OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE IN THE GREAT LAKES ST. LAWRENCE MARITIME TRANSPORTATION SYSTEM

Prepared by Green Marine
in collaboration with the Research and Traffic Group

GREEN MARINE

For the Conference of Great Lakes St. Lawrence Governors & Premiers

GREAT LAKES ST. LAWRENCE GOVERNORS & PREMIERS

Final report
July 19, 2021

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF ACRONYMS

3RV	Reduce, Reuse, Recycle, and Valorize
AIS	Automatic Identification System
CBI	Climate Bond Initiative
CCAP	Climate Change Action Plan
CCNR	Central Commission for the Navigation of the Rhine
CO2	Carbon dioxide
CRE	Conseil régional de l'environnement
DERA	Diesel Emissions Reduction Act
ECA	Emission Control Area
ECHO	Enhancing Cetacean Habitat and Observation
ESG	Environmental, Social & Governance
EU	European Union
GHG	Greenhouse gas
GLLCISP	Great Lakes and Lake Champlain Invasive Species Program
GLSLSDC	Great Lakes St. Lawrence Seaway Development Corporation
GSGP	Conference of Great Lakes and St. Lawrence Governors & Premiers
HDV	Heavy Duty Vehicle
HFO	Heavy Fuel Oil
HVO	Hydrogenated Vegetable Oil
IBTS	Integrated Bilge Treatment System
IMO	International Maritime Organization
IT	Information Technology
IUCN	International Union for Conservation of Nature
IWT	Inland Waterway Transport
LNG	Liquified natural gas
MARAD	Maritime Administration - Department of Transportation
MARPOL	International Convention for the Prevention of Pollution from Ships
MARS	Marine Acoustic Research Station
META	Maritime Environmental and Technical Assistance
MGO	Marine gas oil
MGTP	Montreal Gateway Terminals Partnership
MMTL	McAsphalt Marine Transportation Ltd.
MTS	Maritime transportation system(s)
NAB	National Australia Bank
NIB	Nordic Investment Bank

LIST OF ACRONYMS

NOx	Nitrogen oxides
NRC	National Research Council of Canada
NTCF	National Trade Corridors Fund
PETMAF	Programme d'aide à l'amélioration de l'efficacité du transport maritime, aérien et ferroviaire
PM	Particulate matter
PREGTI	Programme visant la réduction ou l'évitement des émissions de gaz à effet de serre par le développement du transport intermodal
PtL	Power-to-liquid
RD&D	Research, development, and demonstration
SDTC	Sustainable Development Technology Canada
SLSMC	St. Lawrence Seaway Management Corporation
SOx	Sulfur oxides
STQ	Société des traversiers du Québec
TMS	Traffic management system
U.S. EPA	U.S. Environmental Protection Agency
ULSFO	Ultra-low sulfur fuel oils
UVNSRT	Underwater vessel noise source reduction target
VLSFO	Very low sulfur fuel oils

EXECUTIVE SUMMARY

Much has been accomplished in recent years to address important environmental issues in the Great Lakes St. Lawrence region's maritime transportation system (MTS). Today, there is clearly a renewed interest and a sense of urgency to push further and faster to build a green economy that includes an environmentally sustainable maritime sector.

In line with the first regional strategy to improve the efficiency and competitiveness of the Great Lakes St. Lawrence MTS, the Conference of Great Lakes and St. Lawrence Governors & Premiers (hereinafter referred to as "GSGP") commissioned Green Marine to carry out a study on the opportunities to improve environmental performance in the region's MTS. The goal of the study is to provide recommendations to federal, state and provincial decision-makers as to how their future policies and initiatives could help the region's maritime industry to reduce its environmental footprint while also increasing the system's overall competitiveness. The report also provides industry stakeholders with a set of short- and long-term actions.

This study focuses on environmental issues prioritized by the GSGP. The report includes: 1) a survey of maritime transportation's **best environmental management practices and the new technologies** recently implemented by Green Marine participants in the Great Lakes St. Lawrence region along with other industry stakeholders elsewhere; 2) a review of **relevant governmental environmental policies and programs** in Canada and the U.S.; 3) the **opportunities for innovative financing mechanisms** to reduce the industry's environmental impacts; and, 4) **high-level strategies and recommendations** to advance the environmental performance of the MTS.

ISSUES PRIORITIZED IN THIS STUDY

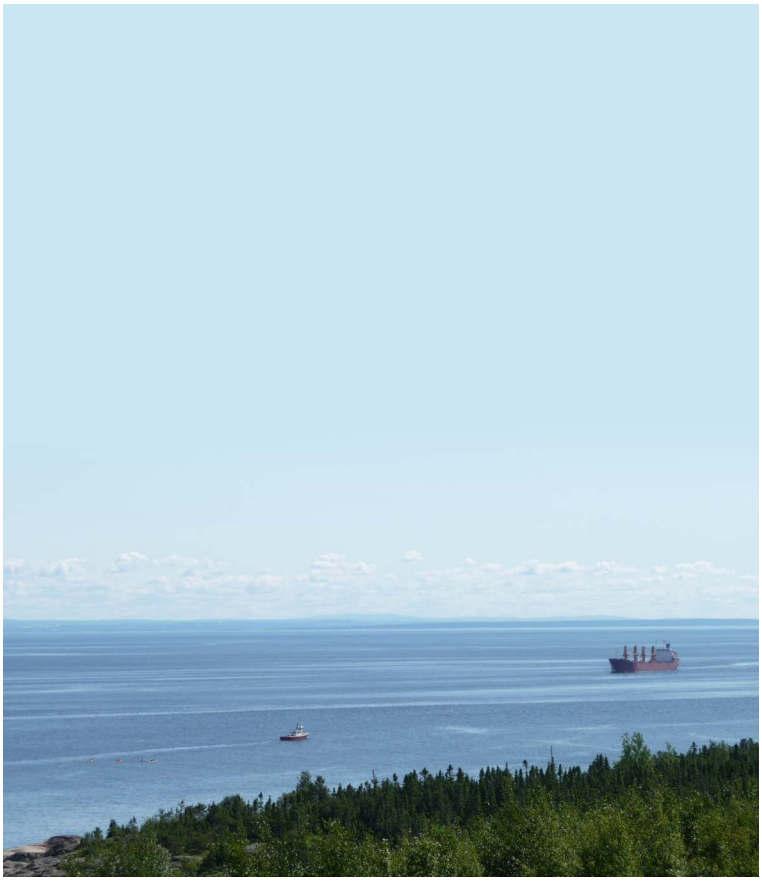
- **Air quality & climate change**: greenhouse gases and other air pollutants, energy efficiency and climate change
- **Climate change adaptation & resilience**
- **Water quality**: vessel incidental discharges, spill prevention, and stormwater management
- **Biodiversity**: marine mammals & aquatic invasive species
- **Waste management**
- **Community impacts of port operations**

QUICK WINS TO IMPROVE THE GREAT LAKES ST. LAWRENCE MARITIME INDUSTRY'S ENVIRONMENTAL PERFORMANCE

The survey conducted by Green Marine revealed that, to date, a number of ship owners, port authorities and terminal operators in the region, as well as the two Seaway corporations (U.S. and Canadian), have implemented many best management practices and innovative technologies to improve their overall environmental performance. The report highlights examples of practices and technologies implemented in the region, as well as elsewhere in North America and in peer MTS such as in the Baltic Sea, the Rhine River, and at the Port of Antwerp (Belgium).

For each topic discussed, a short list of efficient near-term actions is suggested for industry stakeholders and, in some cases, for federal, state and provincial governments. These selected actions – deemed quick wins or low hanging fruits – aim to measure the industry's impact and promptly improve the overall environmental performance of the MTS. Where relevant, some longer-term actions are also proposed. The complete list of recommended actions by stakeholder type can be found in Annex 1 of the report. It is worth noting that with the exception of climate resilience and adaptation, most of the actions in Annex 1 are also listed and detailed in the Green Marine program. The latter includes an even larger set of best environmental management practices and other actions that can be implemented or undertaken by industry stakeholders to further reduce their environmental impacts.

AIR QUALITY AND CLIMATE CHANGE



Based on the survey's findings, a few key near-term actions are proposed to help the industry quickly improve air quality and tackle climate change. One of the first actions that each port authority, terminal operator, shipyard manager and ship owner should undertake is threefold: **monitor operations**, **assess the impact** by estimating annual emissions, and **set ambitious reduction targets.** Ideally, governments in the region would also estimate the emissions and set targets at the MTS level to set the bar for the region's maritime industry. The way to achieve those targets will differ from one company or port to another as there is no 'one size fits all' solution. For quick gains in energy efficiency, for example, one could begin by identifying areas of improvement through an **energy efficiency audit**.

Some basic measures have a demonstrated track record of improving vessel energy efficiency, such as speed and trim optimization, preventive engine maintenance, reduced idling, and voyage planning. Other short-term actions that can lead to immediate reductions in greenhouse gas (GHG) emissions

EXECUTIVE SUMMARY

include investments in 1) **digitalization** such as digital equipment and smart shipping technologies to improve efficiency of operations, including real-time monitoring of fuel consumption for ship owners, as well as 2) **electric or hybrid technology** vehicles, equipment, machinery, and even smaller non-commercial vessels to reduce the use of fossil fuels. Assessing the economics and environmental benefits of installing **shore power** in ports for commercial vessels and cruise ships is also recommended given that vessels can spend a relatively significant time at berth. Carrying out **pilot projects on voyage optimization** and on the usage of **alternative fuels** could also help determine potential energy efficiency gains for the MTS.

The maritime industry must also adapt and become resilient to climate-related issues and challenges in the region, namely fluctuating water levels, shoreline erosion, and the integrity of aging maritime infrastructure. The first near-term action suggested for ports, terminals, shipyards and the Seaway is to **assess the impacts, vulnerability, and risks of climate change** on infrastructure, which could be done with the support of different levels of government. Once this step is completed, a second proposed near-term action is to adopt a Climate Change Action Plan with concrete measures to promote the adaptation and resilience of assets. All ongoing and future infrastructure projects should without exception be designed through a risk-informed and multicriteria-based framework to ensure the sustainability of assets.

KEY ACTIONS FOR ALL INDUSTRY STAKEHOLDERS

- **Monitor operations**
- **Assess impact - estimate annual emissions**
- **Set ambitious reduction targets**

WATER AND SOIL QUALITY

Ship owners can help to improve water quality in the St. Lawrence River and the Great Lakes primarily by **limiting vessel incidental discharges**. Quick wins could include **minimizing oily discharges** by reducing the volume of treated bilge water released into the aquatic environment by installing an integrated bilge treatment system on new-builds and/or adopting a similar approach on existing vessels. The modernization of control and monitoring equipment on oily water separators may also help to avoid exceeding regulatory standards and the unintended pollution of surrounding waters. Furthermore, ship owners can avoid using oily water separators and discharging treated bilge water in sensitive areas or even adopt a zero-discharge policy whereby all treated bilge water is managed on land. Another short-term strategy to reduce water pollution from ships consists of eliminating all oil-to-water interfaces. Over the longer term, port authorities and ship owners could work together to foster stewardship through increased access to port reception services and/or pump and haul out providers.

Ports, terminals, shipyards and the Seaway can also do their part to limit or avoid polluting land and water. If not already done, they first need to identify site-specific potential pollution sources (e.g., areas, equipment, activities) and associated pollutants on the territory managed by them. The second step is to select, implement and subsequently monitor maintenance and prevention measures (e.g., of vehicles and machinery, spill clean-up equipment, and treatment systems). Efforts could also be made to **improve stormwater management practices** to ensure **adequate treatment and monitoring,** especially in states and provinces where stormwater is not highly regulated.

The adequate prevention of land and water pollution involves raising awareness among employees and providing for their continual training, which is yet another short-term action that should be implemented by maritime organizations and private companies.

BIODIVERSITY

Unsplash - Todd Cravens

The impact of underwater noise on marine mammals has received increasing attention and study in recent years. Several research projects are currently under way to help address this environmental issue, including projects in the St. Lawrence and Saguenay rivers. Until recommendations arise from current research projects, a few short-term actions can be undertaken by the maritime industry. Ship owners can help **protect marine mammals** by **adhering to all voluntary measures** (e.g., slowdowns, rerouting, avoidance areas) implemented in the region's designated areas. They can also incorporate quiet vessel technologies during retrofits and/or the construction of new vessels. Additionally, ship owners and port operators can use hydrophones to monitor

EXECUTIVE SUMMARY

underwater noise generated by vessels or by construction and dredging activities. Once equipped with a better understanding of the impacts of underwater noise, a longer-term goal would be for industry stakeholders to set underwater noise reduction targets along with an action plan.

For governments, a short-term action could involve collaborating with industry stakeholders to develop smart shipping solutions to better target and manage voluntary slowdowns, rerouting, and avoidance areas along the St. Lawrence River.

In terms of aquatic invasive species, the issue of ballast water management and treatment has received a high degree of attention and is now regulated in Canada under the International Maritime Organization's *International Convention for the Control and Management of Ships' Ballast Water and Sediments* and, in the U.S., under the *Vessel Incidental Discharge Act*. This report focuses on biofouling which, unlike ballast water, is not regulated. To help prevent the introduction and spread of aquatic invasive species, ship owners can **limit biofouling** by using environmentally friendly **anti-fouling paints and coatings, biofouling-resistant materials**, and **marine growth prevention systems** to prevent aquatic organisms from settling on underwater surfaces or within internal or niche areas. **Regular inspection and cleaning** of underwater surfaces is also very helpful.

