PROJECT MEMO

Estimating Emissions Reductions from Technology Implementation

Prepared for:

The Conference of Great Lakes St. Lawrence Governors and Premiers

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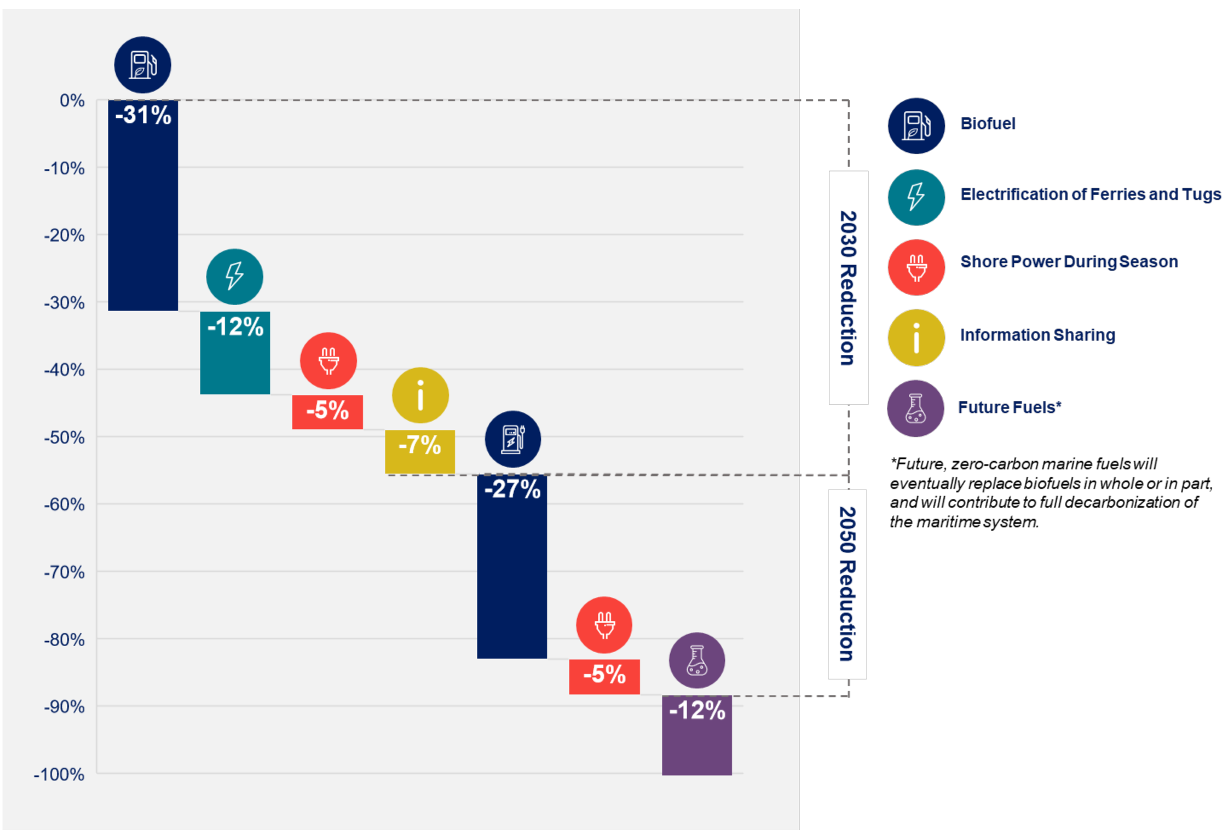
Project Background and Summary

The Conference of Great Lakes St. Lawrence Governors and Premiers (GSGP) sought CPCS's assistance with the development of estimates of the potential maritime carbon dioxide emissions reductions that could be achieved with implementation of several types of technologies in the Great Lakes and St. Lawrence River System (GLSLS). Four technologies were reviewed:

- Biofuel,
- Electrification of ferries and tugs,
- Shore power provided to vessels, which includes two technologies:
    - Shore power during the navigation season,
    - Shore power provided to vessels during winter layup, and
- Information sharing technology, such as port call optimization and voyage optimization systems.

