Great Lakes and St. Lawrence Seaway Maritime CO_2 Emissions Study

Prepared for: The Conference of Great Lakes St. Lawrence Governors and Premiers

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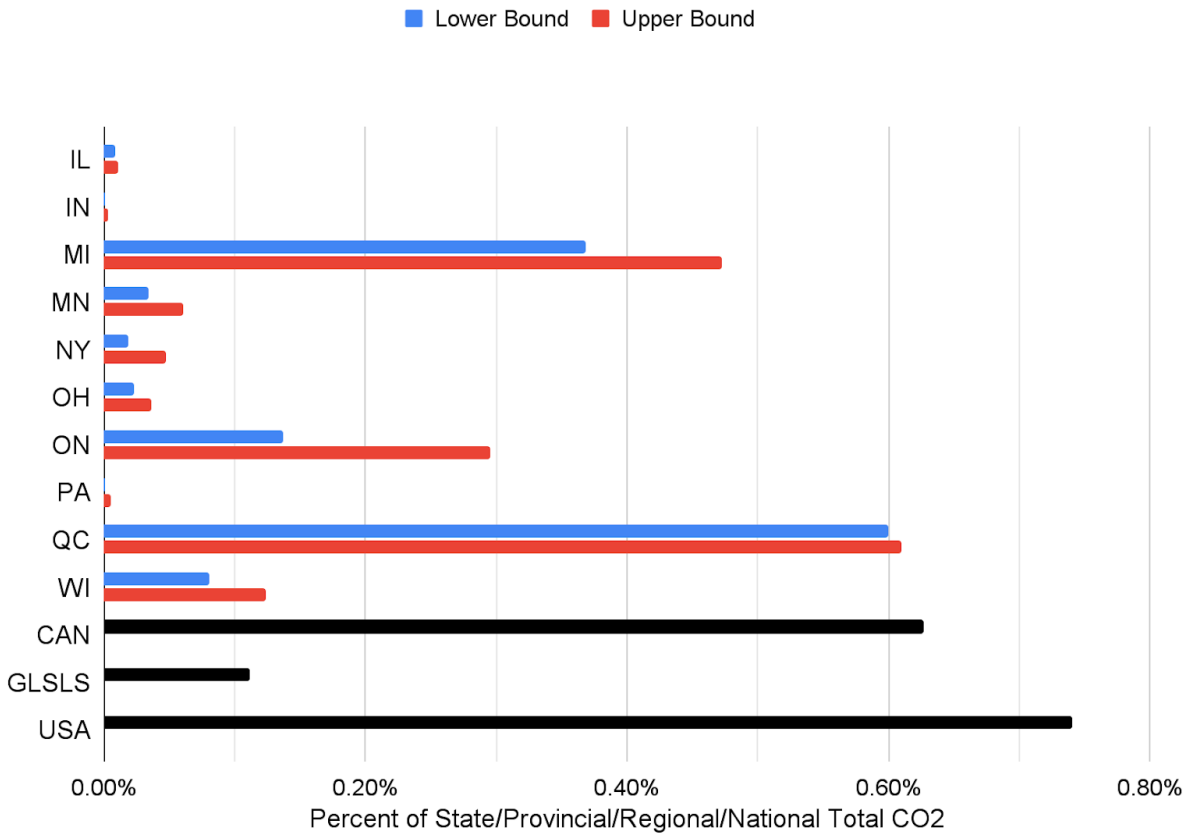
Cover image: “New Lock at the Soo major construction continues” from the U.S. Army Corps of Engineers, Kokosing, Alberici, and Traylor (2024)

Executive Summary

The Conference of Great Lakes St. Lawrence Governors and Premiers' (GSGP) current Maritime Strategy goals include shrinking the environmental impact of the region's transportation system. Maritime is the most energy-efficient mode of transportation, with correspondingly low air emissions, but the maritime system's economic size and importance mean that the system may still have a significant impact on regional air emissions. For example, the Great Lakes St. Lawrence River (GLSLS) maritime system carries over 250 million tons of cargo each year, and this cargo is a critical input to manufacturing supply chains around the region. Understanding maritime transportation's share of regional air emissions provides insight into how regional policymakers can support decarbonization of the maritime system, and how policymakers can leverage the maritime system's efficiencies to support broader regional decarbonization work.

This study found that the GLSLS maritime system accounts for a very small share (less than 1%) of each State or Province's carbon dioxide emissions. Figure ES-1 illustrates the degree to which the GLSLS maritime system contributes to overall CO_2 emissions in each State and Province.

Figure ES-1: Shares of Total CO_2 Emissions from GLSLS Maritime



As shown above, the GLSLS maritime system has a small contribution to the region's overall carbon dioxide emissions, less than 1%. This small share of emissions is primarily a result of two factors:

1. The inherent energy efficiency of water transportation, which is more efficient than trucking, rail, and air transportation.
2. The relatively low utilization of the region's maritime transportation system compared to other modes of freight transportation. For example, maritime transportation only handled 4% of the total freight tonnage moved in GLSLS States in 2019.[1]

Maritime's low environmental impact is an opportunity for policymakers interested in decarbonizing the region's transportation system. Policymakers interested in decarbonization should seek to shift and add more freight to water. Increasing GLSLS maritime freight volume is simultaneously an investment in the region's environmental and economic development.

[1] Analysis of Freight Analysis Framework data. Federal Highway Administration. 2025.

Introduction

The Great Lakes and St. Lawrence River (GLSLS) region is home to a maritime transportation system (MTS) that is critical to the regional economy. Each year, this maritime system moves 252 million tons of cargo worth $120 billion US dollars. Maritime is the most energy-efficient mode of transportation, but the large volume of cargo moved by this system means maritime's emissions portfolio is important.

The Conference of Great Lakes St. Lawrence Governors and Premiers' (GSGP) current Maritime Transportation System Strategy has three major goals:

1. double maritime trade,
2. shrink the environmental impact of the region's transportation network, and
3. support the region's industrial core.