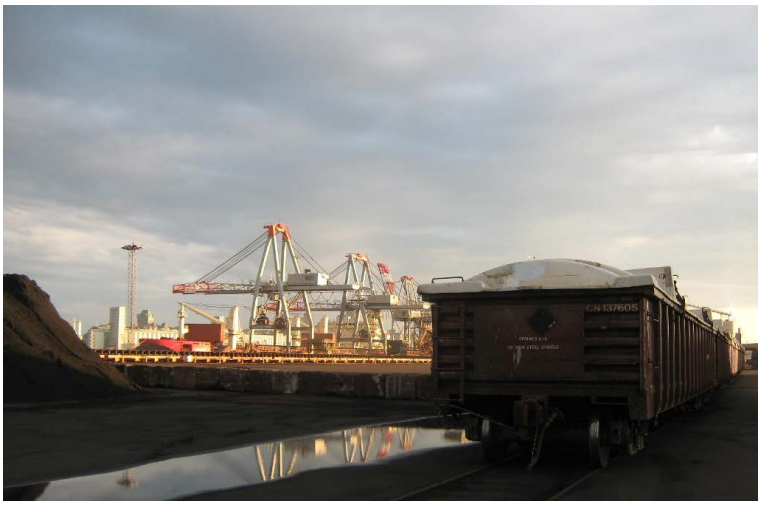
KEY ACTIONS FOR GOVERNMENTS

- **Develop smart shipping solutions** to better target and manage voluntary slowdowns, re-routing, and avoidance areas along the St. Lawrence

WASTE MANAGEMENT

Despite the efforts made to date by the maritime industry to improve waste management, further **reduction of waste at source** and the diversion of waste from incinerators and landfill sites are required to significantly reduce the industry's impact. Three basic steps to reduce the generation of waste are to 1) **integrate the 3RV principle** (reduce, reuse, recycle, and valorize) in the company's or organization's culture; 2) **carry out annual waste inventories** (i.e., determine total volume) and characterizations (i.e., identify waste types); and 3) **develop and implement a Waste Management Plan** with waste reduction targets (for plastics, dunnage, wood, card board, single use items, etc.), reuse/recycling/valorization targets, sustainable purchasing practices, and safe and compliant disposal of hazardous waste material.

COMMUNITY IMPACTS



Although this report focuses mainly on environmental issues, it also includes a brief overview of the impacts of port operations on the surrounding community, which include noise, dust, polluting air emissions, odours, lights and traffic. To **minimize nuisances**, ports, terminals, and shipyards can develop and implement a Nuisance Mitigation Plan for all construction work and regular operations, which should include measures that serve to reduce any anticipated impacts on the community. **Real-time monitoring of noise, dust emissions and air quality in critical areas** is increasingly common at ports and enables them to **improve responsiveness** in the event of a complaint or concern.

HIGH-LEVEL STRATEGIES AND RECOMMENDATIONS

Four high-level strategies are suggested (detailed in Annex 2 of the report) with a set of recommendations and short-term actions that are collectively in line with the regional maritime strategy. These high-level strategies are mainly aimed at governments but are in some cases also directed to industry stakeholders.

Continued collaboration within all sectors of the maritime industry is crucial to take the necessary steps in meeting the challenge of establishing a regional MTS that is both environmentally and economically sustainable. Success will ultimately help to support the region's economic competitiveness, job creation, and improved environmental health for the benefit of the region and its population.

FOUR HIGH-LEVEL STRATEGIES

- **Promote research, development & demonstration**
- **Plan for the energy transition**
- **Incentivize green shipping**
- **Harmonize U.S. and Canadian governmental policies and regulatory approaches**

EXECUTIVE SUMMARY

TOP 10 RECOMMENDED SHORT-TERM ACTIONS FOR THE INDUSTRY

BIODIVERSITY
- Protect marine mammals
- Limit biofouling

Adhere to all voluntary measures (slowdowns, re-routing, avoidance areas)

Use biofouling resistant paints / coatings / materials, MGPS, and regularly inspect and clean hull

WATER QUALITY
- Limit vessel incidental discharges
- Improve stormwater management

Use green infrastructure and treat & monitor stormwater quality

Minimize oily discharged (IBTS, zero discharge policy, no oil-to-water interfaces)

AIR QUALITY & CLIMATE CHANGE
- Monitor & reduce emissions
- Improve efficiency
- Adapt to become resilient

Calculate annual emissions & set ambitious reduction targets

Carry out energy efficiency audits and assess the benefits of shore power in ports

Digitalize and test voyage optimization

Assess the impacts of climate change on maritime infrastructure

WASTE MANAGEMENT
- Reduce waste at source

Do more than basic recycling! Integrate the 3RV principle

COMMUNITY IMPACTS
- Reduce nuisances and be responsive

Monitor air quality, dust emissions and noise in critical areas

3RV: reduce, reuse, recycle, and valorize; IBTS: Integrated Bilge Management System; MGPS: Marine Growth Prevention System

1) INTRODUCTION

In 2016, the Conference of Great Lakes St. Lawrence Governors & Premiers (hereinafter referred to as "GSGP") released the first regional strategy to jumpstart the Great Lakes St. Lawrence Maritime Transportation System (MTS)[i]. The Strategy was developed in partnership with key stakeholders, including industry representatives, federal agencies, and non-governmental organizations.

The Strategy's three main goals are to: 1) double maritime trade; 2) shrink the environmental footprint of the region's transportation network; and 3) support the region's industrial core. To achieve these goals, four main objectives have been established: 1) increase efficiency and reduce costs; 2) build new markets; 3) grow economic activity around the MTS; and 4) deliver results while managing for the future. These objectives will be met through the implementation of policies, programs, and projects aimed at enhancing regional competitiveness, resilience, sustainability, connectivity, and harmonization.

States and provinces can actively engage through concrete actions and measures to reduce the environmental footprint of the region's maritime industry to help ensure the sustainable future of the MTS. This requires focusing efforts on major environmental issues related to air, water and sediment quality, aquatic and coastal habitats, biodiversity, and all within the context of a changing climate. In this context, the GSGP commissioned Green Marine to complete a study on the opportunities to improve environmental performance in the region's MTS.

Founded in 2007, Green Marine's North American environmental certification program is the result of a voluntary effort by the shipping industry to exceed regulations. With its 14 performance indicators, the program covers a large range of environmental issues that the maritime industry faces, including air, water, and land pollution, as well as biodiversity. There are currently more than 150 ship owners, port authorities, terminal operators and shipyard managers throughout Canada and the U.S. participating in the program along with the two Seaway corporations. Approximately 65 of those 150 participants operate in the Great Lakes St. Lawrence region. Green Marine therefore has extensive knowledge of the best management practices and innovative technologies implemented thus far in the region and is in a good position to report on such practices.

1.1 STUDY OBJECTIVE AND SCOPE

The objective of this study is to inform and provide recommendations to federal, state, and provincial decision-makers, as well as key industry stakeholders, as to how existing and future policies, programs and initiatives can help the region's maritime industry to reduce its environmental footprint, while also increasing the system's overall competitiveness.

This study is not an exhaustive review of all practices, measures, or innovative technologies worldwide. Nor does it cover all environmental issues related to maritime transportation. Instead, the report focuses on select environmental issues prioritized by the GSGP. It should also be noted that Section 2 is largely based on knowledge of best environmental management practices and technologies implemented by Green Marine participants with close to 45% of them operating within this MTS.

1.2 REPORT SECTIONS

The main sections of this report include:

- A survey of maritime transportation environmental best practices and new technologies implemented in the Great Lakes St. Lawrence region and elsewhere in Canada, the U.S., and in peer maritime systems in Europe (Section 2)
- An overview of relevant governmental environmental policies and programs in Canada and the U.S. (Section 3)
- Examples of opportunities for innovative financing mechanisms to facilitate investments that reduce the maritime industry's environmental impact (Section 4)
- General recommendations on how to advance the environmental performance of the region's MTS, with a focus on air emissions, energy efficiency, and technology (Section 5).

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

Between 80-90% of goods worldwide are transported by ship, and this is also true for the Great Lakes St. Lawrence region.[ii,iii] More than 230 million metric tons of cargo (valued at US$77.4 billion) are delivered every year by ship on the region's MTS, making the maritime industry a critical component of the region's economy.[iv] Like other industrial sectors, shipping needs to adapt to reduce its environmental footprint, and a great deal of effort is being undertaken in the region to achieve this goal. This section of the report highlights the environmental best practices and innovative technologies adopted by some of the maritime industry stakeholders in the Great Lakes St. Lawrence region in recent years. A few exemplary practices and new technologies from outside the region are also included in this section where relevant. Special attention was given to peer inland waterways of western Europe, such as the Baltic Sea MTS and the Rhine River MTS.

*The **Baltic Sea MTS** is a significant inland waterway that can be accessed without going through locks and has a few ocean-depth ports inland. It provides ocean access and intercountry trade among eight European countries and Russia. Due to geography, marine transportation is the dominant mode for much of the intercountry cargo trade, which includes a high proportion of general cargo and numerous liquid bulk tankers, as well as passenger and cruise ships.*

*The **Rhine River MTS** is a major inland waterway with a series of locks and significant draft limitations. The Rhine fleet, with a large component of dry bulk vessels, competes with land transportation modes.*

Examples from the Port of Antwerp in Belgium are also included, as it represents extremely large-scale marine operations in a region of the world where environmental initiatives are embraced by much of the population and, consequently, where early initiatives are taking place.

Unsplash - Mihai Surdu

2.1 GREENHOUSE GASES AND ENERGY EFFICIENCY

Waterborne shipping is the most carbon-efficient transportation mode when compared with trucks and trains.[v] Nevertheless, with about 70,000 ships worldwide, waterborne shipping is estimated to consume more than 330 million metric tons of fuel every year, which accounts for close to 3% of global carbon dioxide (CO2) emissions. [vi,vii]

In response to the Paris Agreement, the International Maritime Organization (IMO) has committed to ambitious greenhouse gases (GHG) minimum reduction targets: 40% reduction in carbon intensity by 2030, and 50% absolute emissions reduction by 2050. However, an increasing number of countries, cities, organizations, and industrial sectors are now fixing a net-zero emissions target by 2050. Indeed, in late 2020, Canada joined more than 120 countries in committing to net-zero emissions by 2050. Several Canadian provinces and municipalities have already made net-zero-by-2050 commitments, including Guelph, Hamilton, Toronto, and the Province of Quebec. In April 2021, the Biden administration also committed to working with the IMO to adopt a goal of achieving zero emissions from international shipping by 2050. In the maritime sector, a few port authorities, terminal operators, and ship owners have announced a net-zero emissions target by 2050 (e.g., the Northwest Seaports Alliance, Glencore, Maersk, CMA CGM). GHG and other pollutant emissions reduction targets have also been set for the Rhine River MTS in Europe, which is a peer of the Great Lakes St. Lawrence MTS in that it is a major inland waterway with a series of locks. The reduction targets for the Rhine River MTS have been set at 35% by 2035 (compared with the 2015 baseline) and to largely eliminate emissions by 2050. These ambitious targets are expected to drive technological developments and the quest for low-carbon fuels and renewable energy sources with lower global warming impacts.

In the Great Lakes St. Lawrence region, an increasing number of port authorities and terminal operators are aiming for a 1% reduction of GHG emissions intensity per year, and most ship owners based in the St. Lawrence region are aiming for a 1% or 2% GHG emissions reduction per year. A few terminal operators have also set shorter term targets including Glencore,[viii] which has set a total emission (Scope 1, 2 and 3) reduction target of 40% by 2035 (based on 2019 levels) and Valero,[ix] which is aiming to reduce and offset Scope 1 and 2 GHG emissions by 63% by 2025 (based on 2011 levels).

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

Energy efficiency can play an important role in reducing GHG emissions and this is an area where significant improvements can be made. Many of the region's maritime industry stakeholders have already started to take action to reduce emissions and increase the energy efficiency of equipment and operations. Energy efficiency audits accompanied by Energy Efficiency Management Plans can lead to significant improvements on existing ships and on land-based activities and infrastructure. Such audits have been carried out in recent years by ship owners in the region (e.g., CSL, Groupe CTMA, and Groupe Desgagnés). To date, efforts toward decarbonization in the region focus mainly on 1) logistics, digitalization, and digital transformation; 2) ship hydrodynamics and machinery; and 3) alternative fuels and energy sources. The following three subsections provide a few noteworthy examples for each of these focus areas.

2.1.1 LOGISTICS, DIGITALIZATION AND DIGITAL TRANSFORMATION

Three European studies cited below suggest that significant gains in energy efficiency and GHG reductions can be achieved in peer MTS by improving supply chain logistics as well as through digitalization[1] and digital transformation[2]. A digitalization study sponsored by the Finnish Transport and Communications Agency in the Baltic Sea Region provides an overview of opportunities for GHG reduction via efficiency improvements at ports and data-sharing at the port-vessel interface.[x] The study examined the role of digitalization in the maritime transportation sector as a tool to achieve IMO's 50% GHG reduction target by 2050. The study indicates that "data sharing along the supply chain on a platform-based structure, combined with machine learning algorithms and predicting analytics, was recognized as one of the important measures for emission reductions. Emission savings could be achieved by optimization of the utilization of cargo carrying capacity, voyage of a ship and cargo handling in a port. Maritime ports act as digital links in the value chains of maritime logistics."

Also in the Baltic Sea Region, another study used the Baltic Sea's short sea freight sector example to highlight common inefficiencies and lock-ins in the shipping industry.[xi] The study compares different sustainable and tenable alternative solutions that could be applied immediately and with a widescale effect. Based on a possible trajectory for emissions reduction from the shipping sector, the voyage optimization and cargo coordination aspects of digitalization could together significantly contribute to reducing GHG emissions in the Baltic Sea.