Figure 1 presents a summary of the relative magnitude of emissions reductions associated with each technology. Technologies that had an emissions reduction of 1% or less are excluded.

Figure 1: Emissions Reduction Potential of Studied Technologies



Based on 2030 and 2050 reduction estimates for each technology, biofuel would make the most significant contribution to emissions reductions for the GLSLS. Biofuel is followed in reduction share by vessel electrification, shore power, and information sharing. If all technologies were fully implemented by 2030, GLSLS system emissions would be reduced by 55 percent.

Assuming each technology pathway matures and is fully implemented by 2050, biofuels would still generate the greatest reduction in emissions: a further 27 percent reduction between 2030 and 2050. The effects of electrification and information sharing would remain the same, though shore power's emissions reduction could grow by an additional 5 percent in the twenty-year span. To achieve a zero-emission system by 2050 with all examined technologies implemented, future not-yet-developed technologies would have to reduce emissions by another 12 percent.

Methodology

To determine the emissions reduction potential of the technologies of interest, the project team conducted a literature review to identify prior examples and estimates of emission reductions attributed to each of the technologies listed above. This review included ongoing or completed deployments of each technology around the world as well as academic studies that modeled results of the technology's use.

For each technology, four to five studies that included concrete estimates of emissions reductions in the near or long term were examined. An emissions reduction estimate within each of those bodies of literature was chosen based on whether it was a real-life observed estimate, the circumstances of the estimate could be compared to the operating context of the GLSLS, and the method to develop the estimate was clear and evidenced.

Emissions reduction estimates were adjusted to reflect the operational context of the GLSLS based on a systemwide maritime emissions inventory developed by The International Council on Clean Transportation (ICCT) in 2022 using 2019 data. For example, electrification of ferries and tugs can significantly reduce the emissions associated with these vessels, but the technology is only relevant to a subset of GLSLS vessels. Similarly, providing vessels with shore power can reduce emissions while they are at dock, but will not reduce emissions when they are cruising. Figure 2 below summarizes emissions inventory information that was used to adjust the emissions reduction estimates.

Figure 2: Emissions by Vessel Type and Operating State

	Bulk carrier	Chemical tanker	Container	Ferry-ropax	Oil tanker	Service-tug	Others	Total
Berth	51,176	33,123	37,618	14,691	12,965	7,583	13,718	170,874
Anchor	18,283	56,686	28	13,036	33,754	2,160	14,514	138,461
Cruising	921,927	73,400	51,823	24,000	22,562	131,211	54,473	1,279,397
Maneuvering	18,727	3,079	1,732	3,216	1,046	5,070	3,957	36,827
Total	1,010,113	166,288	91,201	54,943	70,327	146,023	86,663	1,625,559

Source: Zhihang Meng and Bryan Comer, Great Lakes – St. Lawrence Seaway Ship Emissions Inventory 2019, The International Council on Clean Transportation, March 23, 2022.

Lastly, many of the reviewed technology studies provided both immediate emissions reduction estimates as well as projections for long-term reductions by 2050. Therefore, hypothetical emissions estimates for an intermediate year of 2030 were provided, as well as estimates for a fully-mature and fully-implemented technology in 2050.

Technologies

Biofuels

Four estimates were considered for the final emissions reduction factor. Biofuel here refers to B100 or Bio-Liquified Natural Gas (BioLNG) rather than a biodiesel mix. Both B100 and BioLNG are sourced purely from organic material. BioLNG, however, is sourced primarily from waste with a high methane content while B100 relies more heavily on recycled plant and animal oils. Reduction estimates are available in the case that a biodiesel mix is used, or the vessel operates on a hybrid system, though B100 is primarily examined here to better understand the feasibility and impacts of vessels using pure biofuel.