GSGP's current Green Shipping Action Plan supports the goal of shrinking the environmental impact of the system by recommending actions such as intergovernmental coordination and preparing a regional greenhouse gas emissions (GHG) inventory. In particular, GHG emissions inventories can support the objective of reducing environmental impacts by providing insight into emissions by State, Province, pollutant, or economic sector. This level of detail allows policymakers to set informed emissions targets.

Current Maritime Emissions

Estimates of maritime CO_2 emissions in the region were drawn from the International Council on Clean Transportation's (ICCT) 2019 GLSLS emissions inventory. An example of the ICCT's grid-based emissions data is shown in Figure 1, where brighter colored areas indicate higher emissions. These carbon dioxide emissions were assigned to individual States and Provinces based on their location within or along geographic borders. Many grid cells spanned State or Provincial borders, so a range of potential emissions was estimated for each State or Province based on how many bordering grid cells were counted as part of the State or Province. Appendix B explains the data analysis methodology in further detail.

Michigan had the greatest level of GLSLS maritime CO_2 emissions, followed by Québec and Ontario. However, Michigan and Ontario also had the broadest ranges of estimates, meaning much of their CO_2 was emitted along borders and could have originated from adjacent States or Provinces. Figure 2 illustrates the relative volumes of GLSLS maritime emissions between each of the region's States and Provinces. The bars represent the lower and upper bounds of interval estimates: longer bars correspond to a wider possible range of CO_2 in a State or Province.

Figure 1: Example of Regional Maritime CO_2 Emissions Data from International Council on Clean Transportation

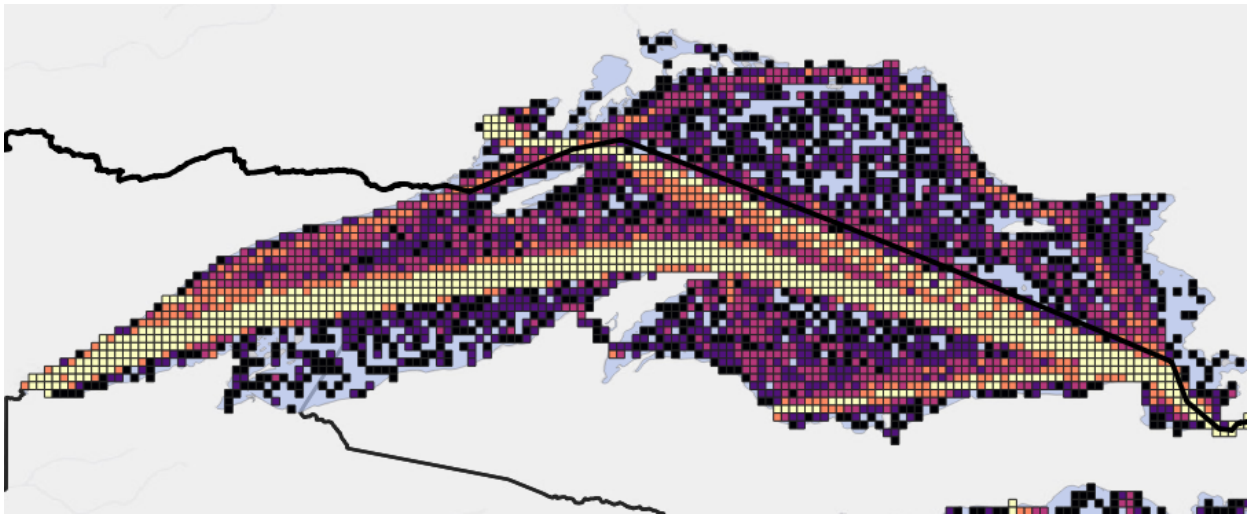
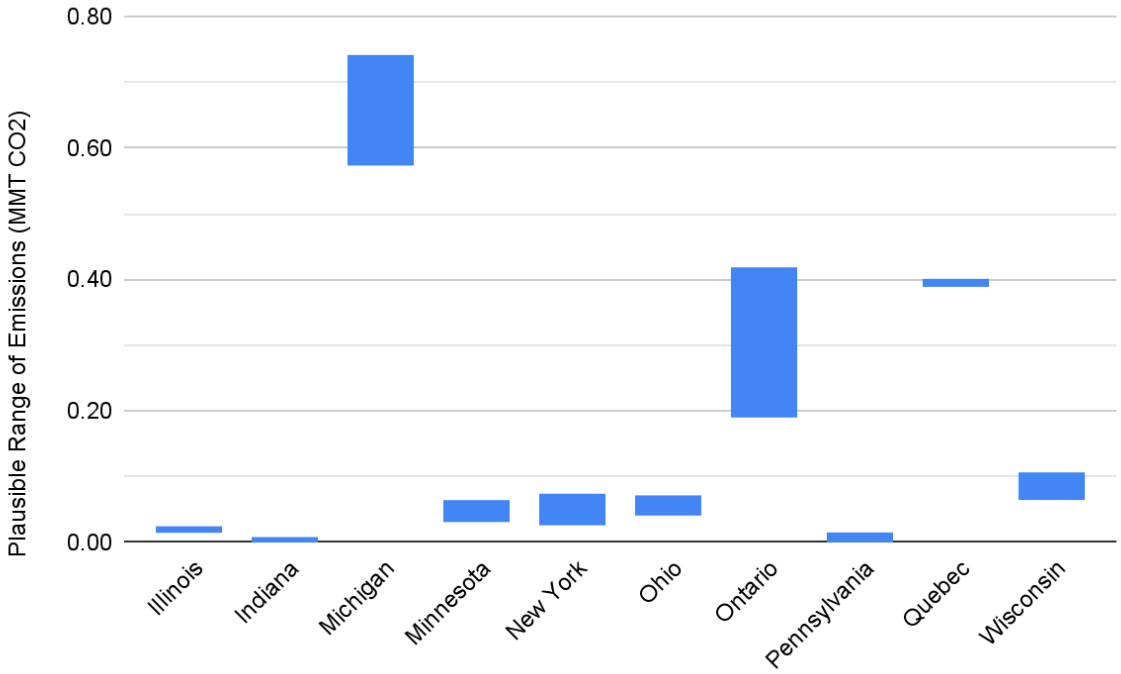