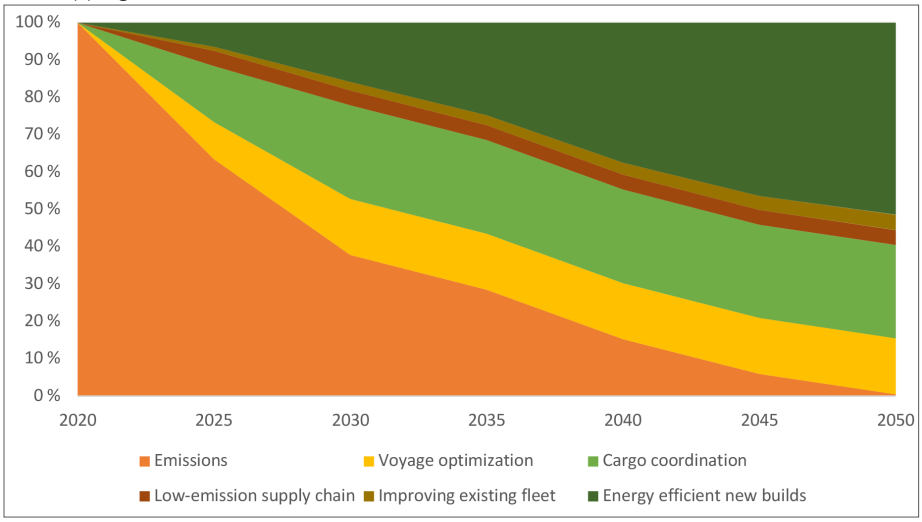
Figure 1 illustrates this trajectory, and the positive impacts of digitalization are reflected in the middle three segments of the chart, namely, in decreasing order, cargo coordination, voyage optimization, and low-emission supply chain. These projected efficiency improvements are largely gained via data-sharing and data analysis.

For the Great Lakes St. Lawrence MTS, the potential for emissions reduction related to cargo coordination may not be as promising as for the Baltic Sea MTS. The goal of improving cargo coordination is to reduce the proportion of ballast trips and to reduce the number of empty containers carried by container ships or light-loaded bulk ships, thereby directly reducing emissions and improving the vessel's revenue (a win-win scenario if the potential is there). The volumes of general and containerized traffic combined with the large network of origin-destination pairs that exist in a marine-dominant region such as the Baltic Sea will most likely have more opportunities to benefit from market knowledge of cargo demand and vessel/container supply than would the Great Lakes St. Lawrence bulker fleet. Nonetheless, a long-term strategic plan action for the Great Lakes St. Lawrence region might be to identify future additional backhaul opportunities for the domestic fleet, and/or a role for more general cargo vessels within the fleet.

Voyage optimization, by contrast, may have a greater potential than cargo coordination in the Great Lakes St. Lawrence region, since it is less traffic-type dependent and rather tied to various types of delays. Voyage optimization includes contributions from at-sea response to weather information as well as port planning. In the region's MTS, up-to-date and accurate water level information relevant to mariners is already provided via Internet, telephone, and Automatic Identification System (AIS) by both the U.S. National Oceanic and Atmospheric Administration and by the Canadian Coast Guard. This information is particularly important, for example, for the west end on Lake Erie, which can experience vessel delays due to draft limitations when strong winds from the west shift lake waters from the west end of the lake to the east side.

A recent analysis of shipping movements in nine European ports found that cargo vessels spent only 60-70% of their port time at berth and only 40-65% of that time was used for operations.[xii] Similarly, container ships in a harbor spent

FIGURE 1.
SEQUENTIAL IMPLEMENTATION OF EMISSIONS-REDUCTION MEASURES



Source: Gustafsson et al. (2019)

1. Digitalization refers to the use of digital data and digital technologies to increase the efficiency of exiting processes for a vessel at port and to enable new processes, while digitization refers to installing digital equipment (onboard ships for example), to go from analogue and manual data to digital data, which helps make information more readily available, sharable and actionable. (Refer to Section 2.1.1.1 for a further explanation.)

2. Digital transformation refers to the transformation of processes to fully take advantage of the opportunities that digitalization offers. (Refer to Section 2.1.1.1 for a further explanation.)

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

70% of their time at berth and only 58% of that time was spent conducting operations. Based on this information, one could assume that Great Lakes St. Lawrence port efficiency improvement relative to voyage optimization could be two-fold: 1) improvement in turn-around at port; and 2) better use of time now associated with queueing delays. These efficiency gains would translate into more time available to haul cargo, which means better fleet utilization and lower emissions per tonne-kilometer of cargo handled.

Efficiency is important for both port authorities and vessel owners. Port authorities want to maximize berth utilization, and vessel owners want to minimize time at port (both wait time and service time). The optimal procedure for all parties would be to have vessels arrive in time to take a berth but not so early as to encounter unproductive waiting delays at port. It therefore would be worth analyzing recent delay data, for example, to help assess the potential of voyage optimization in the Great Lakes St. Lawrence region.

Regarding the Seaway's lock system, it currently is only used at approximately 50% of its capacity and, therefore, no significant transit delays are normally encountered unless an infrastructure breakdown occurs. In fact, the Seaway lock system availability has exceeded 99% since 2016.[xiii] To manage any potential navigation delays related to ice conditions during the closing season, the Seaway coordinates ship passages through locks weeks in advance, which ensures timely and safe navigation. Therefore, potential gains for voyage optimization are likely limited here.

Existing initiatives at large container ports (e.g., those established by the Montreal and Vancouver Fraser port authorities) are discussed in Section 2.1.1.3. It is expected that real-time performance monitoring initiatives will have less but potentially still significant payback for the region's domestic cargo fleet, which mostly visit non-containerized ports in the region's MTS.

www.ccr-zkr.org

In the case of the Rhine River Inland Waterway, the Central Commission for the Navigation of the Rhine (CCNR) has been tasked to identify which greening techniques fit into zero-emission development of inland waterway transport (IWT) and the related impacts (Task-C in Intermediary Overall Study Report). [xiv] The overall findings of Task-C draw upon the forecast efficiencies from digitalization and a move to biofuels (see Section 2.1.3.3), such as hydrogenated vegetable oils (HVO), and power-to-liquid (PtL), which is a process of combining CO2 and hydrogen to obtain liquid fuel. The report suggests that emission reductions can primarily be achieved by decreasing the energy demand with the improved utilization of vessels, slow and smart steaming with less waiting time at locks, and the efficient integration of IWT in seaports.

A few companies and port authorities in the Great Lakes St. Lawrence region as well as the Seaway have already begun investing in digital equipment and technologies to improve traffic management in ports, to better predict ship arrival and departure times, to optimize ship voyages, as well as to allow real-time monitoring of various parameters to optimize vessel operations.

Based on the data collected and processed, operations are adapted to reduce GHG emissions and increase energy efficiency. A few noteworthy examples are provided in this section.

2.1.1.1 SHIP OWNERS

For ship owners, digitalization translates into real-time data monitoring and accelerated problem identification and solving, as well as optimizing operations and processes. Digital transformation refers to the standardization of the digital data collected aboard ships to 'break the silos' of separately collected information and make better use of all available data, thereby improving the efficiency of operations even further. In this way, data-smart ships facilitate more energy efficient operations with reduced environmental impacts, as well as innovative solutions that further improve sustainability. E-navigation is an example of digital transformation and defined by the IMO as "the harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."[xv]

Ship-board performance monitoring systems and sea-trial monitoring services can help ship operators to reduce fuel consumption by providing key performance indicators such as real-time fuel consumption, specific fuel consumption, fuel per nautical mile and engine power. State-of-the-art sensors are now available that facilitate obtaining accurate performance data used in turn to optimize ship operation and maintenance or to evaluate fuel reduction technologies.

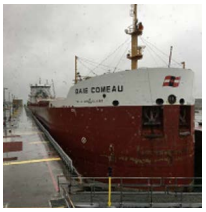
CSL recently developed its own O2 digital technology. A total of 11 ships in CSL's Great Lakes fleet are now outfitted with this technology combining the use of various sensors that simultaneously provide real-time operational data aboard a vessel and ashore to ensure regulatory compliance. The system is equipped with an energy management feature that provides continuous electricity and fuel consumption data that facilitates adjusting navigational speed to improve efficiency and thereby reduce GHG emissions.

Algoma Central Corporation is working with Buffalo Automation to develop the AutoMate software. Automate is being developed to use artificial intelligence and neural networks to plan safe and efficient ship transits based on data acquired from cameras, sensors, broadband radars, GPS, LiDAR and AIS to facilitate ships to operate semi-autonomously. Algorithms and sensors are to be used to interpret weather and seafaring conditions, and adjust speed automatically to meet a scheduled time, thereby reducing idle time and increasing fuel efficiency. The company also partnered with Beaverlabs to build a platform to capture and transmit data from vessels ashore. The Beambox has a small footprint, supports standard communication interfaces commonly available on vessels, and integrates with existing networks, allowing it to fit within this unique environment while remaining cost effective.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

The cruise and ferry operator Groupe CTMA uses the Pronova system, which allows the company to reduce GHG emissions based on real-time consumption and engine efficiency data. This information allows Groupe CTMA to find a balance between its port and starboard propulsion engines so that they are in complete synergy.

2.1.1.2 SEAWAY



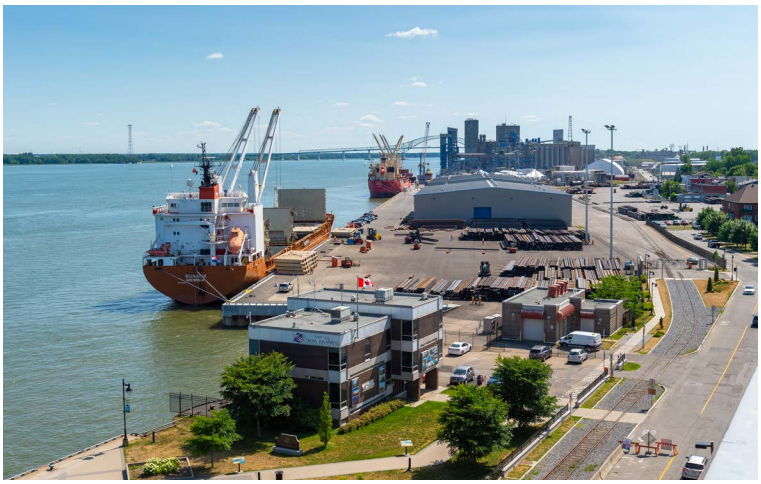
In July 2002, the St. Lawrence Seaway Management Corporation (SLSMC) and the Great Lakes St. Lawrence Seaway Development Corporation (GLSLSDC) implemented a universal AIS and integrated this communication protocol within the Seaway's existing traffic management system (TMS). Through AIS channels, the Seaway's TMS can broadcast information to ship owners on marine weather, tides, water levels, currents, ice conditions, other safety-related messages, as well as the availability of the next lockage. The AIS-based TMS helps ship owners to optimize voyages by reducing transit time and enhancing fleet management (e.g., improved scheduling of lock passages and more accurate estimates of arrival times leading to more efficient scheduling of appointments with pilots and ship inspectors), which ultimately leads to fewer delays, greater fuel savings, and less GHG emissions. The SLSMC and GLSLSDC are also working in partnership with the Volpe National Transportation Systems Center operating under the U.S. Department of Transportation to develop a traffic flow management system that will provide vessel travel-time estimates between key locations along the Seaway, thereby further improving operational efficiencies.

Ship owners are taking electronic charts to a new level to maximize draft, thereby satisfying cargo demand with the fewest possible vessel trips. In 2012, the SLSMC and GLSLSDC jointly implemented a Draft Information System. High-resolution bathymetric charts are used in combination with vessel squat curves, vessel draft and vessel speed to provide mariners with real-time under keel clearance for every vessel that has this equipment aboard. These vessels can safely navigate with an extra 7 centimeters of draft, which translates into roughly an additional 300 to 400 extra tonnes of cargo being carried on a maximum-sized Seaway vessel, therefore further reducing GHG emissions.

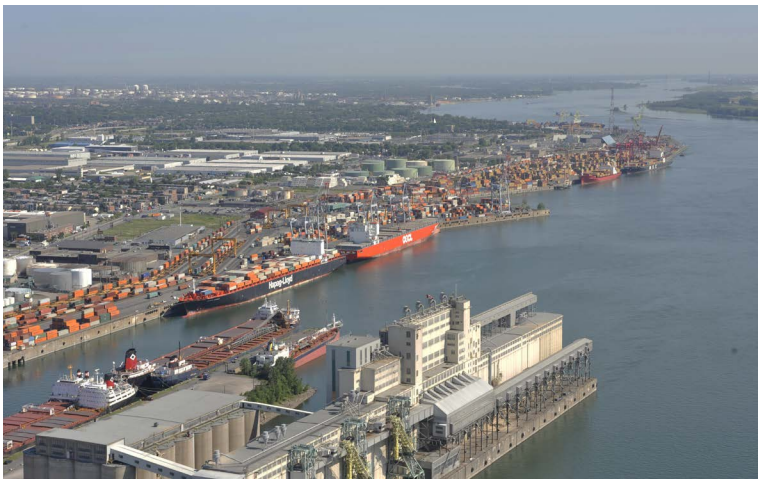
2.1.1.3 PORTS AND TERMINAL OPERATORS

Optimizing logistics and switching to digital technologies at ports and terminals also result in increased efficiencies and reduced GHG emissions. Of the various examples in the region's MTS, three are briefly described below along with a few examples elsewhere in Canada and Europe.

The ports of Montreal and Trois-Rivières have jointly developed an information technology (IT) solution to standardize messages and pre-arrival notification forms, providing greater simplicity and efficiency for ship owners and their crews calling at both ports.[xvi] This solution is currently being piloted with shipping

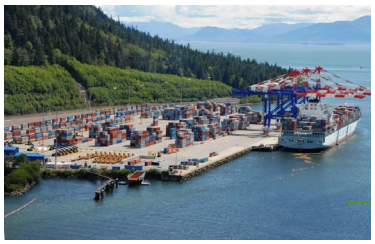


agencies in both port areas and will be deployed to all port clients in 2021. The new fully automated common portal will give clients, ship owners, and crews an efficient tool whereby they can document a personalized profile, apply for port services, and integrate data related to vessel pre-arrival procedures, all of which is mandatory procedure in Canadian port waters. Focused on sharing information and best practices, it will ultimately make it possible to increase the productivity, competitiveness, efficiency and safety of port services and procedures, while at the same time reducing GHG emissions.