Figure 3: Reviewed Biofuel Literature

Source and Author	Method	System Reduction Estimate
Domestic Great Lakes & St. Lawrence Shipping Industry: Transition to Biofuels – Transit Cost Analysis GSGP, 2023	Modeled study	67% for B100 and 50% for B75
Navigating the Future of Sustainable Marine Shipping (2024) Chamber of Marine Commerce, 2024	Measured reduction of 10 deployed dry bulk vessels	40% immediate with 50% use in single vessel. 70% for full use
Biodiesel as an Effective Decarbonization Transition Solution for Existing Ships Canada Steamship Lines, 2023	Auxiliary test on one vessel	11.70%
Energy transition in shipping: First BioLNG production project at a French port Total Energies Marine Fuels, 2021	Measured from 26 new BioLNG-powered ships in France, Singapore, and Rotterdam	20%

Based on the study methods, implementation, and timeline, the Chamber of Marine Commerce (CMC) estimate of 40 percent is the best-evidenced reduction to inform GSGP's emissions reduction estimates. The CMC reduction factor is based on vessels operating in the GLSLS and has estimates for both vessels that are operated partially on biofuel or fully using biofuel. These two estimates for both the near term and long-term are useful because they reflect the fact that biofuel supplies are not uniformly available across the GLSLS yet. Additionally, the study is based on GLSLS-specific vessels; ten *Equinox*-class bulk carrier vessels were tested to gather these estimates.[1]

The CMC's 40 percent reduction estimate was used for near term estimates as it is assumed that new vessels will not be acquired immediately in the Great Lakes system to meet these goals, nor will biofuel be fully available for marine applications. The estimate has been applied to all ships in anchor, cruising, and maneuvering phases except for ferries and tugs that are assumed to be electrified. The 2050 estimate then, assumes that not only will more vessels be able to be equipped or built to operate on biofuel, but will be operating entirely on biofuel rather than a hybrid

[1] Navigating the future of sustainable marine shipping, Chamber of Marine Commerce, February 2024. https://www.youtube.com/watch?v=aNbET7PNo6A

system. Figure 4 below illustrates the near-term and long-term estimated reduction associated with biofuels.

Figure 4: Biofuel Emissions Reduction Estimates

	2030	2050
2019 Systemwide Emissions Baseline (tonnes)	1,625,559	1,625,559
2019 Emissions from Relevant Vessels and Operating States (tonnes)	1,275,993	1,275,993
Emission Study Reduction Factor	40%	75%
Emissions CO2 Reduction (tonnes)	510,397	956,994
Total Emissions Reduction Potential (from 2019 system baseline)	**31%**	**59%**

Electrification of Ferries and Tugs

Six studies were examined for the estimated emission reduction factor of electrifying ferries and tugs in the GLSLS. Electrification here is only applied to all voyage phases of ferries and tugs in the GLSLS as the battery capacity necessary for larger vessels undertaking longer-term voyages is not yet mature.

Figure 5: Reviewed Vessel Electrification Literature

Source	Method	System Reduction Estimate
Great Lakes Commercial Vessels That Operate Like Ferries: A Potential Path to Electrification GSGP (2023)	Measure of eligible vessels that had routes under 500 miles and can stop where EVSE is available	100% reduction possible for 8 vessels (package freight, bulk freight, and tankers)
A Green Maritime Shift: Lessons from the electrification of ferries in Norway Norwegian University of Science and Technology (2021)	Based on 2017 ferry electrification in Norway	100% per ferry and 12.7% for the overall system
The little (electric) engine that could: The Port of San Diego unveils the nation's first all-electric tugboat San Diego Tribune (2023)	San Diego single tugboat electrification	3,100 metric tons of CO_2 per tugboat
Decarbonizing Maritime Transport Siemens (2022)	Modeling of EU electrification of ferries	27% from hybrid propulsion and 19% from battery propulsion
Europe Takes First Steps in Electrifying World's Shipping Fleets Yale 360 (2018)	2010 conversion of all Norway car ferries to hybrid lithium-ion and diesel locomotion	95% of ferry emissions for each hybrid ferry used
How Asia is Advancing Vessel Electrification Riviera (2023)	Based on Asian port use of electric ferries, tugboats, and rescue vessels	100% for all eligible vessels