Figure 2: GLSLS Maritime CO_2 Emissions Estimates by State and Province

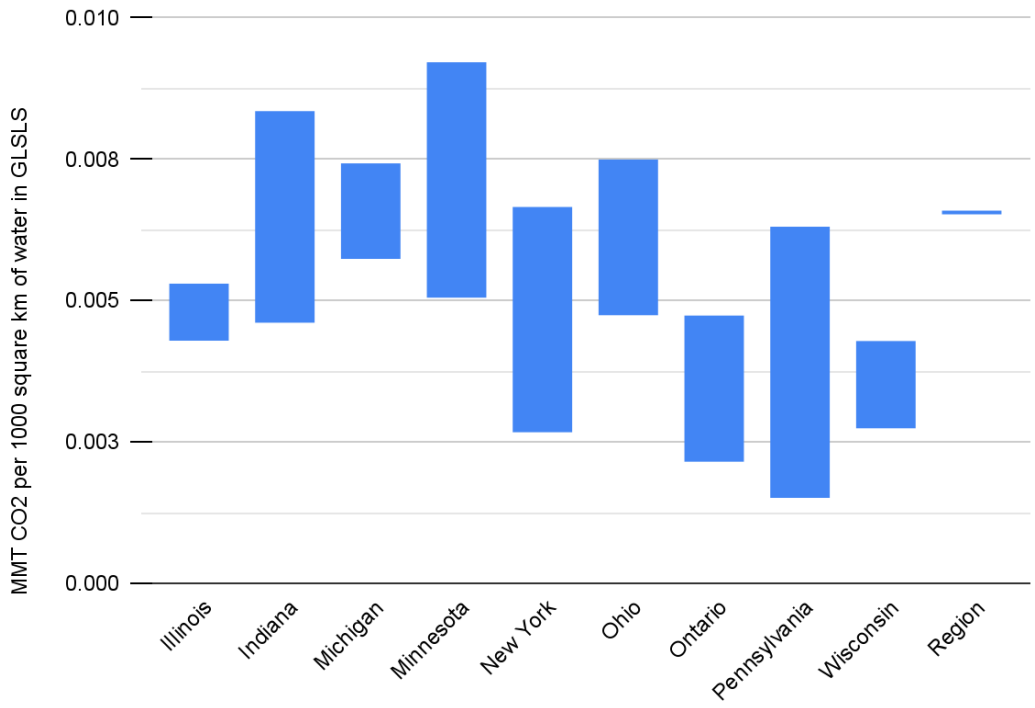


Select States and Provinces significantly lead the region in terms of GLSLS maritime carbon emissions, and much of the difference in emissions is due to the geographic boundaries of the States and Provinces. Michigan and Ontario each have over 88,000km^2 of GLSLS water area, together accounting for about 75% of the region's total water area. Québec has only

about 2,100km^2, but that area contains much of the St. Lawrence River, a dense area for vessel movements.

Figure 3 illustrates the relative quantity of GLSLS maritime CO_2 across States and Provinces adjusted by how much total GLSLS water area they have. The bars again represent interval estimates, except for the GLSLS Region as a whole, which is fully captured in the original maritime emissions dataset. Québec was omitted from the figure due to the St. Lawrence River's high emissions area intensity. Appendix C elaborates on these results.

Figure 3: GLSLS Maritime CO_2 adjusted by Water Area (Québec Omitted)



Maritime's Share of Regional Total Emissions

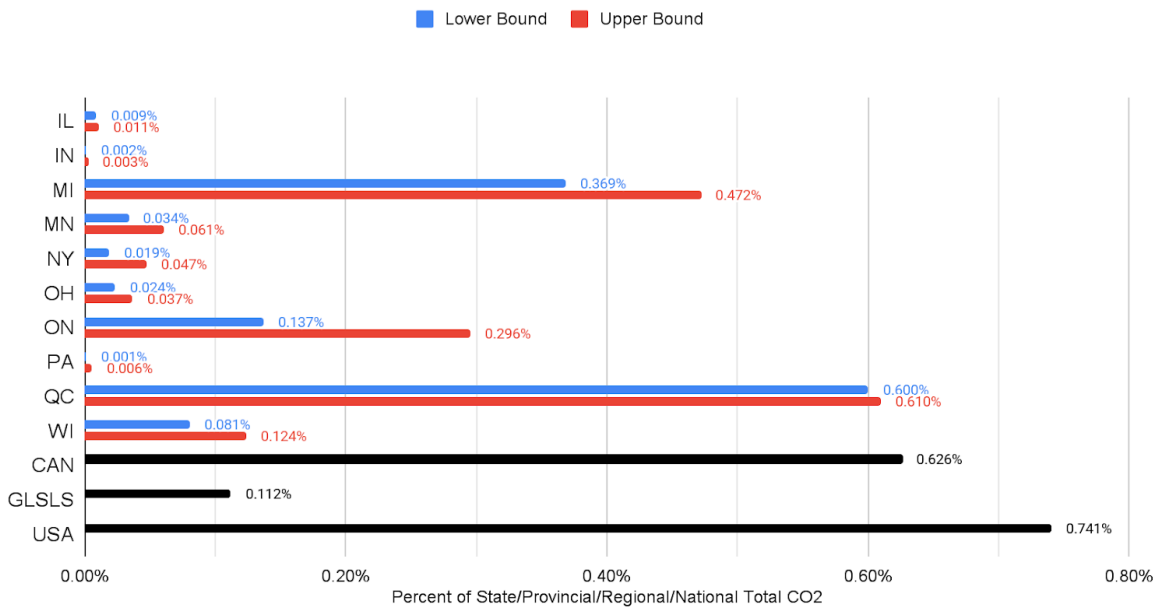
To understand the region's total emissions, information on State and Provincial total emissions was collected from the US Environmental Protection Agency (EPA) and Environment and Climate Change Canada (ECCC). These State- and Province-level assessments provide emissions estimates by sector, including transportation. All emissions data sources used or consulted in this analysis are further detailed in Appendix A.