The Montreal Port Authority has also joined 35 other global partners in an ePIcenter project aimed at offering concrete solutions to international supply chain challenges.[xvii] Led by the Port of Antwerp, ePIcenter moves towards unifying the digital presence of businesses around the world, making them more efficient and resilient, notably using cutting-edge technology such as the Internet of Things, synchromodal operations, Industry 4.0 automation and information exchange, as well as autonomous vehicles. In 2019, the Montreal Port Authority also launched a C$37-million project to improve cargo mobility. The project's goal is to increase the port's capacity, efficiency and safety by reducing wait times and bottlenecks for container transport, which will also result in reduced GHG emissions from trucks. The port upgraded its Trucking PORTal application to include predictive data on processing times at the port's various container terminals to improve traffic flow on port territory by helping drivers to plan their routes better.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES



In Western Canada, one noteworthy example is the collaboration between the Vancouver Fraser Port Authority, Prince Rupert Port Authority, Transport Canada, and other Pacific Gateway partners in terms of the West Coast Supply Chain Visibility Program.[xviii] This multi-phase, multi-year program aims to develop and implement customized operational planning and optimization tools for participating industry members to support actions to increase capacity and operating efficiencies throughout the supply chain.

Two noteworthy European examples are the PortXchange tool originating at the Port of Rotterdam, and the NxtPort system at the Port of Antwerp. The PortXchange tool is a digital collaboration platform connecting all the different players involved in port calls to make their handling faster and more efficient. [xix] For each port call, numerous parties (e.g., ship owner, agents, terminal operators, and other service providers) must coordinate various activities at the right time. The tool facilitates planning, executing, and monitoring all of these activities based on a standardized data exchange. After successful trials in Rotterdam resulted in a 30% reduction of idling time, the tool was launched as an independent organization in Summer 2019 and is now also implemented at the ports of Felixstowe, Moerdijk, Algeciras and Houston. The NxtPort Data Utility Platform also supports data sharing by supply chain partners to increase operational efficiency, safety and revenues.[xx] The information from such a tool and platform may have more potential to improve supply chain operations for general cargo and container ports than for bulk cargo ports but may also help predict queueing delays at Great Lakes St. Lawrence ports.

2.1.2 SHIP HYDRODYNAMICS AND MACHINERY

While new-builds are being designed to be hydrodynamic and energy efficient, existing vessels can also be improved. A few examples are briefly described below.

CSL has improved the energy efficiency of its fleet in many ways. The company modified the hull on one of its vessels to make it more hydrodynamic. It has also improved its fleet's energy efficiency by installing thermal oil heating and heat recovery systems, automating engine room fans, and replacing oversized pumps.

Interlake Steamship Company installed repowered engines on four of its vessels for improved efficiency and reduced noise. The company also has a new-build under construction. The *Mark W. Barker*, set to sail in 2022, will have numerous features to ensure a smaller environmental footprint compared with older ships. These features include greater hydrodynamic efficiency of the propeller, a controllable-pitch propeller (thereby no need for harbor assist tugs), diesel engines (that are also LNG compatible) that generate less sulfur oxides (SOx), nitrogen oxides (NOx) as well as particulate matter (PM), shaft generators that facilitate electricity being generated from the main engines, and fully electric heating. The company purchased locally produced materials and parts to further reduce the environmental footprint.

Groupe Desgagnés ships are now designed to navigate with a shallow draft to facilitate navigation in rivers and the Arctic. They are also equipped with bow and stern thrusters, which allow for greater maneuverability and safety, as well as greater energy efficiency.

Fednav has installed propeller boss cap fins and pre-swirl fins on its new-builds to optimize energy efficiency and reduce underwater noise.

2.1.3 ALTERNATIVE FUELS AND ENERGY SOURCES

Alternative fuels that have a lower carbon footprint and emit fewer air pollutants compared to heavy fuel oil (HFO) are becoming increasingly popular in the maritime industry to reduce the impact of ships on air quality and climate change. Further advanced research and development are required before some of the potential alternative fuels, energy sources and technologies are used or implemented by shipping companies in the region's MTS, such as green hydrogen and fuel cell systems, green ammonia, methanol, batteries, wind power, and solar energy. Others such as biofuels, liquified natural gas (LNG) (discussed in Section 2.2), and electric power have already been tested and are currently used by some Great Lakes St. Lawrence ship owners.

2.1.3.1 ELECTRIFICATION

Some port authorities, terminal operators, stevedoring companies, as well as ship owners in the Great Lakes St. Lawrence region have invested significantly over the last decade to acquire electric or hybrid equipment and machinery, as well as to install shore power. This section highlights a few electrification examples in the Great Lakes St. Lawrence region.

SHIP OWNERS

In 2020, the Great Lakes Towing Company acquired two new harbor tugs with a hybrid system that facilitates the vessels operating frequently on electric power without having to use the more powerful main engines, thereby reducing air emissions as well as engine maintenance costs.

Also in 2020, the Maid of the Mist Corporation launched two all new fully electric vessels with zero-emission to offer tours of the world-famous Niagara Falls and Niagara River Gorge.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

PORT AUTHORITIES AND THE SEAWAY

Since 2010, PortsToronto has been using 100% renewable electricity to power all its operations – the only port authority in Canada to do so. In 2018, it was estimated that the port had reduced its carbon emissions by more than 17,600 tonnes since 2010.

In 2016, the Hamilton-Oshawa Port Authority implemented an Industrial District Energy System at Pier 10, which includes an energy center consisting of a two-megawatt natural gas engine providing electric power to the grid, while at the same time co-generating hot water and steam to supply port tenant buildings and operations on the Industrial District Energy loop.

Since 2018, the Port of Montreal is offering shore power for wintering ships at more than 20 of its facilities as well as one shore-power facility for cruise ships at the Grand Quay. In 2020 alone, 26 ships used the port's shore power through 35 hookups, which is estimated to have reduced GHG emissions by more than 3,200 tonnes that year alone.

TERMINAL OPERATORS AND STEVEDORING COMPANIES

Termont Montreal is the world's first port operator to retrofit its entire fleet of 62-yard tractors into hybrid diesel-electric models, which reduces its tractor-related GHG emissions by approximately 30%. In 2021, Termont plans to complete the commissioning of the first electric rail mounted gantry in the Province of Quebec.

Montreal Gateway Terminals Partnership (MGTP) is the first Canadian container terminal facility to recently convert two rubber tire gantry cranes from diesel to electric power. In 2020, MGTP also purchased a total of 10 gantry cranes on electric wheels that consume 92% less fuel than diesel-fueled cranes.

Over the last few years, QSL has increased its use of fixed and mobile conveyors powered by electric power at operational sites. This option significantly reduces GHG emissions and is now prioritized across QSL's network of terminals.

Finally, McAsphalt Industries Ltd. has shore power available at three of its terminals (Hamilton, Windsor, and Eastern Passage), two of which are in the Great Lakes St. Lawrence region. McAsphalt uses shore power when vessels stay at berth without cargo- or ballast-related operations taking place. The installation provides enough power for hotel load (i.e., all onboard electrical systems other than propulsion) on the vessels.

2.1.3.2 FUEL ADDITIVES / CATALYSTS

A few companies are now offering various fuel additives and catalysts that are claimed to improve the combustion process of existing fossil fuel engines, thereby directly reducing the GHG emissions, particulate matter, and other air pollutants. Long-term benefits are believed to include longer engine life and reduced filter maintenance and repair. **Some ship owners in the region are using additives and catalysts.** For example, Canfornav is using Aderco's additives.

2.1.3.3 BIOFUELS

The use of biofuels, produced from the conversion of biomass such as plant material and animal waste into liquid fuels such as bioethanol and biodiesel, is considered a good option to reduce the GHGs emitted by ships. The greatest GHG reductions are achieved with 2nd generation biofuels produced from agricultural residues, used cooking oil, or municipal waste.[xxi]

As mentioned in Section 2.1.1, the CCNR's report indicates that the overall findings of Task-C draw upon the forecast efficiencies from digitalization and a move to biofuels, such as HVO and PtL, a process of combining CO2 and hydrogen to obtain liquid fuel.[xxii] However, the availability of these fuels and the related bunkering costs are hard to predict. The CCRN report also states that decarbonization without conventional combustion engines comes with significant challenges for energy storage and much higher costs. Its authors consider it too early to pick a fuel/technology. Further technology-neutral developments and pilot applications are required. Since the retrofitting of existing vessels often requires extensive and costly conversions, the focus for advanced drivetrains should be on new builds.

CSL is the only ship owner known to use biofuels in the region's MTS. In August 2019, the company ran its first test of a marine biofuel on a self-unloading bulk carrier, using a 50% biofuel made from waste agricultural products. In 2020, the company used 100% marine biofuel on the main engines of two of its Canadian ships with plans to expand to eight Canadian ships in 2021. On a whole lifecycle basis, biofuels can reduce GHG emissions by up to 80%.[xxiii]

However, one of the limiting factors for biofuel use by the maritime industry for now at least is its limited sustainable production compared to the possible demand for ships.

2.1.3.4 WIND POWER

The only example of a maritime stakeholder currently making use of wind power in the region's MTS is the Port of Milwaukee. In 2012, the port, in partnership with the Environmental Collaboration Office of the City of Milwaukee, installed a wind turbine that provides 100% of the electricity needed to power the port's administration building, making it the first municipal facility that is a net-zero electric energy user in the municipality. The turbine generates clean power exceeding the building's needs and the surplus provides power additional to the grid.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

In Europe, one noteworthy example is the Swedish company Wallenius Marine that is working on developing the Oceanbird, a 200-meter-long wind-powered oceangoing car carrier (also fitted with a backup engine), in collaboration with the KTH Royal Institute of Technology and the naval research institute SSPA. [xxiv] The vessel is expected to save 90% of carbon emissions compared with a conventional ship. The vessel prototype is currently being tested in the Baltic Sea to gather data and optimize its performance and aerodynamics.

Wallenius Marine

GREENHOUSE GASES & ENERGY EFFICIENCY: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

As evidenced in the section above, there is a broad range of measures, technologies, and strategies to reduce GHG emissions in the maritime industry. There is no 'one size fits all' solution with different industry sectors usually requiring different solutions. For example, gains in energy efficiency will be achieved in very different ways for a container carrier, a bulk carrier, and a tug operator.

*In the short term, monitoring of one's operations is the first step to identify where improvements can be made. Several best management practices can be implemented by all companies and organizations, including carrying out GHG inventories and developing action plans with reduction targets. Measures that have had a demonstrated track record of improving energy efficiency include speed and trim optimization, preventive engine maintenance, reduced idling, voyage planning, lighting upgrades, etc., and those can be implemented with software or other non-hardware solutions without taking the vessel out of service.**

Further GHG reductions usually require investing in newer equipment and technologies. As indicated above, there are already several examples of electrification and digitalization taking place in the region's MTS. This trend will likely accelerate in the next few years. For commercial ships, the biggest GHG emissions reduction may be attained at unloading ports for self-unloading vessels, which requires adapting this type of vessels for use of shore power. Direct electrification of auxiliary power at port may be far cheaper than deriving electricity via hydrogen production and conversion for on-vessel storage. This is potentially a near-term conversion with long-term viability for ports, especially where hydropower is readily available. The first step would be to assess the economics for the port and vessel owner. Electricity is sold to industrial users based on a demand charge: the lowest rate is realized by a continuous fixed draw of electricity. Shore power therefore becomes more economical with more frequent vessel visits. One can assess the fuel price at which shore power would be more economical for a given number of vessel visits per month. The busiest self-unloading ports would be the first ones to assess. Reviewing the economics of previous government-assisted shore power installations in Canada and in the U.S. might also give an initial idea of the short-term merits for ports.

The first step for digitization would be to assess vessels' delay data and status of vessels' utilization of the Seaway's information on pending queue delays. Such data provides the basis of assessing savings potential as well as identifying any limitations to using these data.

In the longer term, moving away from fossil fuels by using alternative fuels and energy sources is probably the sole key to full decarbonization. There are a few different options in terms of alternative fuels, and it is not yet clear which one(s) can replace fossil fuels in the long run. Even though a few companies have started exploring alternative fuels, significant investments in research, development, and demonstration (RD&D) by governmental agencies, fuel suppliers, the industry and other stakeholders will be required to achieve this goal. Any regional ambition in that regard will also require coordination at the policy level.

A list of the main recommended short- and long-term actions for the maritime industry to tackle climate change are outlined in Appendix 1.

** See Green Marine's GHG and Air Pollutants Performance Indicators for more detail on best management practices and additional actions the industry can take to improve its environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.2. AIR EMISSIONS

Waterborne shipping generates polluting air emissions through the combustion of fossil fuels. In addition to GHG (see section 2.1), SOx, NOx as well as PM are air pollutants emitted by ships that directly worsen air quality. These emissions cause health and environmental concerns, especially in areas where busy urban ports facilitate intense shipping activity.

