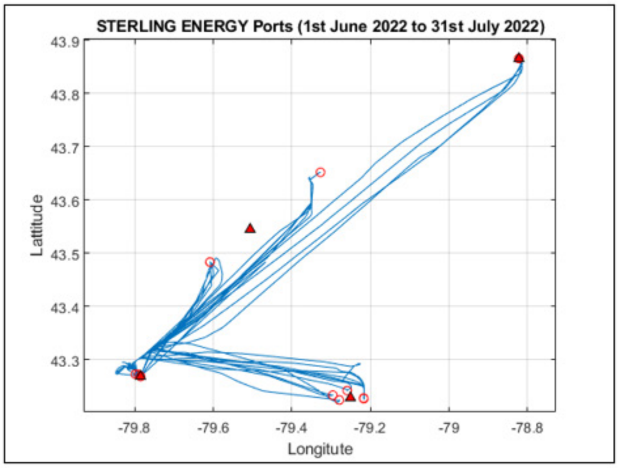


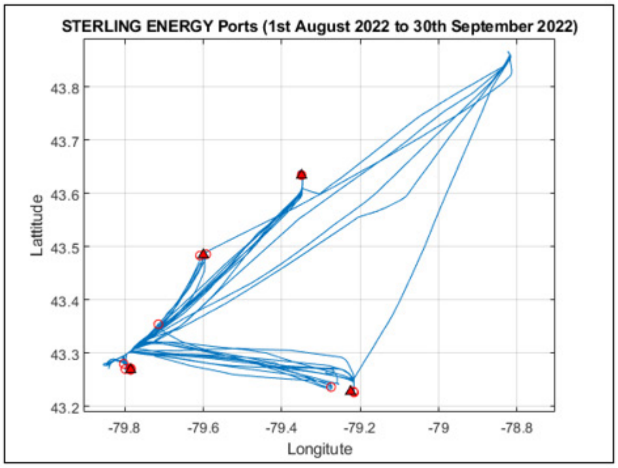


STERLING ENERGY (POWERED TANKER)

Operating ports: Hamilton (Canada); Oakville (Canada); Toronto (Canada); Oshawa (Canada); St. Catherines (Canada)
Approximate shipping distance between farthest ports: 66 miles
Great Lakes or rivers the vessel travels: 1 (Lake Ontario)

The Sterling Energy has a total of five ports, which exceeds the threshold of three ports for electrification consideration. However, it is noteworthy that the distance between the farthest ports is less than 70 miles. In such cases, it may not be necessary to have charging infrastructure at every port, indicating that the vessel still holds potential for electrification.