All eight GLSLS States' emissions reports listed transportation among their top two most polluting economic sectors in recent years (Environmental Integrity Project). Ontario and Québec cited transportation as their top economic sector for GHG emissions in 2018 and

2021, respectively. Transportation includes freight transportation activity from trucking, railroads, and maritime shipping. Therefore, understanding maritime's share of transportation emissions provides context for understanding potential pathways for freight network decarbonization in the region.

GLSLS maritime CO_2 emissions were compared against transportation CO_2 emissions and total CO_2 emissions. Figure 4 summarizes how the volume of GLSLS maritime emissions varies across States and Provinces in the region. Illinois, Indiana, and Pennsylvania each have over 170 MMT CO_2 in their total emissions but each State's geographic area covers a relatively small share of the GLSLS water area, which means that a very small percentage of those States' emissions are associated with the GLSLS maritime system. Québec, Michigan, and Ontario have the greatest share of emissions associated with the GLSLS maritime system. Québec, Michigan, and Ontario each exceed the GLSLS regional average maritime share of about 0.11%. All other State and Provincial intervals except Wisconsin are below the regional average. Canada's national maritime CO_2 as a share of national total CO_2 was about 0.63%, which exceeded both Ontario and Québec. The United States' share was about 0.74%, which exceeded that of any GLSLS State.

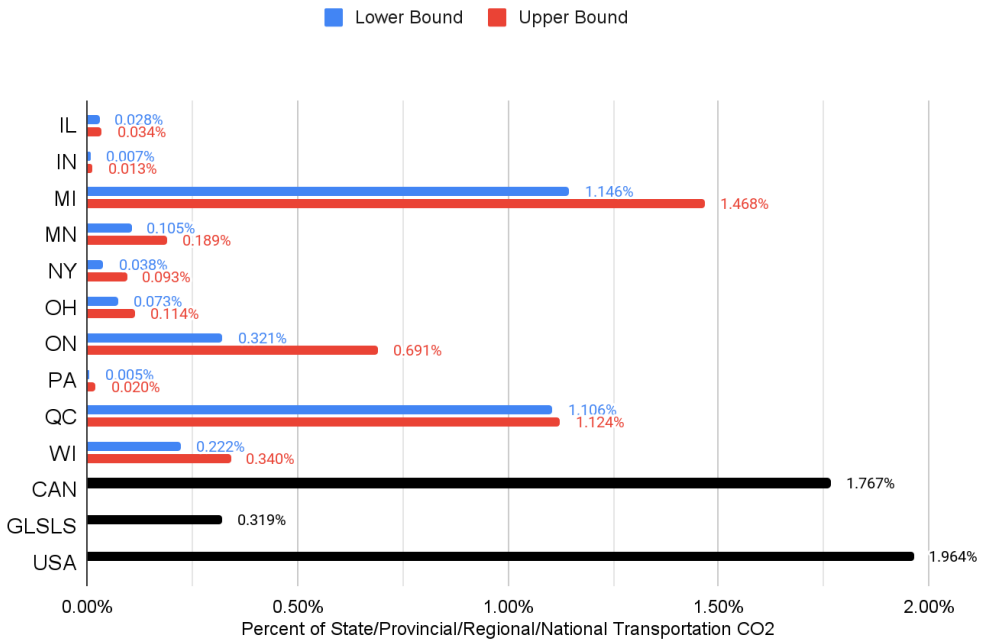
Figure 4: GLSLS Maritime as a Share of States' and Provinces' Total CO_2



GLSLS States' and Provinces' shares of total CO_2 associated with transportation activity ranged from 23% in Indiana to 54% in Québec (EPA, ECCC). Figure 5 shows that GLSLS maritime activity also accounts for a small share of each State's or Province's

transportation-related emissions. The three top States and Provinces from Figure 4 continue to have the greatest GLSLS maritime shares of transportation emissions. Additionally, the share of State or Provincial transportation emissions associated with GLSLS maritime emissions is lower than nation-wide assessments of maritime emissions as a share of transportation emissions.

Figure 5: GLSLS Maritime as a Share of Transportation CO_2



The analyses of GLSLS maritime emissions volume, intensity, and shares had several salient findings:

- Overall, maritime transportation in the GLSLS makes up a very small share of total emissions and transportation-related emissions.
- Emissions volumes vary greatly between States and Provinces due to differences in the area of navigable water included in each State and Province, and the location of shipping lanes within State and Provincial boundaries. For example, Michigan ranks among the top States and Provinces for total GLSLS maritime emissions, but this large volume of emissions is due in part to Michigan's large water area and the presence of highly-concentrated shipping lanes in the State, such as the Soo Locks, St. Clair River, and Detroit River.

Discussion

Each State's or Province's share of CO_2 emissions from maritime activity in the Great Lakes St. Lawrence region is low. The small emissions footprint of the GLSLS maritime system highlights both the fuel efficiency of shipping and the relatively low utilization of the system. These two key characteristics of the system go hand in hand with GSGP's Regional Maritime Strategy, which aims to "double maritime trade, shrink the environmental footprint of the region's transportation network and support the region's industrial core." In the current strategy and GSGP's next 5-year Action Plan, multiple overlapping steps can be taken to harmonize these goals with the GLSLS region's sustainability advantages and low utilization in mind.

Regional Coordination: The GSGP should coordinate messaging across States and Provinces to advance key maritime initiatives. One of GSGP's main strengths is to facilitate intergovernmental cooperation, and there are several items worth including in the upcoming 5-year Action Plan.