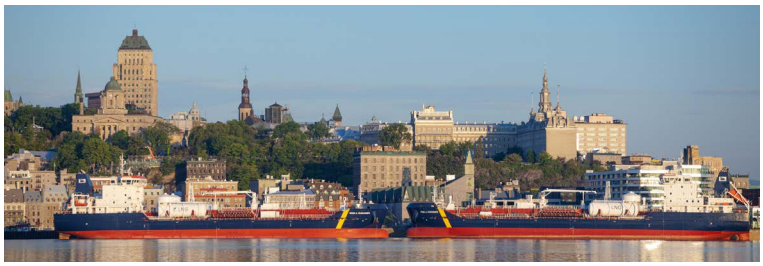
Since January 2015, all vessels operating in an IMO-designated Emission Control Area (ECA) must use fuel with a maximum sulfur content of 0.10%. As well, since January 2020, the IMO (through International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI) set a stricter sulfur content limit for fuel oil aboard ships operating outside designated ECAs, making it 0.50% compared with the previous 3.5% limit. **To meet these new sulfur standards, most Great Lakes St. Lawrence ship owners have turned to low sulfur fuel, while some have opted for exhaust gas cleaning systems (i.e., scrubbers), and a very few have switched to LNG.** ECAs and MARPOL Annex VI also set limits for NOx (IMO's Tier I, II and III standards for ship engines, equivalent to U.S. Environmental Protection Agency (U.S. EPA) Tiers 1, 2 and 3). To reduce their NOx emissions, ship owners install new, cleaner running engines as part of their fleet renewal or retrofitting.

2.2.1 LOW SULFUR FUEL OILS

The use of marine gas oil (MGO) as well as very low and ultra-low sulfur fuel oils (VLSFO and ULSFO, respectively) that comply with the regulatory requirements inside and/or outside ECAs is one option to reduce SOx emissions. To date, **most ship owners in the region have opted to switch from using HFO to MGO, VLSFO and/or ULSFO** to comply with SOx-related national and international regulations. Two such companies are NEAS and McAsphalt Marine Transportation Ltd. (MMTL).

2.2.2 LIQUIFIED NATURAL GAS (LNG)

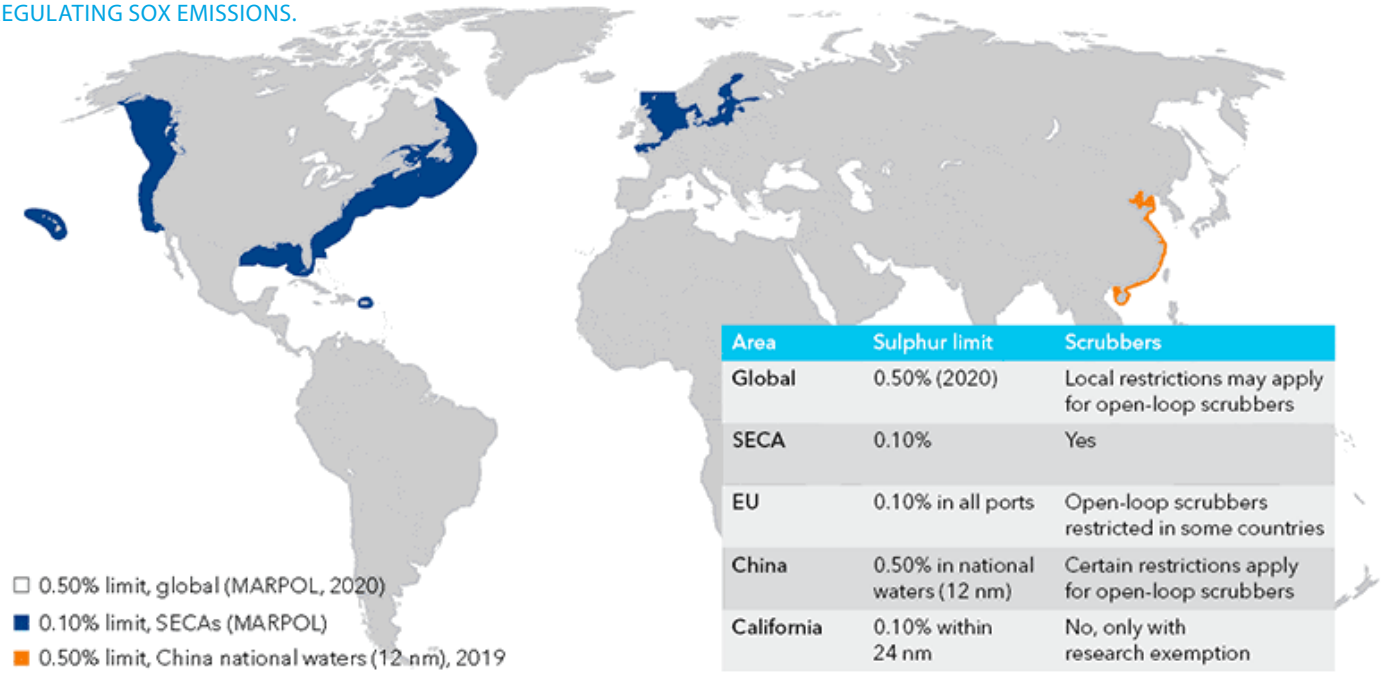
LNG marine fuel is another commercially available option for ship owners to comply with regulations. LNG almost fully eliminates SOx emissions and significantly reduces NOx and PM compared with conventional marine fuels. In recent years, **one commercial ship owner in the Great Lakes St. Lawrence region, Groupe Desgagnés, as well as one ferry operator, Société des traversiers du Québec (STQ), acquired a few new vessels with LNG-powered engines** (e.g., dual-fuel tankers, LNG-powered ferries, respectively).



LNG fueling by truck in the Great Lakes St. Lawrence region has been available since 2017 at the Port of Montreal. To date, more than 100 LNG fuelings (31 in 2020 alone) have been carried out at the port, totaling close to 30,000 tonnes of GHG emissions saved. LNG fueling is also available at the Port of Hamilton, the Port of Oshawa, the Port of Quebec, as well as in Tadoussac and Matane (for STQ ferries).

The benefits and the increasing popularity of LNG are mainly due to its low sulfur content and its lower price compared to MGO (even HFO in some areas). LNG-powered engines and exhaust aftertreatment system technologies result in lower NOx emissions. However, the reduction in GHG emissions with LNG is much less significant compared with the reduction of SOx and NOx emissions. [xxvi,xxvii]

FIGURE 2. EMISSION CONTROL AREAS (ECAS) FOR TIER III AND POSSIBLE FUTURE ECAS. NOTE THAT THE ECAS IN THE NORTH SEA AND BALTIC SEA ARE ONLY REGULATING SOX EMISSIONS.



Area	Sulphur limit	Scrubbers
Global	0.50% (2020)	Local restrictions may apply for open-loop scrubbers
SECA	0.10%	Yes
EU	0.10% in all ports	Open-loop scrubbers restricted in some countries
China	0.50% in national waters (12 nm)	Certain restrictions apply for open-loop scrubbers
California	0.10% within 24 nm	No, only with research exemption

Source:DNV GL, 2019[xxv]

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.2.3 EXHAUST SCRUBBERS

Exhaust gas open-loop, closed-loop and hybrid scrubber technologies have proven to be very effective in reducing SOx emissions. Water is used to remove sulfur oxides and other pollutants from exhaust gases as they pass through the scrubber tower before venting into the atmosphere. However, the resulting wash water from open-loop scrubbers is in turn a source of water pollution. The cost of installing a scrubber on an existing vessel can vary from approximately US$2.9 to 3.6 million (compared with US$14.3 to 19 million to convert a ship to LNG) (Bergqvist et al., 2015). In 2020, more than 4,300 ships worldwide were outfitted with exhaust gas scrubbers, most of which are open-loop systems (Comer et al., 2020).

In the Great Lakes St. Lawrence region, a few Canadian and U.S. ship owners have invested in scrubbers to meet the regulations in force. Algoma invested in the installation of closed-loop exhaust gas scrubbers certified for use on its Equinox Class ships to remove at least 97% of all SOx emissions from the exhaust stream. Interlake Steamship Company also installed closed-loop exhaust gas scrubbers on five of its vessels.

For closed-loop scrubbers, bleed-off water, which is the small portion of wash water that is bled off the system and treated to remove suspended solids, can also be a source of pollution if not treated appropriately. Both Algoma and Interlake Steamship Company ensure this bleed-off water is treated and then directed to an effluent monitoring module for continuous monitoring of the parameters specified under the IMO, U.S. EPA and Transport Canada regulations (e.g., pH, turbidity, polycyclic aromatic hydrocarbons, temperature). If any of these parameters are above the allowable concentration, the effluent is directed back to treatment. Only treated bleed-off water at or under the specified concentrations will be placed overboard.

The IMO is currently studying the issue of water pollution arising from the use of certain scrubbers, and an increasing number of countries and ports around the world now restrict or prohibit the discharge of open-loop scrubber wash water within their waters.[xxviii] In the Great Lakes St. Lawrence region, the Port of Sept-Îles prohibits the use of open-loop scrubbers within the port's boundaries.

AIR EMISSIONS: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

*Without any doubt, the greatest drivers to reduce air emissions in the past few years have been the ECAs and the entry into force of the lower IMO sulfur limit, which effectively led to significant reductions of SOx, NOx and PM. Further reductions below the current limits can be achieved in the short term by burning even lower sulfur fuel oils or by using scrubbers.**

Each option brings different challenges. While very low and ultra-low sulfur fuel oils are costly and not always reliably available in sufficient quantities from suppliers (and still a source of pollutants in the refining process), scrubbers are being increasingly challenged as a source of water pollution. Pollutants from scrubber wash water can affect water quality and aquatic life through acidification for example. To our knowledge, the domestic fleets operating in the Great Lakes St. Lawrence MTS that use this technology exclusively use closed-loop scrubbers. With the IMO studying the issue of water pollution relative to the use of scrubbers, ship owners using this technology in the region should stay informed and eventually implement suggested mitigation measures, if applicable to them.

RD&D projects are also underway to design and upgrade scrubbers to capture carbon at the point of exhaust. Beyond those short-term solutions however, longer-term reductions will only be possible with the use of alternative fuels.

** See Green Marine's SOx & PM and NOx Performance Indicators for more detail on best management practices and additional actions the ship owners can take to improve its environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.3 CLIMATE CHANGE ADAPTATION AND RESILIENCE

Climate change is resulting in present and expected climatic variations, including changes in temperature and precipitation patterns, an increasing frequency of extreme winds, waves and weather events, varying snowfall and ice cover, different freezing and melting cycles, as well as changing sea and surface water levels, river discharge patterns, shoreline erosion and fog manifestation. The stakes and challenges of climate adaptation[3] and resilience[4] for the maritime industry in the Great Lakes St. Lawrence region mainly revolve around fluctuating water levels, shoreline erosion, and the integrity of aging port infrastructure.

Managing water levels in the Seaway is critical for safe navigation, making this issue one of the main climate change-related challenges for the maritime industry operating in the system. Responsible actions towards sustainable solutions for resilience could include considering forecast models, developing a risk-informed decision framework, and setting resilience-based parameters. While flooding carries its own risks (e.g., variability in navigation periods, lock availability, shoreline erosion, port infrastructure damage), lower water levels can also limit the usability of infrastructure such as docks and piers, and negatively affect shoreline ecosystems.[xxix] For example, in 2020, vessels were forced to stop at Lake Ontario's locks because of heightened current velocity on the St. Lawrence River caused by increased water flow through the Moses-Saunders Dam.[xxx] Extreme precipitation from storm events and the resulting floods exacerbate impacts on shoreline erosion as well as port and Seaway infrastructure stability (e.g., facilities, docks, locks, bulk depots). Waterside facilities at the Port of Cleveland were compromised by flooding on Lake Erie in 2019. At the Port of Milwaukee, waterside infrastructure was severely damaged by 2020 flooding events.

How climate change will affect waterside infrastructure and safe navigation in the region's MTS is still not well understood and therefore remains difficult to accurately predict. Several ports have begun **analyzing the risks associated with climate change and have started planning and implementing preventive measures based on the best available data and predictive models to improve climate resilience.** An increasing number of ports are **adopting a Climate Change Action Plan** (e.g., the Trois-Rivières Port Authority) **or Sustainable Development Action Plans that consider climate change** (e.g., the Quebec Port Authority). Port authorities realize they must consider risks related to climate change at the conceptual design stages of any new port infrastructure project. As an example, when designing new projects, the Quebec Port Authority uses Quebec City's updated mapping of flood risk areas, which considers the increasing frequency, length and intensity of precipitation characterizing climate change in the municipal region.

In 2021, the Trois-Rivières Port Authority plans to begin a three-year study on the vulnerabilities and risks of hydro-sedimentary changes, an important environmental issue identified at this port. The study should help to understand and anticipate the effects of climate change on the maintenance activities of port maritime assets in the double context of climate change and the projected expansion of maritime infrastructure. New bathymetric data and improved knowledge on hydro-sedimentary dynamics is crucial for a sustainable expansion of port infrastructure. The study constitutes the preliminary phase of a project with the broader objective of implementing hydraulic development solutions to reduce sediment deposits within the port's vicinity, thereby reducing the need for maintenance dredging.

Other contributing factors to shoreline erosion include river channeling, flow control and ship wakes, especially in shallow waters and during periods of low water levels. **The Seaway and some ship owners in the region are implementing best management practices to reduce shoreline erosion.** In spring 2021, the SLSMC launched a voluntary speed reduction program in four areas particularly sensitive to shoreline erosion along the Montreal to Lake Ontario section of the navigation channel. Reducing ship wakes should help to limit shoreline erosion and the associated impacts on local communities. In the same vein, CSL's O2 technology discussed in Section 2.1.1.1 is programmed to reduce vessel speed in four areas sensitive to shoreline erosion between Montreal and Sorel.

CLIMATE CHANGE ADAPTATION AND RESILIENCE: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

In terms of climate adaptation and resilience in the maritime industry, port infrastructure vulnerability should be prioritized. Assessing the sustainability, resilience, and adaptability of existing port assets and designing new sustainable, adapted, and resilient port infrastructure through a risk-informed and multi-criteria-based framework is crucial.