From the studies examined, a 100 percent emissions reduction estimate was determined as the most-appropriate reduction factor for this high-level estimation effort. For the studies modeling or implementing fully electric ferries, the estimate of CO_2 reduction at an individual vessel level is 100 percent, as no part of the vessel itself emits any byproducts of fuel combustion. In reality, electricity supplied to these vessels will have a varying degree of carbon intensity across the GLSLS, as much of the region's power is obtained from fuel sources like coal and natural gas. However, EPA emissions modeling indicates that the carbon intensity of electricity supplied across the GLSLS varies widely from region-to-region, which makes making a consistent estimate of the GLSLS's electricity's carbon intensity difficult.

While large-scale vessel electrification technology is not mature, electrification technology for smaller, shorter-range vessels like tugs and ferries is more mature and already being implemented in the GLSLS. Therefore, this project assumes that all the GLSLS's ferries and tugs could be electrified by 2030. The same, then, is true for the 2050 estimate as all electrified ferries and tugs would have zero emissions.

Figure 6: Vessel Electrification Emissions Reduction Estimates

	2030	2050
2019 Systemwide Emissions Baseline (tonnes)	1,625,559	1,625,559
Emissions from Relevant Vessels and Phases (tonnes)	200,966	200,966
Emission Study Reduction Factor	100%	100%
Emissions CO2 Reduction (tonnes)	200,066	200,966
Emissions Reduction System Share	**12%**	**12%**

Shore Power in Season

Three studies were examined for estimating shore power's effect on emissions reductions if used during the navigation season. Figure 7 summarizes the identified literature.

Figure 7: Shore Power Literature Reviewed

Source	Method	System Reduction Estimate
Shore power needs and CO_2 emissions reductions of ships in European Union ports ICCT (2023)	Modeling if container and passenger ships larger than 5,000 GT connect to shore power	24% reduction of at-berth emissions
Clearing the air: Would shoreside power reduce air pollution emissions from cruise ships calling on the Port of Charleston, SC? J. Corbett and Bryan Comer (2013)	Estimated for the system based on the EPA shore power calculator	26%
Shore Power Technology Assessment at U.S. Ports 2022 Update Eastern Research Group (2022)	Estimated for the system based on the EPA shore power calculator	32% to 49% depending on the location

From this selection of studies, the emissions reduction estimation sourced by the EPA for the Port of Charleston is the most relevant to GSGP's emissions reductions and is supported by the EPA's emissions calculator for all range of vessels and port sizes using shore power. The 2019 study measured the reduction effect of tankers and bulk carriers above 5,000 tons using shore power in season. To calculate the estimate, the study took into consideration the power grid's mix of energy-generating units, auxiliary engine emissions, change in vessel traffic patterns throughout the season, and hoteling power demand by vessel type. This is also the most recent study available within the report for a similar sized port system.

A 49 percent reduction was estimated for 2030 to reflect the fact that not all locations will have shore power implemented by 2030, nor will all US and Canadian vessels be capable of effectively connecting to and utilizing shore power. Note that the shore power estimate here includes shore power for ferries and tugs as well, which means a small percentage of emissions reduction is "double-counted" between this technology and vessel electrification.

Figure 8: Shore Power Electrification Emissions Reduction Estimates

	2030	2050
2019 Systemwide Emissions Baseline (tonnes)	1,625,559	1,625,559
Emissions from Relevant Vessels and Phases (tonnes)	170,874	170,874
Emission Study Reduction Factor	49%	100%
Emissions CO2 Reduction Tonnes (tonnes)	83,728	170,874
Emissions Reduction System Share	**5.2%**	**10.5%**

Shore Power During Winter Layup

Emissions reduction estimates from the provision of shore power during winter layup were calculated using a different approach than other technologies. This technology is mainly relevant to a sub-set of GLSLS vessels and operating states, and 2022 ICCT emissions estimates did not provide estimated emissions for the winter layup period. Therefore, this project utilized other daily emissions estimates from other GSGP reports to generate a baseline estimate of bulk vessels' emissions in winter layup. Figure 7 illustrates how a winter layup baseline emission estimate was created, and Figure 8 illustrates how these emissions make up less than 1% of the GLSLS system's total emissions.