- To address low system utilization, States and Provinces should be encouraged to **support the Highway H_2O** marine highway initiative and **new Soo Lock construction**, ensuring that they remain staffed and funded. Highway H_2O promotes GLSLS marine transportation to commercial entities, increasing the volume of domestic and international goods moved through the system. The new Soo Lock will mitigate bottlenecking now that the only two currently operational locks have exceeded their intended lifespan and require more unscheduled maintenance.
- It is key for **short-sea shipping** to be communicated as a necessary maritime growth opportunity that can satisfy expected increases in freight demand, not just mode shift away from trucking.
- **Icebreaking** is a priority already in the GSGP's portfolio, as winter system closures encourage shippers to simply use trucking year-round. Icebreaking resources between the US and Canada are limited, so coordinating their further investment and use can alleviate the issue of businesses needing to find modal alternatives during freezing months.
- Strategy going forward should promote the maritime transportation system's (MTS) main features as a carbon-efficient answer to expected increases in freight demand. The messaging should focus on the how the system is addressing bottlenecking and seasonality threats.

A sound strategy must also identify the system's de facto most attractive selling points.

Research: The GSGP should survey existing shippers in the region to understand why they chose to use the system and how they have been successful thus far. The current 5-year Action Plan includes implementing a "communications strategy to showcase success stories" and identifying "private investment opportunities." To those ends, the GSGP should continue seeking shipper testimonies about the MTS, highlighting the region's low GHG emissions and utilization for new shippers. Market research on the state of GLSLS maritime shipping could extend into the regulatory environment of the region as well.

Regulation: The GSGP should continue addressing structural and regulatory deterrents such as the Harbor Maintenance Tax (HMT), trade policy, or lengthy customs clearance. For example, the GSGP could coordinate with universities on research into the relative burdens of the HMT compared to burdens on land freight, like heavy vehicle and fuel taxes. Understanding how current policy disincentivizes maritime and incentivizes other modes can reveal market inefficiencies, and fixing those inefficiencies will grow maritime as a more economically viable mode.

Works Cited

"Air Pollution Emission Inventories." Environmental Integrity Project (EIP). Accessed June 17, 2025. https://environmentalintegrity.org/State-emissions-inventory/

Browning, Louis, Cristiano Facanha, Andrew Papson, Jeff Ang-Olson, Seth Hartley, and Ed Carr. Rep. *Representing Freight in Air Quality and Greenhouse Gas Models*. National Academy of the Sciences, 2010.

Great Lakes St. Lawrence Governors & Premiers. "Green Shipping Action Plan." Chicago: Great Lakes St. Lawrence Governors & Premiers, September 2021. https://gsgp.org/media/4orf3ztk/green-shipping-action-plan.pdf

Great Lakes St. Lawrence Governors & Premiers. "Strategy for the Great Lakes-St. Lawrence River Maritime Transportation System." Chicago: Great Lakes St. Lawrence Governors & Premiers, June 2016.

Meng, Zhihang, and Bryan Comer. "Great Lakes-St. Lawrence Seaway Ship Emissions Inventory, 2019." International Council on Clean Transportation, March 2022. https://theicct.org/wp-content/uploads/2022/03/Great-Lakes-emissions_final.pdf

Office of Atmospheric Protection (EPA), Methodology Report: Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990-2022 § (2024). https://www.epa.gov/ghgemissions/methodology-report-inventory-us-greenhouse-gas-emissions-and-sinks-State-1990-2022

Veysey, Drew, Molly Freed, Wendy Jaglom-Kurtz, Jake Glassman, Adefunke Sonaike, Kayleigh Rubin, and Nathan Iyer. "State Priority Climate Action Plans Assessment Spreadsheet." RMI, December 2, 2024. https://rmi.org/insight/State-priority-climate-action-plans-assessment-spreadsheet/

Environment and Climate Change Canada (ECCC). NATIONAL INVENTORY REPORT 1990 – 2019: GREENHOUSE GAS SOURCES AND SINKS IN CANADA, April 2021. https://publications.gc.ca/collections/collection_2021/eccc/En81-4-2019-1-eng.pdf

Office of Transportation and Air Quality. "U.S. Transportation Sector Greenhouse Gas Emissions 1990–2019." U.S. Environmental Protection Agency, December 2021. nepis.epa.gov/Exe/ZyPDF.cgi/P1013NR3.PDF?Dockey=P1013NR3.PDF

Appendix A: Data Sources

GLSLS Maritime CO2 Emissions

Maritime carbon dioxide emissions in the Great Lakes and St. Lawrence region were drawn from the International Council on Clean Transportation's (ICCT) report "Great Lakes-St. Lawrence Seaway ship emissions inventory, 2019." This report used Automatic Identification System (AIS) data of vessel movements to estimate maritime CO_2 emissions in a grid of 0.05° x 0.05° cells in the GLSLS region.

US GHG Inventories

Governments themselves have set targets and taken measures to reduce GHG emissions. The 2021 Infrastructure Investment and Jobs Act ("Bipartisan Infrastructure Law") in the US includes a Carbon Reduction Program (CRP) provision requiring all States to prepare a carbon reduction strategy (CRS) and to update it at least every four years. The CRS serves to "identify projects and strategies to reduce transportation emissions." This bill both mandates and funds these CRS, and States may also apply the bill's funding toward related projects such as Priority Climate Action Plans (PCAP). These CRS and PCAP documents summarize emissions goals, so they are usually linked to States' GHG emissions inventories.

Additionally, the Clean Air Act established the Greenhouse Gas Reporting Program (GHGRP), which requires facilities to report their emissions to the EPA if they exceed 25,000 metric tons of CO_2 equivalent in a year. The EPA also requires States to submit emissions inventories every three years in compliance with the Clean Air Act.