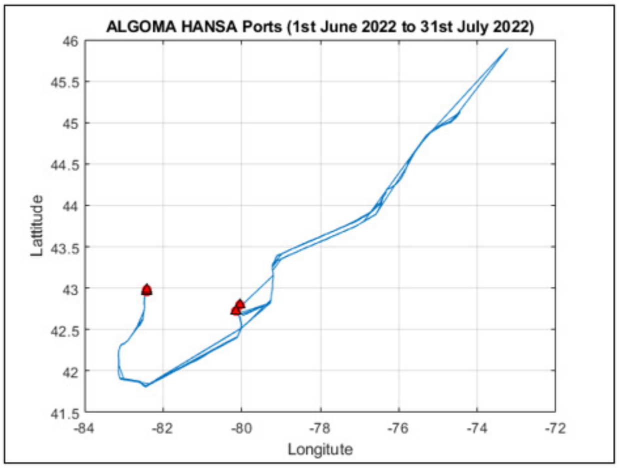


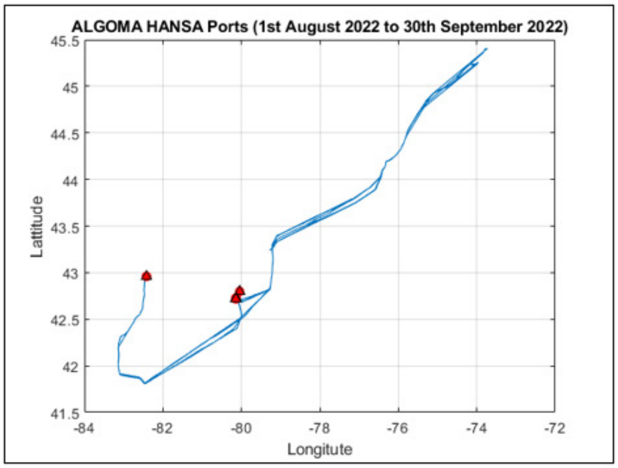


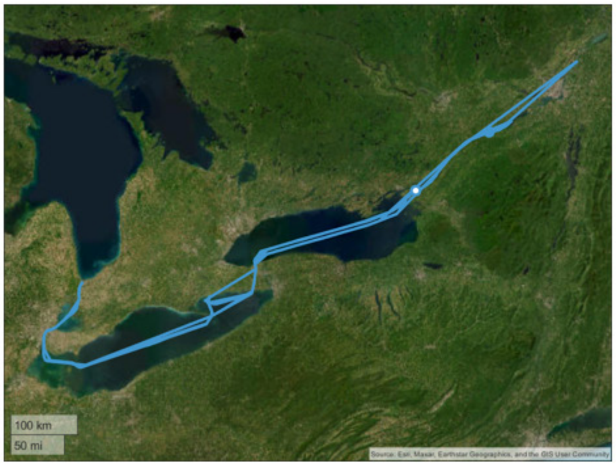
ALGOMA HANSA (PACKAGE FREIGHT VESSEL)

Operating ports: Sarnia (Canada); Port Dover (Canada)
Approximate shipping distance between farthest ports: 460 miles
Great Lakes or rivers the vessel travels: 3 (Lake Erie, Lake Ontario and the St. Lawrence River)

Algoma Hansa operates in Lake Erie, Lake Ontario and the St. Lawrence River, commencing its journey from Sarnia and traveling to Montréal with a stop in Port Dover. It is worth noting an intriguing observation regarding all vessels traveling to Montréal: the code does not register Montréal as a port, even when the halt time for a location to be considered a port is significantly reduced. Additionally, in close proximity to Port Dover, Algoma Hansa experiences two distinct halts within a 5-mile radius. The vessel's route remains highly consistent during the two analyzed periods.



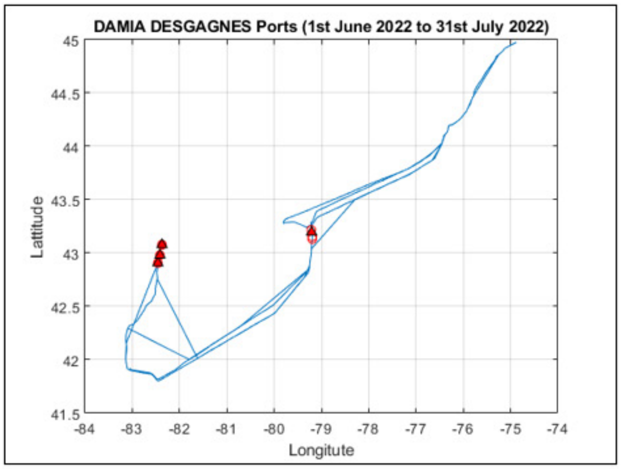


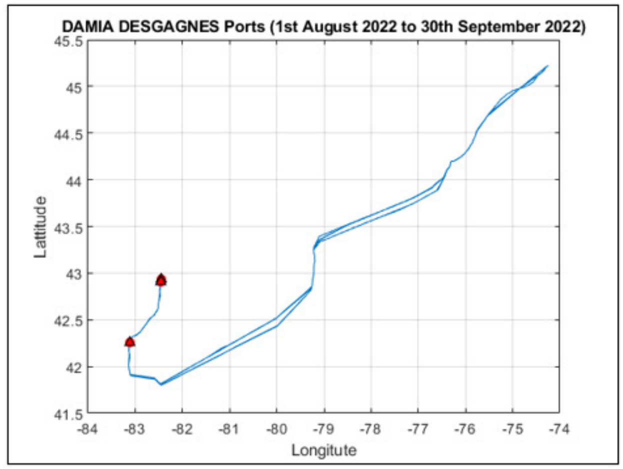


DAMIA DESGAGNÉS (POWERED TANKER)

Operating ports: Sarnia (Canada); Youngstown, NY
Approximate shipping distance between farthest ports: 560 miles
Great Lakes or rivers the vessel travels: 3 (Lake Erie, Lake Ontario and the St. Lawrence River)

The Damia Desgagnés has a similar route as the Algoma Hansa, except its second port is Youngstown, NY.





APPENDIX B

List of all 191 vessels considered for the project, including those without AIS data and erroneous data. Vessels analyzed for this project are marked in blue.