Figure 9: Winter Layup Emissions Estimate

Attribute	Value	Source
Total Count of Bulk Carrier and General Cargo Vessels in US and Canadian	83	2022 ICCT emissions inventory
Average Days of Layup	69	Soo Locks closure from January 15 to March 25
CO2 Emissions per Day at Dock (tonnes)	1.93	*Vessel Emissions and Operating Cost Estimates for Great Lakes and St. Lawrence Commercial Navigation** GSGP, 2020.
Total CO2 emissions (tonnes)	11,053	Multiplication of values above.

Note: this figure reflects estimated daily idle state emissions of a small articulated tug-barge in Table 14 of the referenced report. This low emissions rate was chosen because vessels on winter layup only use generator power for basic electrical services.

Figure 10: Winter Layup Electrification Emissions Reduction Estimates

	2030	2050
2019 Systemwide Emissions Baseline (tonnes)	1,625,559	1,625,559
Emissions from Relevant Vessels and Phases (tonnes)	11,053	11,053
Emission Study Reduction Factor	100%	100%
Emissions CO2 Reduction	11,053	11,053
Emissions Reduction System Share	**<1%**	**<1%**

Information Sharing

Five estimates were included in the evaluation of information sharing technology's potential for emissions reduction. Information sharing is defined here to include multiple strategies primarily focused on voyage optimization: reducing vessel speed in the last stages of the voyage based on communication from the port on traffic levels and optimal speeds by vessel type. Therefore, adjustments to the reduction factor were applied to non-ferry and tug vessels in the cruising phase of their voyage.

Figure 11: Information Sharing Literature Reviewed

Source	Method	System Reduction Estimate
Smart Shipping - Challenges and Opportunities for the Great Lakes and St. Lawrence Region GSGP (2020)	Simulations based on vessels using AIS data with notification 24 hours of optimal speed before arrival	10%
Estimated Potential Benefits of Hands-Free Mooring at the New Soo Lock System GSGP (2022)	Measures fuel savings from reduced travel time using HFM at Soo locks	2,135 metric tons CO_2
Port Call Optimization and CO_2-Emissions Savings – Estimating Feasible Potential in Tramp Shipping Swedish Transport Research Institute (2022)	Measures reduction by fewer hours of wait time, speed reduction, and vessel	5 – 15% based on ship type
The Future of Shipping – The Positive Impact of Just-in-Time Port Arrivals Wartsila (2020)	Measured reduction of emissions for the Port of Singapore's Just In Time Arrival system in 2020	10-50% based on ship type
Just in Time Arrival: Emissions Reduction Potential in Global Container Shipping International Maritime Organization (2022)	Measures reduction based on scenarios considering voyage duration, number of voyages, and TEU class	Speed reduced in last 24h: 2-11%, speed reduced in last 12h: 2-8%

Based on the studies examined, a 10 percent emissions reduction factor was used. A 10 percent emissions reduction factor is within the range estimated for most studies, with assumptions that vessels of all size would reduce to optimal speed or adjust voyages based on information sharing in the last 12-24 hours of the voyage. The GSGP estimate based on AIS data relies on GSGP vessel inventory and traffic patterns and accounts for port call optimization among all vessel types and allows for speed reduction in a range of hours before arrival at the port.

It is important to note that the emissions reduction associated with information sharing systems will be reduced in the longer-term as other emissions reduction technologies, like biofuel are implemented.

Figure 12: Information Sharing Emissions Reduction Estimates

	2030	2050
2019 Systemwide Emissions Baseline (tonnes)	1,625,559	1,625,559
Emissions from Relevant Vessels and Phases (tonnes)	1,069,714	0
Emission Study Reduction Factor	10%	10%
Emissions CO2 Reduction Tonnes (tonnes)	106,97	0
Emissions Reduction System Share	**6.6%**	**0%**