In 2024, Rocky Mountain Institute (RMI) compiled 45 States' priority climate action plans (PCAPs). These documents refer to States' emissions inventory methodologies, which are often based on the US EPA's State Inventory Tool (SIT). This emissions estimation tool draws default values from the GHGRP and consumption data from EIA's State Energy Data System (SEDS). All eight GL-SLS States report using either SIT directly or supplementing SIT with their own agencies' data to develop emissions inventories.

Canadian GHG Inventories

The 1999 Canadian Environmental Protection Act requires that "The Minister shall establish a national inventory of releases of pollutants [...]." Environment And Climate Change Canada (ECCC) compiles these inventories at the national and Provincial levels. Ontario Regulation 390/18 and Québec's Environment Quality Act also require facilities with large emissions to report to their Provincial environmental agencies, and these data also get submitted for use in the ECCC inventory.

State and Provincial Border Data Sources

International border data was sourced from digital boundary files (DBFs) hosted on national and Provincial data portals. US States were extracted from 2019 TIGER/Line® Shapefiles "States (and equivalent)" shapefiles. Québec's Provincial DBF was extracted from Statistics Canada's "2021 Census – Boundary files" as 2021 is the closest Canadian census year to 2019. Ontario's Provincial DBF was instead drawn from Ontario GeoHub due to its more complete coverage of Great Lakes territory.

The TIGER shapefile was missing a portion of Lake Huron, approximately the area of three tiles in the ICCT data. This gap was closed by extending the US border to that of Canada.

International Bunker Fuels

International bunker fuels (IBFs) are "reported separately based on the location of the fuel sales" by the EPA (Office of Atmospheric Protection 2024). The United Nations Framework Convention on Climate Change (UNFCCC) inventory reporting guidelines call for IBFs to be separated from other fuels. The EPA and ECCC prepare their national inventories in compliance with UNFCCC guidelines, hence all fuel combustion emissions estimates exclude these IBF emissions in EPA's *Inventory* and ECCC's *National Inventory Report*. These IBF emissions remain excluded from this analysis, which is concerned only with where the fuel was consumed rather than sold.

Figure A-1: Inventories Prepared by States and Provinces

States and Provinces have their own guidelines for preparing greenhouse gas emissions inventories. Some States and Provinces just comply with federal law, submitting emissions data on large emitting facilities and using default-populated federal estimation tools, Other States and Provinces prepare their own comprehensive inventories alongside the federal comprehensive inventories. State and Provincial emissions reports also did not always report the needed CO_2 values separate from CO_2 equivalent values. The range of State and Provincial standards for comprehensive emissions inventories justified the use of federal emissions inventories in this study.

State/Province	Data Set	State/Provincial Data Publisher	Date Published	Dates Covered by Data	Main Sources Cited
IL	Pulled from RMI inventory compilation	Illinois Environmental Protection Agency (IEPA)	2022	2012-2022 (FOIA); 2007-2021 (EIP)	EPA SIT
IN	Emissions Summary Data: State Total Data Large Facility Reporting	Department of Environmental Management	2023	1996-2023	EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks by State* (for PCAP); Indiana's Emission Reporting Rule (for Emissions Summary Data)
MI	Point Source Air Emissions Inventory: 1990 to Current (2019 MAERS Submittal to USEPA)	Dept. of the Environment, Great Lakes, and Energy Air Quality Division (EGLE)	2019	1990-2023	EPA SIT

State/Province	Data Set	State/Provincial Data Publisher	Date Published	Dates Covered by Data	Main Sources Cited
MN	Greenhouse gas emissions by activity, sector, source, GHG, and year: Full Results Table	Minnesota Pollution Control Agency	2025	1990-2023	*Inventory of U.S. Greenhouse Gas Emissions and* *Sinks: 1990-2020*
NY	Statewide Greenhouse Gas Emissions: Beginning 1990	Department of Environmental Conservation, Office of Climate Change	2025	1990-2022	SIT, *Inventory*, SEDS, and others
OH	Ohio Emission Inventory System	Ohio Environmental Protection Agency	2025	1990-2023	*Inventory*, SIT, EIA, Ohio Bureau of Motor Vehicles
ON	Greenhouse Gas Emissions by Sector	Environment, Conservation and Parks	2016	2013	ECCC
PA	Air Emissions Report	Department of Environmental Protection, Bureau of Air Quality	2025	1990-2023	EPA SIT

State/Province	Data Set	State/Provincial Data Publisher	Date Published	Dates Covered by Data	Main Sources Cited
QC	Inventory of greenhouse gas emissions in Québec	Ministry of the Environment, the Fight against Climate Change, Wildlife and Parks	2019	1990-2022	ECCC, Statistics Canada, report forms from organizations
WI	HISTORICAL AIR EMISSIONS INFORMATION	Department of Natural Resources	NA	2014-2023	EPA SIT, GHGRP

Figure A-2: Inventories Prepared by Federal Agencies

Data Set	Federal Publisher	Date Published / Last Modified	Notes
Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990-2022	U.S. Environmental Protection Agency (EPA)	2024	Draws methodology from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
Open Data API Dashboard: Total CO2 Emissions by Sector and Fuel	U.S. Energy Information Administration (EIA)	N/A	

Data Set	Federal Publisher	Date Published / Last Modified	Notes
Canada's Official Greenhouse Gas Inventory	Environment and Climate Change Canada (ECCC)	2025	Under folder “A-IPCC Sector”

Figure A-3: Border Data Sources

Source	Notes
2019 TIGER/Line® Shapefiles: States (and equivalent) from US Census Bureau	Digital boundary file, bounding-polygon borders that extend into water bodies rather than just land borders
2021 Census Boundary files from Statistics Canada	Canadian Census taken every five years from 2021. Issues with Ontario lake coverage, so only used for Québec.
Province | Ontario GeoHub “Province” by Land Information Ontario	Published 2003. Last updated 2024 as of time of use.
Great Lakes Shorelines - Overview from ArcGIS, Great Lakes Commission	Last updated 2024.