A-390
A-397
A-410
ACADIA
AGS-359
ALGOCANADA
ALGOMA BUFFALO
ALGOMA COMPASS
ALGOMA CONVEYOR
ALGOMA DISCOVERY
ALGOMA EQUINOX
ALGOMA GUARDIAN
ALGOMA HANSA
ALGOMA HARVESTER
ALGOMA INNOVATOR
ALGOMA INTREPID
ALGOMA MARINER
ALGOMA NIAGARA
ALGOMA SAULT
ALGOMA STRONGFIELD
ALGOMA TRANSPORT
ALGONORTH
ALGONOVA
ALGOSCOTIA
ALGOSEA
ALGOTERRA
ALOUETTE
ALPENA
AM2100
AMERICAN CENTURY
AMERICAN COURAGE
AMERICAN INTEGRITY
AMERICAN MARINER
AMERICAN SPIRIT
ARCTIC
ARGENTIA DESGAGNÉS
ASHTABULA
ATLANTIC HURON
ATLANTIC SPIRIT
BAIE COMEAU
BAIE ST. PAUL
BASSE-COTE
BLAIR MCKEIL
BLOUGH, ROGER
BURNS HARBOR
CALLAWAY, CASON J.
CALUMET
CAPT. HENRY JACKMAN
CARGO BARGE #53
CARGO BARGE U794
CARRICK, JOHN J.
CHIPPEWA
CLAUDE A. DESGAGNÉS
CLYDE
COASTAL TITAN
COMMANDER
CORT, STEWART J.
CROW
CSL ASSINIBOINE
CSL LAURENTIEN
CSL NIAGARA
CSL ST-LAURENT
CSL TADOUSSAC

CSL TECUMSEH
CSL WELLAND
CUYAHOGA
DESGAGNÉS, ACADIA
DESGAGNÉS, CLAUDE A.
DESGAGNÉS, DAMIA
DESGAGNÉS, ESPADA
DESGAGNÉS, GAÏA
DESGAGNÉS, MARIA
DESGAGNÉS, MIA
DESGAGNÉS, MIENA
DESGAGNÉS, NORDIKA
DESGAGNÉS, PAUL A.
DESGAGNÉS, ROSAIRE A.
DESGAGNÉS, SEDNA
DESGAGNÉS, TAÏGA
DIANE
DOWDEN SPIRIT
EDGAR B SPEER
EDWIN H GOTT
ENDEAVOUR
ERIE TRADER
EVANS SPIRIT
FERBEC
FLORENCE SPIRIT
FRONTENAC
G3
GENERAL
GREAT LAKES
GREAT LAKES TRADER
GREAT REPUBLIC
H LEE WHITE
HAMILTON ENERGY
HANNAH
HERBERT C JACKSON
HINCH SPIRIT
HON JAMES L OBERSTAR
HURON
HURON SPIRIT
IGLEHART, J.A.W
INDIANA HARBOR
INNOVATION
INTEGRITY
ISLE ROYALE QUEEN IV
J.S.ST.JOHN
JACOB JOSEPH
JACQUELINE C
JAMES R BARKER
JOHN D LEITCH
JOHN G MUNSON
JOHN J BOLAND
JOSEPH H THOMPSON JR
JOSEPH L BLOCK
JUSTIN
KAMINISTIQUA
KAYE E BARKER
LADY OF THE LAKE
LAMBERT SPIRIT
LAURENTIA DESGAGNÉS
LEE A TREGURTHA
LUCKY
MANITOULIN
MANITOWOC
MAPLE GROVE
MARK W. BARKER
MAUMEE
MCALLISTER 132
MCKEE SONS
MCKEIL SPIRIT
MCLEOD, NORMAN
MESABI MINER
METIS
MICHIGAN
MICHIGAN TRADER
MICHIPICOTEN
MOBY DICK
MOTTI
NIAGARA SPIRIT
NIAGARA SPIRIT
NO. 19
NORDICA
NORMAN
NORMAN G
NUKUMI
NUNAVUT SPIRIT
OAKGLEN
OC 181

OCEAN ABYS
OMNI ATLAS
PATHFINDER
PAUL R TREGURTHA
PERE MARQUETTE
PITTS CARILLON
PML 2501
PML 9000
PML 9000
PRESQUE ISLE
RADCLIFFE R LATIMER
RANGER III
RELIEF
ROBERT S PIERSON
RT HON PAUL J MARTIN
RYERSON, EDWARD L.
SAGINAW
SAM II
SAM LAUD
SARAH DESGAGNÉS
SEDNA
SHERWIN, JOHN
SPARTAN
SPRUCEGLEN
ST. MARYS CEMENT
ST. MARYS CEMENT II
ST. MARYS CHALLENGER
ST. MARYS CONQUEST
STERLING ENERGY
STR WILFRED SYKES
TECUMSEH
THUNDER BAY
TIM S DOOL
VIATEUR'S SPIRIT
WALTER J MCCARTHY JR
WARNER PROVIDER
WARNER, WILLIAM L.
WHITEFISH BAY
WICKY SPIRIT
WISCONSIN
ZELADA DESGAGNÉS