As for GHGs, investments by the maritime industry and governments in risk assessment studies to understand, prepare for, and adapt to the potential impacts of climate change are critical to ensure the perennity and sustainability of the Seaway and port infrastructure. Canadian and U.S. government agencies could coordinate their approach to support ports and the Seaway in this process.

There is ongoing research in the St. Lawrence River region to assess and understand the impact of commercial ship wakes on shoreline erosion, a natural phenomenon also amplified by climate change. The results and recommendations of these studies will hopefully inform how the industry can adapt further to reduce its impact on shorelines and coastal environments. Meanwhile, raising awareness and encouraging adherence to voluntary slowdowns in areas sensitive to shoreline erosion in the region is certainly one of the best ways to limit this impact.

3. Climate adaptation refers to "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change." Source: United Nations (https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean).

4. Climate resilience refers to the "ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate." It involves providing knowledge and information about improving ecosystems' health as well as "assessing how climate change will create new, or alter current, climate-related risks, and taking steps to better cope with these risks." (https://www.cleanwateraction.org/features/water-infrastructure-great-lakes#:~:text=Water%20and%20wastewater%20infrastructure%20challenges,health%20of%20the%20Great%20Lakes).

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.4 VESSEL INCIDENTAL DISCHARGES

The U.S. EPA (2020) lists 20 sources of specific discharges that are incidental to the normal operation of a vessel, including boilers, greywater systems, decks, ballast tanks, hulls and associated niche areas, exhaust gas emission control systems (i.e., scrubbers), and gas turbines, to name a few. Some of these features relate to aquatic invasive species (e.g., ballast tanks as well as hulls and associated niche areas with biofouling) and are discussed in Section 2.7.

Noteworthy actions undertaken to further reduce incidental discharges in the region's MTS are described here. **Many ship owners now have a modernization program for oily water separators aboard their vessels** as well as all related control and verification equipment applicable to new-builds or vessels undergoing major modifications. Some have also implemented an **integrated bilge-water treatment system (IBTS)** such as defined in the IMO's revised guidelines (MEPC.1/Circ.642, 12, Nov. 2008), or follow a similar approach. An IBTS separates fluids at source and significantly reduces the volume of oily water to be treated.

CSL has adopted a zero-discharge policy in marine protected areas and is a leader in Eastern Canada with respect to reducing incidental discharges. Its O2 digital technology (see Section 2.1.1.1) ensures that oily water separators are disabled while navigating in sensitive and protected areas to avoid discharging effluent (containing ≤ 1 ppm of oil). In addition, CSL has installed protective devices (e.g., white and blue boxes) throughout its fleet to guard against the discharge of oily water. The company ensures onshore treatment of black water from its Trillium class ships. Its vessels are also fitted with dust suppression devices and fully enclosed or covered booms to prevent dissemination. Eight of the vessels also have with water-lubricated stern tubes that eliminate the need for maintenance oil.

Fednav ensures that oily water separators are not in use in protected and sensitive areas. The ship owner has installed protective devices (e.g., white boxes) throughout its fleet to guard against the discharge of oily water and uses biodegradable oil or oil-free lubricants in stern tubes and bow thrusters on all vessels.

Groupe Desgagnés has fitted its vessels with water-lubricated stern tubes and water seals, and only uses biodegradable oils.

Nearly all Interlake Steamship Company vessels are equipped with water-lubricated stern tubes and/or strut bearings. Its imminent new build, the M/V Mark W. Barker, will also be equipped with hydraulic equipment that will only use environmentally acceptable lubricants.[xxxi] It will also be equipped with large MacGregor hatches, ensuring cleaner loading and less cargo spillage onto decks, as well as a cargo unloading boom washdown system to reduce cargo dust.

VESSEL INCIDENTAL DISCHARGES: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

Improving and maintaining the water quality of the Great Lakes and St. Lawrence River, one of the world's largest freshwater ecosystems, will always remain a priority. All ship owners should manage and limit oily discharges incidental to ship operations.

Short-term actions to raise awareness, train crew, and further encourage ship owners to adhere to best management practices to eliminate incidental discharges would help the industry further reduce water pollution risks. Actions to prioritize by ship owners in upcoming years could include implementing an IBTS on new-builds and adopt a similar approach on existing vessels, adopting a modernization program for oily water separators including all related control and verification equipment, avoiding the discharge of treated bilge water in sensitive areas and/or adopt a zero-discharge policy, and to eliminating oil-to-water interfaces wherever feasible.*

Longer term advancements could foster stewardship and collaboration between port reception services and/or pump and haul-out providers and their customers and facilitate user feedback with the equipment manufacturers and suppliers.

** See Green Marine's Oily Discharge Performance Indicator for more detail on best management practices and additional actions ship owners can take to improve its environmental performance:* https://green-marine.org/certification/scope-and-criteria/

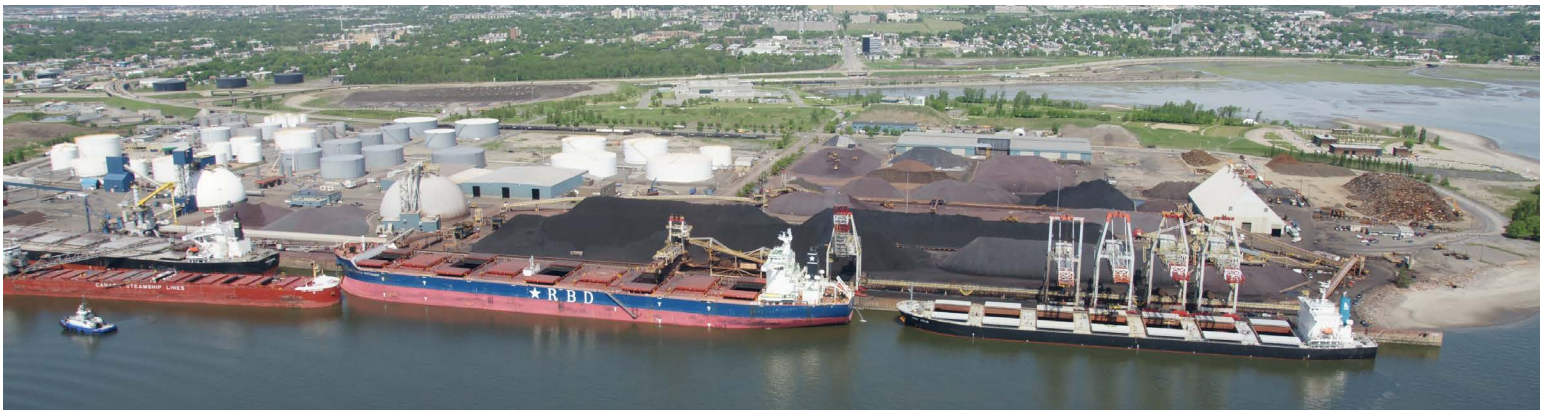
2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.5 SPILL PREVENTION AND STORMWATER MANAGEMENT

In ports, point source and diffuse release of oil and chemical products can result from equipment and machinery leaks and spills. The risk of accidental discharges reaching the water can be significantly reduced by adopting pollution prevention, preventive maintenance, and stormwater management plans, as well as by raising awareness on best environmental practices and implementing adequate treatment technologies. Port authorities and terminal operators in the region have greatly reduced the risk of accidental discharges by these means.

Port authorities, terminal operators and stevedoring employees are increasingly aware of the environmental risks of accidental discharges of hydrocarbons, chemicals, and other potentially toxic products. More stringent regulations, as well as the implementation of voluntary best management practices, also mitigate the risk of accidental discharges to land and water during port-related operations.

One best practice example is QSL's improved waterway protection equipment that is deployed when unloading bulk vessels. These automatic retractable deflectors (patent pending) act as an ultimate protection against unlikely product spills through the narrow areas between the vessel and the dock. Many companies also have spill kits and booms on site as an emergency containment measure in the event of a spill during operation.



SPILL PREVENTION AND STORMWATER MANAGEMENT: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

Spill prevention measures and adequate stormwater management also result in maintaining the water quality of the fragile and rich aquatic ecosystems of the Great Lakes and St. Lawrence River.

*Short-term actions that can provide quick returns include regularly raising awareness and training employees on the use of spill kits, proper clean-up procedures and spill reporting for minor spills. Another essential step is to identify site-specific potential pollution sources (e.g., port areas, equipment, activities) and associated pollutants, as well as to develop, adapt, and implement preventive measures. A third short-term action would be to adapt stormwater management practices to ensure adequate stormwater treatment where appropriate on port territory, as well as treatment system maintenance and water quality monitoring procedures.**

For landside operations in ports, the regulatory requirements in the U.S. vary among states but are far more stringent overall than Canadian and provincial regulations when it comes to stormwater management. A longer-term action could be to do an in-depth analysis of the different regulatory frameworks and identify gaps and areas for improvement and to then develop a holistic, binational approach to align and advance stormwater management by ports and terminal operators by establishing harmonized stormwater quality standards for the region's MTS.

Pollution remediation through RD&D projects to develop affordable green infrastructure adapted for ports to help control stormwater flow and to treat stormwater to some degree is another area of improvement that could be incentivized by government agencies.

** See Green Marine's Spill Prevention and Stormwater Management Performance Indicator for more detail on best management practices and additional actions ship owners can take to improve its environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.6 MARINE MAMMALS

Ships pose certain risks to marine mammals, namely through collisions and underwater radiated noise. Collisions with ships can be fatal to marine mammals, and the likelihood of the collision being fatal is known to increase with vessel speed. Underwater noise generated by ships and port operations, maintenance and construction activities can affect the behavior and movement of marine mammals.

Many ship owners and ports operating in the St. Lawrence Estuary and Gulf have been proactive in minimizing their impact on marine mammals in those waters, by **implementing best management practices** and **raising awareness**, or by **participating in voluntary measures and research projects to gain knowledge on the issue of underwater noise.** Some companies have also adopted a **Marine Mammal Management Plan** to reduce the potential adverse effects of vessels, especially within known sensitive marine areas.

Many local ship owners navigating the St. Lawrence also **adhere to the Canadian government's voluntary slowdown and/or lateral displacement measures and/or suggested avoidance areas in specific zones of the St. Lawrence Estuary and Gulf.** These measures help to protect endangered species, such as the beluga whale, blue whale, and North Atlantic right whale, by reducing both underwater noise and the risk of collisions. For example, CSL's O2 technology discussed in Section 2.1.1.1 is programmed so that ships reduce their speed in sensitive and protected marine areas. In 2020, Desgagnés has made the new federal voluntary slow down measure in Cabot Straight mandatory for its fleet.

A common way to further reduce underwater noise is through **regular hull cleaning and propeller blade maintenance**, which is a measure adopted by many ship owners operating in the St. Lawrence River. CSL is working on installing a cavitation monitoring system to better manage underwater noise in sensitive areas. In 2020, Canfornav installed hydrophones on some vessels to record the noise levels produced by vessels. Using a software called Dolphin Ear to process the recordings, the company's goal is ultimately to determine what improvements can be made to reduce the noise levels.

In Western Canada, the Vancouver Fraser Port Authority led the way for the maritime industry in North America to understand the effects that anthropogenic underwater radiated noise has on marine mammals with its ECHO (Enhancing Cetacean Habitat and Observation) program.

On the other side of Canada, in the St. Lawrence Estuary, the Marine Acoustic Research Station (MARS) Project was recently launched by the Institut des sciences de la mer de Rimouski (at the Université du Québec à Rimouski), Innovation maritime, the Institut maritime du Québec, Multi-Électronique (MTE) Inc., and OpDAQ Systems. In spring 2021, a new world-class acoustic station will be deployed in the middle of the Seaway off Rimouski, which is a habitat known for its diversity and abundance of marine mammals. In the project's first phase, the data collected will determine the noise signature of participating ships (e.g., ships owned by CSL, Fednav, Groupe Desgagnés, and Algoma). The research will help to determine the origin and the level of noise generated by those ships, which will lead to the development of new technologies, quieter vessel designs, and operational practices that produce less noise.

Unsplash – Hanna Oberstetter

In addition, Transport Canada has convened an Underwater Vessel Noise Source Reduction Targets (UVNSRT) working group. Comprised of experts across technical disciplines and backgrounds, the working group's challenge is to develop recommendations on feasible source noise reduction targets for vessels or fleets by summer 2022.

Additionally, **shipping companies as well as ferry, cruise and tug/barges operators now have crew members trained to actively collect valuable marine mammal observation data along their routes** (e.g., CSL, Fednav, Transport Desgagnés, NEAS, Oceanex, Algoma, STQ, Marine Atlantic Inc., Croisières AML, Groupe CTMA, and Atlantic Towing). Together they collect thousands of data points each year that, in addition to assisting scientific research, contribute to gaining knowledge on the distribution and migration patterns of marine mammals. Quebec ship owners also worked with the World Wildlife Fund Canada, the Marine Mammal Observation Network, the Shipping Federation of Canada, and other partners to develop an online tool to train mariners to identify marine mammals and collect whale observation data following a common protocol. The training tool is now available online in English and French. An online application is also being developed to facilitate data collection, with the information made public on the St. Lawrence Global Observatory website.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

MARINE MAMMALS: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

It is undeniable that underwater noise affects marine mammals; however, there is limited information available on the level and source of noise generated by individual ships and port activities and, consequently, where efforts should be put to reduce that noise. This relatively new environmental issue has been given more attention in recent years, and several research projects have been approved or are currently under way to help address it, including some projects in the St. Lawrence and Saguenay rivers.