Appendix B: Data Methodology

ICCT Emissions Attribution Methodology

The State and Provincial borders were overlaid with ICCT's emissions grid in QGIS for the emissions attribution analysis. A tile area attribute was computed and added to the ICCT schema. The ICCT tiles were then split into child polygons at their intersection with borders to attribute them to States and Provinces. Another attribute was then added to the ICCT schema to record each polygon's area as a proportion of its parent tile. The area proportion attribute in each polygon was then multiplied by its parent tile's CO_2 emissions value to estimate emissions in that area. These values were grouped by State and Province then summed to derive the estimated maritime CO2 emitted in each territory's borders. This estimate makes the strong assumption that emissions are uniformly distributed across space despite there being routes where vessels are spatially concentrated.

The interval estimate computed a lower bound for emissions using only ICCT tiles located entirely within a single State or Provincial border. The upper bound was then computed by also adding all of the emissions from tiles that only partially intersected States and Provinces, such as those along borders. This produces the broadest plausible range of CO_2 emissions in order to make no assumptions about the spatial distribution of emissions inside ICCT data points. Many high-emissions data points lie along borders, so the certainty of double-counting and misattribution support the use of this interval estimate.

Geospatial Analysis

Figure B-1: Borders Overlayed with ICCT Emissions Data

Data point colors correspond to CO_2 emissions quintiles, with the brightest being the top 20% of emissions from about 140 to 42,000 metric tons. Note that quintiles were computed after removing data points with zero CO_2 or no value given for the purpose of graphical contrast.

Figure B-2: ICCT Schema

A new area attribute was created for each grid tile with the $area function using the Field Calculator in the ICCT data's attribute table. This procedure was applied to the State and Provincial borders to compute the area-intensity of their maritime carbon emissions using the interval estimates.

ICCT Map for appendix — Features Total: 10536, Filtered: 10536, Selected: 0

	id	left	top	right	bottom	fuel con	CO2	area
1	57138	-73.5487609859...	45.61075744600...	-73.4987609859...	45.56075744599...	13087752702.00...	42183310969.00...	21683854.290
2	57139	-73.5487609859...	45.56075744599...	-73.4987609859...	45.51075744600...	13056778099.00...	40760158629.00...	21702905.290
3	64152	-71.2487609859...	46.81075744599...	-71.1987609859...	46.76075744600...	8007919334.000...	26002942944.00...	21221570.060
4	64151	-71.2487609859...	46.86075744600...	-71.1987609859...	46.81075744599...	6127184915.000...	19813371719.00...	21202098.840
5	64304	-71.1987609859...	46.86075744600...	-71.1487609859...	46.81075744599...	5687585569.000...	17516181530.00...	21202098.840
6	57290	-73.4987609859...	45.66075744599...	-73.4487609859...	45.61075744600...	5402956655.000...	17553100825.00...	21664786.320
7	29957	-82.4487609859...	42.96075744600...	-82.3987609859...	42.91075744600...	4829152600.000...	15298102697.00...	22669845.670
8	29956	-82.4487609859...	43.01075744600...	-82.3987609859...	42.96075744600...	3887868089.000...	12384928455.00...	22651695.170
9	58200	-73.1987609859...	46.06075744599...	-73.1487609859...	46.01075744600...	3088618027.000...	10082559560.00...	21511633.210
10	58353	-73.1487609859...	46.06075744599...	-73.0987609860...	46.01075744600...	2845851773.000...	9278469986.000...	21511633.210
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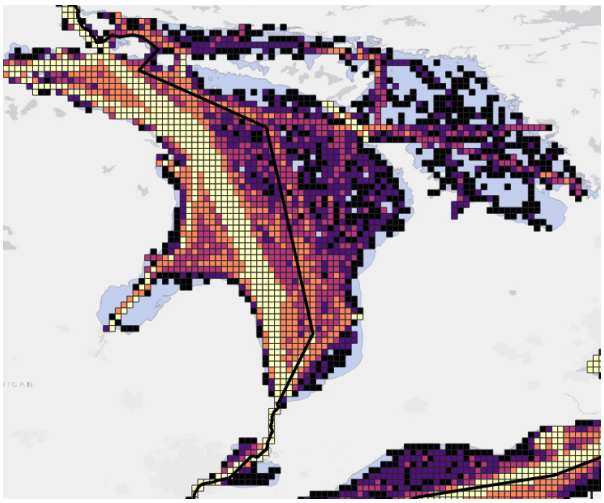
12	58201	-73.1987609859...	46.01075744600...	-73.1487609859...	45.96075744600...	2671218948.000...	8694795691.000...	21530836.470
13	56987	-73.5987609860...	45.51075744600...	-73.5487609860...	45.46075744600...	2299046312.000...	7399482132.000...	21721939.310

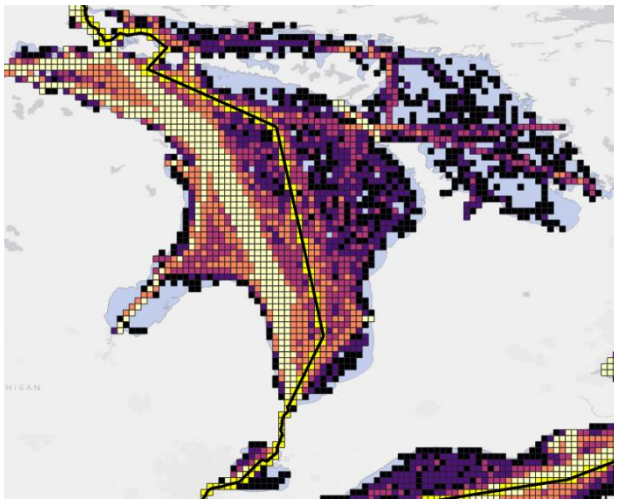
Show All Features

Figure B-3: Example of Attributing Emissions on International Borders

In the figure below, the border between Michigan and Ontario on Lake Huron is depicted by the solid black line. Yellow-highlighted tiles in Figure X lie on that shared border and have their CO_2 values one-to-many joined with both Michigan and Ontario, counting toward the

upper-bound estimates of both. The remaining tiles located in each State or Province alone compose the lower-bound estimates.





Appendix C: Maritime Emissions and Results

Estimates of Maritime Emissions

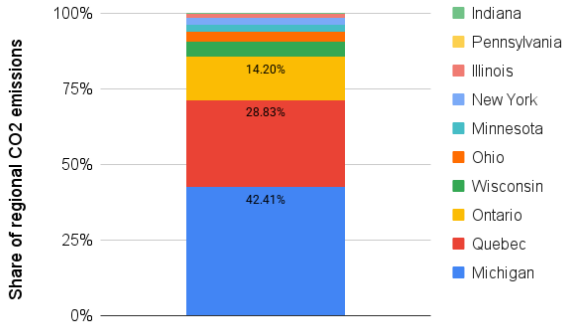
Literature on methodologies for estimating maritime emissions has previously suggested using port calls as a data source, which can exclude private terminals and even domestic movements (Browning et al. 2010). The International Council on Clean Transportation's (ICCT) 2019 GLSLS emissions inventory circumvents some of these concerns by using AIS data to estimate fuel usage and carbon dioxide emissions in a grid of locations across the waterways (Meng and Comer 2022). AIS-based studies can account for actual vessel routes and fuel switching due to Emission Control Areas, which is another advantage over port call-based inventories. The study also found that approximately 80% of GL-SLS maritime emissions are attributable to the US and Canada, indicating the importance of an analysis focused on these 10 States and Provinces. Although the EPA and ECCC each use AIS data in their emissions inventories, ICCT's regional focus offers a viable alternative estimate to validate official results.

Figure C-1: Interval Estimates of GLSLS Maritime CO2 by State and Province

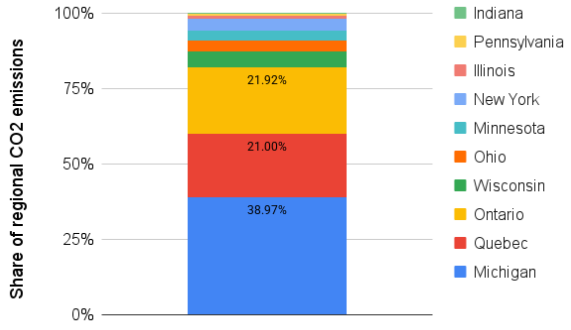
The table below summarizes key values displayed in Figure 2. Additionally, the table gives an alternative measure of uncertainty for the interval estimates of maritime emissions. This measure is the percentage of the upper bound of maritime CO_2 that was emitted ambiguously on a border.

State or Province	MMT CO2 Lower Bound	MMT CO2 Upper Bound	MMT CO2 on Borders	Border CO2 as Percentage of Upper Bound
Michigan	0.57643	0.73859	0.16216	21.95%
Québec	0.39187	0.39800	0.00613	1.54%
Ontario	0.19304	0.41545	0.22242	53.54%
Wisconsin	0.06756	0.10351	0.03595	34.73%
Ohio	0.04386	0.06854	0.02468	36.01%
Minnesota	0.03399	0.06137	0.02738	44.61%
New York	0.02900	0.07098	0.04197	59.13%
Illinois	0.01763	0.02147	0.00384	17.90%
Pennsylvania	0.00298	0.01209	0.00911	75.35%
Indiana	0.00284	0.00508	0.00225	44.18%

Figures C-2 to C-3: Regional Maritime Emissions Breakdown



C-2: Emission Breakdown Using Lower-bound Estimates



C-3: Emission Breakdown Using Upper-bound Estimates

Notes on GLSLS vs. National Values

Figures 4 and 5 compare emissions from the ICCT, combining both IBF and non-IBF sources, with emissions from the EPA and ECCC, which report IBFs separately. The largest ports in both the US and Canada are outside of the GLSLS region, so the national maritime CO_2 shares used in creating these figures are inflated by IBF exclusion and deflated by the size of outside ports.

Results in Depth

The analysis revealed several areas of high maritime emissions as well as a considerable margin of error in emissions attribution, summarized in Figure 2. Regional maritime CO_2 emissions in 2019 totaled 1.63 million metric tons, primarily concentrated 39.0-42.4% in Michigan (0.58-0.74 MMT), 21.0-28.8% in Québec (0.39-0.40 MMT), and 14.2-21.9% in Ontario (0.19-0.42 MMT). The remaining States each had ranges below Ontario's lower bound. However, the three highest areas for emissions also had the broadest estimated ranges, owing to long stretches of shared borders with high traffic that make attribution to one State or Province less clear.

States and Provinces with greater water surface area in the GLSLS had greater emissions, so each emissions estimate was adjusted by the corresponding area to better compare. The GLSLS system overall saw 0.0066 MMT of maritime CO_2 emitted per 1000 km^2 of water on average. The St. Lawrence River is largely situated in Québec, resulting in the highest emissions per area at about 0.19 MMT of CO_2 per 1000 km^2 of water. Michigan had the second largest concentration by lower bound at 0.0058-0.0074 MMT of CO_2 per 1000 km^2, and the next most intensive States Illinois, Indiana, Ohio, and Minnesota's lower bounds fell within only 0.0015 of Michigan's. Ontario was the second lowest in pollution concentration

at 0.0022-0.0063 MMT of CO_2 per 1000 km^2 despite being the third largest polluter in absolute terms. Québec's range was the only one to fully exceed the regional average. Ontario's, Pennsylvania's, and Wisconsin's ranges were the only ones to fully lie below the regional average.

Overall, Michigan, Québec, and Ontario were identified as the top States and Provinces in terms of maritime CO_2 plausibly emitted within their political borders. High absolute emissions did not equate to high area intensity of emissions, as the States and Provinces excluding Québec were far more comparable in terms of the latter. These two quantities can respectively inform policies that prioritize maximal emissions curtailment and policies that target low-efficiency or high-density traffic areas.