*Until recommendations for the maritime industry arise from current research projects, various measures can be implemented by the industry. Some meaningful short-term actions include adhering to all voluntary measures along the Estuary and Gulf of St. Lawrence (slowdowns, rerouting, and avoidance areas), incorporating applicable quiet vessel technologies during retrofits and/or construction of new vessels, and monitoring underwater noise with hydrophones (e.g., construction, dredging, vessels). Additional measures and practices to raise awareness, help reduce noise and encourage participation and collaboration in research activities can also be implemented.**

Governments could focus on developing smart shipping solutions to better target and manage voluntary measures. For example, the Canadian Coast Guard Marine Communications and Traffic Services could inform international ship owners about voluntary measures in a similar manner to the way they communicate mandatory measures (e.g., via NAVWARN or voice communication to vessels at specified times: before entry into Canadian waters and when vessels are about to enter areas where a voluntary measure is in place).

As outcomes of the MARS project, Transport Canada's UVNSRT working group, the ECHO Program, or others become available, a medium-term goal for ship owners and ports could be to set underwater noise reduction targets and develop an action plan to meet these targets. A longer-term goal for government agencies could then be to develop and implement programs to incentivize ship owners to upgrade or renew their fleet with quieter technologies or hull designs. Government agencies could also provide financial support in the form of research grants to encourage new research, development and demonstration projects aimed at reducing the impact of commercial shipping on marine mammals.

** See Green Marine's Underwater Noise Performance Indicators for ship owners and ports for more detail on best management practices and additional actions ship owners and ports can take to improve their environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2.7 AQUATIC INVASIVE SPECIES

Aquatic invasive species refer to foreign species that, in the absence of their natural predators, can out-compete native species and unbalance ecosystems. Aquatic invasive species can negatively affect biodiversity, water quality, and habitat conditions, among other elements. Human health and economy are also affected, as some aquatic invasive species are vectors for disease, while others reduce opportunities for recreation, damage infrastructure, reduce fishery and aquaculture productivity, and can lead to trade restrictions.

The zebra and quagga mussels, the bloody red shrimp, and the Chinese mitten crab are examples of aquatic invasive species that have caused great harm to the Great Lakes St. Lawrence region's environment and economy. The most well-known impacts are in the Great Lakes. The zebra mussel alone is estimated to have had a total economic impact ranging between $3 billion and $7.5 billion in the Great Lakes region as of 2004.[xxxii]

In the context of the maritime industry, aquatic invasive species are primarily introduced and spread in two ways: through ballast water discharge and biofouling. Ballast water has received a lot of attention since the introduction of zebra mussels in the Great Lakes in the early 2000s. Ballast water is now regulated in Canada since 2017 under the IMO's and, *Convention for the Control and Management of Ships' Ballast Water and Sediments*, and since 2018 in the U.S. under the *Vessel Incidental Discharge Act*. In addition, the Seaway corporations implemented a Ballast Water Exchange and Testing Program in 2006 to help prevent aquatic invasive species from the unmanaged discharge of foreign ballast water from entering the Great Lakes St. Lawrence River system. Since then, there has not been a new type of non-native species attributed to ballast water reported in the Great Lakes.[xxxiii]

Biofouling, however, is not regulated in the U.S. or Canada. Ships can be a vector of aquatic invasive species as organisms attached to the underwater or wetted surfaces of vessels (e.g., the hull, submerged equipment, mobile apparatus) can be transferred from their natural environment to a new one. **Most ship owners in the region's MTS are already implementing one to several measures to reduce the risks of introducing and spreading aquatic invasive species through biofouling.** However, tested and approved effective autonomous underwater hull grooming and cleaning capture technologies to manage biofouling are not yet available for ship owners.

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

AQUATIC INVASIVE SPECIES: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

*Unlike ballast water, there is currently no Canadian, U.S., or IMO regulation on biofouling. Regardless, ship owners can effectively manage biofouling by implementing the following best management practices over the short-term to help prevent the growth of aquatic organisms on submerged or wetted surfaces of vessels, and thereby reduce the risk of introducing and spreading aquatic invasive species in the Great Lakes and St. Lawrence River:**

- *Apply environmentally friendly anti-fouling paint or other coatings with effective lifespan*
- *Select biofouling resistant materials for pipes and unpainted equipment and apparatus*
- *Conduct regular inspection and cleaning of hull and other submerged surfaces*
- *Use Marine Growth Prevention Systems to prevent aquatic organisms from settling in internal or niche areas (e.g., sea chests, propeller thrusters, keels and rudders) using electrolysis through copper, aluminum and iron anodes.*

However, RD&D is necessary to be able to better address this issue. Government and ship owners should invest in this area to develop, for example, environmentally friendly coatings (no release of microplastics or other chemicals deleterious to the aquatic environment), autonomous underwater hull grooming and cleaning capture technologies, as well as coordinated U.S. and Canadian permitting and policies that would allow such advancements.

** See Green Marine's Aquatic Invasive Species Performance Indicator for ship owners for more detail on best management practices and additional actions ship owners can take to improve their environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2.8 WASTE MANAGEMENT

This section focuses on the waste produced during vessel and port operations, such as compostable waste, recyclables, trash and dunnage, but excludes construction waste.

The space aboard commercial vessels is often limited and storing waste in a compact, safe way for later disposal is frequently a challenge. Since 2013, the MARPOL prohibits the discharge of any garbage at sea (with only a few exceptions that apply under specific conditions). Under Annex 5 of the International Joint Commission's 2012 Great Lakes Water Quality Agreement, garbage discharge is also prohibited in the Great Lakes.

A few ship owners in the region have implemented several best management practices to reduce, reuse, and recycle onboard waste, thereby minimizing the volume of ultimate waste[5] produced. **A few port authorities and terminal operators also apply best management practices based on the 3RV principle** (reduce, reuse, recycle, and valorize). **Waste audits, waste management plans,** and **action plans with waste reduction targets** have also been carried out or developed by some ship owners, port authorities and terminal operators in the region.

Circular economy projects are also slowly gaining more popularity in the region. Circular economy can be defined as «a system of production, exchange and consumption that aims to optimize the use of resources at all stages of the life cycle of a good or service, in a circular logic, while reducing the environmental footprint and contributing to the well-being of individuals and communities.»[xxxiv] The principle is simple: it involves turning existing waste into a source of material for a new purpose, thereby reducing waste generation, the consumption of raw resources, as well as the use of water and energy sources.

A few noteworthy leadership examples in the Great Lakes St. Lawrence region are listed below.

2.8.1 SHIP OWNERS

Groupe Desgagnés achieved Recyc-Québec's ICI ON RECYCLE ('Here We Recycle') certification for eight vessels. The program acknowledges significant waste management efforts. The M/V Bella Desgagnés passenger vessel has been certified with an overall 85% reclamation rate of residual material since 2015 and the aim is to achieve zero-waste at landfill by or before 2024. The Desgagnés head office in Quebec City, and its subsidiary offices, Petro-Nav in Montreal and Transarctik in Sainte-Catherine, Quebec, have also been certified for their waste management and reduction efforts with Elite to Performance plus levels.

CSL has committed to gradually remove incinerators from its fleet to eliminate the resultant air emissions and to instead focus efforts on recycling and composting food waste. So far, 14 out of 16 incinerators have been removed/decommissioned from its Canadian fleet. In 2021, CSL officially joined the IMPA SAVE program - Getting to Zero Project[xxxv] that aims at reducing the use of plastic drinking bottles onboard ships by 2025.

5. Waste that cannot be further processed as it contains no more reclaimable materials

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.8.2 PORTS AND THE SEAWAY

The **Quebec Port Authority has achieved the *ICI ON RECYCLE* certification** that acknowledges significant waste management efforts. The port now has a comprehensive waste management plan accompanied by an action plan setting goals and specific reduction targets for upcoming years.

Water and shoreline garbage removal initiatives, such as the Great Lakes Plastic Cleanup, are slowly gaining popularity in the region. The Quebec Port Authority organized a successful shoreline cleanup activity in 2019 with its employees and tenants as well as a scuba diving cleanup activity of Bassin Louise. The Quebec Port Authority and PortsToronto have installed Seabins as part of the Seabin Project. This project is a worldwide comprehensive research, technology, and educational initiative aimed at removing floating waste such as microplastics from aquatic environments such as port waters. To date, the project has deployed 860 Seabins worldwide, collecting more than 3,600 kilograms of waste daily, for a total exceeding 2 million kg as of July 2021 since the project's inception.[xxxvi]

In 2019, the Quebec Port Authority worked in collaboration with the *Conseil régional de l'environnement (CRE) de la Capitale nationale*, the Englobe engineering firm, and the City of Quebec on a circular economy project. The project consisted of mixing the city's excavation debris with locally produced compost from residential organic waste to produce quality soil for landscaping purposes around a new parking lot at the Port of Quebec.

WASTE MANAGEMENT: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

Despite the efforts made so far by the maritime industry in the region to improve waste management, further reduction of the volume of waste generated and diversion of waste from incinerators and landfill sites would be required to significantly reduce the impact of the industry. It will actually take a profound change in each and everyone's organizational culture to significantly reduce the industry's impact and go beyond basic recycling.

Three short-term actions that all maritime industry stakeholders should consider implementing include to first integrate the 3RV principle (reduce, reuse, recycle, and valorize) into the culture of their organization. Proper waste management through application of the 3RV principle can often result in cost savings. The second and third recommended actions are to carry out annual waste inventories (i.e., total volumes) and characterizations (i.e., identification of waste types), and to develop a Waste Management Plan with reduction targets, reuse/recycling/valorization targets, and sustainable purchasing practices. Green Marine's program provides a roadmap with additional measures to reduce the volume of waste produced onboard ships and in ports through a series of concrete actions and best management practices.*

Over the longer term, better coordination with ports and government agencies to facilitate ship waste management upon arrival at berth needs to be addressed. Without adequate shoreside reception facilities in ports and coordination of transport to waste, recycling, composting or valorization facilities, optimized ship waste management is not possible. This is especially problematic with waste generated onboard ships crossing international borders.

** See Green Marine's Waste Management Performance Indicator for more detail on best management practices and additional actions the industry can take to improve its environmental performance:* https://green-marine.org/certification/scope-and-criteria/

2) SURVEY OF MARITIME TRANSPORTATION ENVIRONMENTAL BEST PRACTICES AND NEW TECHNOLOGIES

2.9 COMMUNITY IMPACTS OF PORT OPERATIONS

Port operations can have an impact on the surrounding community through the generation of air, noise and light pollution, as well as odors and traffic/congestion issues. The Green Marine program includes numerous best management practices to reduce these impacts that are implemented by most port authorities and some terminal operators and shipyard managers in the region. This section rather focuses on a few noteworthy examples of technologies and best management practices that can significantly reduce some of these impacts and allow port authorities to react quickly when problems arise.

A few port authorities located in urban areas of the region are now conducting real-time monitoring of noise levels, dust emissions, and air quality to rapidly detect anomalies and apply corrective measures accordingly (e.g., the Quebec Port Authority, the Trois-Rivières Port Authority). The Trois-Rivières Port Authority recently worked in collaboration with the Seti-Media firm of data specialists to deploy an environmental monitoring network at the interface between the port site and the surrounding community. The network includes cameras and monitors that measure air quality (including dust and PM_1 to PM_{10}), noise levels, vibrations, as well as weather indicators. The synchronized data collected helps to determine the origin of emissions. These tools facilitate the port authority's thorough understanding of its impacts on the local community, as well as conduct effective preventive monitoring, and rapidly implement corrective measures as required.

Terminal operators handling bulk cargo may have to deal with the dust emissions generated during the loading or unloading of some products at their storage facilities.

Some terminal operators in the region, such as Glencore, have invested heavily to monitor and reduce dust emissions. Since 2013, Glencore has invested close to C$55 million at its terminal in the Port of Quebec to continuously reduce the fugitive dust emissions generated by its operations. Numerous improvements have been made, including to the loading and

unloading facilities, conveyor system and standard operational procedures. Dust control measures with the aid of dust suppression systems, as well as real-time air quality monitoring and sampling, are carried out. The company is also participating in research projects in 2021 and onward to develop specialized equipment to empty cargo holds while the holds remain closed to further reduce dust emissions. QSL and the Quebec Port Authority have also invested in the installation of dust suppressors using water at the Beauport site.

COMMUNITY IMPACTS OF PORT OPERATIONS: OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE

Several ports and terminal operators in the region have already implemented some measures and practices in problematic areas to help reduce their impacts on the surrounding local community. At minimum, all ports, terminal operators, shipyards, and the Seaway should develop and implement a Nuisance Mitigation Plan for construction work and regular operations that includes all relevant best management practices and mitigation measures to reduce the impacts of noise (e.g., use lynx alarms, strobe lights at night, sound screens, and limit idling), dust emissions (e.g., use dust suppressants such as water, cover piles, use closed conveyors), light (e.g., limit lighting to where necessary, optimize lighting), odor (e.g., adequate housekeeping practices, provide covered garbage and recycling bins/containers in appropriate locations), and traffic (e.g., procedure to limit congestion using signboards, a traffic coordinator or checker). For ports, mitigation measures should also be systematically part of all service contracts and should be communicated to tenants.*

Another relevant short-term action for ports could be to install digital instruments in critical areas to do real-time monitoring of air quality (including dust emissions) and noise levels. Such real-time data allows port authorities to react promptly to problematic situations.

** See Green Marine's Community Impacts Performance Indicator for more detail on best management practices and additional actions ports, terminals, shipyards, and the Seaway can take to improve their environmental performance:* https://green-marine.org/certification/scope-and-criteria/

3) EXISTING GOVERNMENTAL ENVIRONMENTAL PROGRAMS IN CANADA AND THE U.S.

This section briefly describes the main policies and programs implemented by the U.S. and Canadian federal governments, as well as by the Quebec's provincial government.

3.1 FEDERAL PROGRAMS IN CANADA

The first two Canadian examples aim at incentivizing sustainable shipping by supporting the maritime industry's efforts to reduce its environmental footprint, while the other Canadian programs support RD&D through investments in research and green technology.

3.1.1 DUTY REMOVAL

One of the most effective initiatives for the Canadian Great Lakes St. Lawrence fleet was Canada's removal in 2010 of the 25% duty on foreign built vessels. This change was the main stimulus for the ongoing fleet renewal by the major Canadian carriers in the region. The early replacement of the oldest and most inefficient ships with new vessels of higher load-capacity and more efficient technologies led to expectations of a 40% reduction in fuel consumption per tonne-km of bulk cargo transported. Ongoing replacements of somewhat newer vessels are expected to result in energy efficiency improvements of 30%.

Overall, the huge role that the removal of the Canadian duty had in spurring Canadian fleet renewal is a major success story for the industry. Further removal of disincentives and/or the introduction of affirmative incentives could yield significant further progress, especially in the U.S.

3.1.2 NATIONAL TRADE CORRIDORS FUND (NTCF)

The National Trade Corridors Fund (NTCF) is a C$2.3 billion merit-based program designed to help infrastructure owners and users invest in the critical assets that support economic activity in Canada. One key objective supported by the NTCF is to improve the fluidity and/or performance of the transportation system, which often has a direct impact on reducing energy consumption and emissions.[xxxvii] To date, the NTCF has invested CA$443 million in 27 marine sector projects across Canada. A few noteworthy examples of projects supported by the fund include:

- West Coast Supply Chain Visibility Program – Vancouver Fraser Port Authority and Prince Rupert Port Authority (see Section 2.1.1.3)
- Short Sea Shipping - Concept Development for Vancouver Fraser Port Authority
- Optimization of the Port of Montreal Intermodal Network
- Terminal 21 Construction Project at the Port of Trois-Rivières.

3.1.3 NATIONAL RESEARCH COUNCIL OF CANADA (NRC)

The National Research Council (NRC) supports business innovation and the science agenda of the Government of Canada. NRC's Oceans Program has as its goal to advance the Ocean Supercluster[6] and Canada's blue economy by supporting the development of technology to improve ocean health. Its four theme areas are: 1) Coastal Resilience: to study and mitigate the impacts of climate change on Canada's coasts and rivers; 2) Intelligent Marine Assets: to facilitate the development of the next generation marine technologies; 3) Pollution Remediation: to remove ocean pollutants such as microplastics, oil spills and underwater noise; and 4) Bio Assets: to improve ocean monitoring and produce value-added products from bio-resources.

NRC's assistance ranges from a fee-for-service of NRC specialists to financial assistance for small and medium-size enterprises with awards of up to C$150,000 to prove the feasibility of proposed solutions, and up to C$1 million to build a prototype if a technology is deemed feasible.

3.1.4 SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA (SDTC)

Sustainable Development Technology Canada (SDTC) is an independent federal foundation that provides seed funding of C$50,000 to $100,000 for the development and demonstration of new environmental technologies. Since its inception, SDTC has invested more than C$1.28 billion in 450 companies. Two marine-related companies have received SDTC assistance: 1) CryoLogistics for the development of a modular CO2-cooled shipping container that reduces diesel use and food spoilage in the refrigerated supply chain; and 2) Global Spatial Technology Solutions, which is an artificial intelligence company in the maritime sector that collects and processes multiple data sets to save lives, energy and the environment by reducing fuel use, emissions, as well as the risk of ship groundings and collisions.

3.1.5 TRANSPORT CANADA'S MARINE SECTOR PROGRAMS

Transport Canada's Marine Sector Programs that are relevant to the environment are summarized in Table 1. In addition, Transport Canada's Innovation Centre is a transportation innovation RD&D organization that supports emerging transportation technologies to help ensure Canadians can benefit from a safe, secure, clean and integrated transportation system. The Innovation Centre's Marine RD&D focuses on two pillars: 1) advancing clean marine technologies; and 2) improving the understanding of underwater noise generated by vessels.

6. Ocean Supercluster members, other government departments, industry (including small, medium and large enterprises), not-for-profits, Indigenous organizations and academia.

3) EXISTING GOVERNMENTAL ENVIRONMENTAL PROGRAMS IN CANADA AND THE U.S.

TABLE 1 TRANSPORT CANADA PROGRAMS RELEVANT TO MARINE AND THE ENVIRONMENT

MARINE	
Contribution Program for the Centre of Excellence for the Marine Transportation of Oil and LNG	Funds the center's research and promotion of best practices for transporting oil and LNG by water. Planned spending was C$1.49 million.[xxxviii]
Quiet Vessel Initiative	Looks at ways to help researchers and designers improve their knowledge so that they can reduce vessel noise. Planned funding C$26 million over 5 years.[xxxix]
ENVIRONMENTAL	
Transportation Assets Risk Assessment Program	Funds projects that assess risks and vulnerabilities of federal transportation assets, including those managed by ports authorities, related to climate change. Funding information is unavailable.[xl]
Shore Power Technology for Ports	Funds marine shore power technology, local electrical grids, and Canadian ports. The program provides up to 50% of the funding for implementing marine shore power technology at Canadian ports. Total funding of C$19.5 million has been provided to more than 7 ports.[xli]
Clean Transportation System – Research and Development Program	Funds projects aimed at reducing air pollutants and GHG emissions in the aviation, marine and rail sectors. Annual funding of up to C$100,000 per project (representing up to 50% of expenditures) and up to C$600,000 for the total program.[xlii]

Source: Transport Canada website (https://tc.canada.ca/en/programs)

Note: Information available on Transport Canada's webpage includes programs targeting other modes of transportation. It is evergreen and constantly provides updated information on all funding and non-funding programs.

3.2 PROVINCIAL PROGRAMS IN CANADA

The most successful programs by the Province of Quebec to incentivize green shipping are described in this section. No similar programs were found in the Province of Ontario. However, Ontario has ordered two electrified ferries (for Wolfe Island and Amherst Island service) with the Government of Canada covering up to one quarter of the estimated C$125 million cost.[xliii] The GHG savings projected over the 60-year lifespan of the ferries is 446,000 tonnes of CO2.)

PETMAF and PREGTI resulted, respectively, in the Quebec government investing CA$31.42 M and CA$8.7 M in the maritime industry between 2013 and 2021. The grants awarded were catalysts (leverage effect) allowing the Quebec maritime industry to invest a total of CA$178 M over the last eight years in projects to improve efficiency and reduce GHG emissions. The PETMAF program has recently been renewed for five more years (2021-2026) with a total budget of CA$40.1 M.

Since 2006, the Quebec government has adopted Climate Change Action Plans (CCAP 2006-2012 and 2013-2020) and, more recently, a new electrification and climate change policy framework (Plan for a Green Economy 2030 - a roadmap for the next 10 years). The set targets aim to reduce the province's GHG emission by 37.5% by 2030 as compared to 1990 levels. The 2013-2020 Action Plan, through the Electrification and Climate Change Funds (replacing the Green Funds since November 2020), financed various programs developed to help achieve the goal, two of which involve the maritime industry:

- A government assistance program to improve the efficiency of maritime, air and rail transport (PETMAF is the French acronym for *Programme d'aide à l'amélioration de l'efficacité du transport maritime, aérien et ferroviaire*[xliv]) by using more efficient transport equipment as well as equipment low GHG energy emitting sources, and
- A program to reduce or avoid GHG emissions through the development of intermodal transport (PREGTI is the French acronym for *Programme visant la réduction ou l'évitement des émissions de gaz à effet de serre par le développement du transport intermodal*[xlv]), which focuses on transporting goods and people by setting up intermodal projects and promoting maritime and rail services.

Examples of projects accepted to date under these two programs include several energy audits, electrification feasibility studies, shore power projects, construction of dual-fuel LNG tankers, modernization and/or purchase of new electric or hybrid equipment and machinery, and digital technologies such as real-time monitoring of machinery and equipment and real-time ship/tug fuel consumption surveillance systems. A news item in The Motorship refers to the role of the PETMAF program in the Groupe Desgagnés decision to include dual-fuel LNG capability in its new tanker, the M/V *Rossi A. Desgagnés*:

> "*Rossi A. Desgagnés* represents an investment exceeding C$50 million (US$37.2 million), of which almost C$9 million (US$6.7 million) is attributable to the LNG dual-fuel powering arrangements. The project has been supported by the Quebec Transport Ministry under the terms of its PETMAF initiative to foster improved transportation efficiency and reduced greenhouse gas (GHG) emissions. The scheme provides C$1,000 (US$744) per tonne of reduced or avoided GHG emissions, up to a maximum funding allocation of C$3 million (US$2.2 million)." [xlvi]

Overall, the projects carried out by the maritime industry under the PETMAF and PREGTI programs between 2013 and 2020, are estimated to have reduced GHG emissions on an annual basis by more than 65,000 tonnes of CO2 equivalent. PETMAF was renewed for another five years recently with a C$40 million budget.

3) EXISTING GOVERNMENTAL ENVIRONMENTAL PROGRAMS IN CANADA AND THE U.S.

3.3 UNITED STATES PROGRAMS

3.3.1 U.S. EPA PROGRAMS

The U.S. EPA is the lead federal agency for environmental regulations as well as initiatives to address climate change. U.S. EPA's programs most relevant to the region's MTS are its SmartWay program and its Ports Initiative.[xlvii,xlviii] The SmartWay program is focused on landside initiatives, including drayage activities, while the Ports Initiative includes both landside and vessel operations at ports.

The SmartWay program was launched in 2004 as a voluntary public-private program that:

- Provides a comprehensive and well-recognized system for tracking, documenting and sharing information about fuel use and freight emissions across supply chains
- Helps companies identify and select more efficient freight carriers, transport modes, equipment, and operational strategies to improve supply chain sustainability and lower costs for goods movement
- Supports global energy security and offsets environmental risk for companies and countries
- Reduces freight transportation-related emissions by accelerating the use of advanced fuel-saving technologies
- Has the support of major transportation industry associations, environmental groups, state and local governments, international agencies, and the corporate community.

The Ports Initiative's long-term goal is for U.S. ports to become global leaders in clean, efficient freight and passenger transportation. Through this initiative, the U.S. EPA supports efforts to improve efficiency, enhance energy security, save costs, and reduce harmful health impacts by advancing next-generation clean technologies, and practices at ports. The U.S. EPA also facilitates collaboration among the port industry, communities, and all levels of government to help ensure timely and effective infrastructure development.

The U.S. EPA also has several grant programs. The two most relevant to the region's MTS are discussed below.

3.3.1.1 DIESEL EMISSIONS REDUCTION ACT (DERA) NATIONAL GRANTS PROGRAM

The Diesel Emissions Reduction Act (DERA) Grants Program provides funding opportunities that have been used in conjunction with the U.S. EPA's Ports Initiative. Since 2008, a total of 152 DERA grants totaling US$148 million have been awarded for port-specific projects. An additional US$66 million was awarded through DERA to multi-sector projects that involve ports. Two examples of funding through the DERA National Grants Program are:

- The Port of Cleveland/Cuyahoga County Port Authority receiving a US$750,000 grant towards replacement of 1940's-era single-engine tugboats with new dual Tier 3 engine tugboats.
- The Northwest Seaport Alliance received US$782,482 to replace diesel-powered cargo-handling equipment with cleaner-running electric models.

3.3.2 MARITIME ENVIRONMENTAL AND TECHNICAL ASSISTANCE (META) PROGRAM

The Maritime Environmental and Technical Assistance (META) Program was established by the U.S. Maritime Administration - Department of Transportation (MARAD) to pursue maritime environmental RD&D projects in partnership with federal, state, and local agencies, the maritime industry, and the academic community with the goal of providing all stakeholders with useful information and insight on maritime environmental issues. The META program, in partnership with other agencies and entities, has addressed many environmental issues, including port electrification, biofuels, hydrogen fuel cell feasibility studies for ports, ferry and ocean-going vessel applications, LNG feasibility studies (including one for the Great Lakes), and air emissions reduction technology assessments.

3.4 KEY TAKEAWAYS

In Canada and the U.S., a few governmental programs **promote RD&D** in the maritime industry through investment in various RD&D projects, mostly aiming at tackling climate change, as well as reducing air emissions and the impact of the industry on marine mammals. Such investment is crucial to accelerate green shipping in the region's MTS. In Canada, Transport Canada's Clean Transportation System RD&D program, Contribution Program for the Centre of Excellence for the Marine Transportation of Oil and LNG, and Quiet Vessel Initiative are good examples of programs funding RD&D projects aimed at reducing GHGs, other air pollutants, as well as underwater noise. SDTC also funds marine-related RD&D projects aimed at reducing GHGs and other air emissions, as well as other environmental issues. In the U.S., MARAD pursues maritime environmental RD&D projects via its META Program, which supports projects aimed at reducing GHGs and other air emissions. MARAD has played a key role in funding feasibility assessments of alternative fuels in the maritime sector and could potentially be a source of funding for an assessment of the viability of shore power for Great Lakes ports that receive self-unloading vessels.

To advance and accelerate the transition toward cleaner and more environmentally friendly technologies for the maritime industry, **successful governmental programs focusing on marine mammal protection, clean marine technologies, but also on biofouling, smart shipping, climate resiliency, and pollution remediation should be created, maintained and/or renewed.**

Governmental **incentive programs** help to leverage maritime industry projects that reduce the industry's environmental footprint. Such programs in Canada include duty removal, the National Trade Corridors Fund, Transport Canada's Shore Power Technology for Ports Program, and Quebec's PETMAF program. In the U.S., DERA's National Grants Program also leverages maritime projects that, for example, aim at reducing air emissions and addressing climate change. These programs can provide significant support to the maritime industry's efforts to reduce GHGs and other air emissions. The EPA's DERA National Grants Program may even be used as a source of funding for a pilot project to improve the environmental performance of the U.S. Great Lakes fleet.

Based on the information found in the context of this study, the Government of Quebec PETMAF assistance program to improve the efficiency of maritime, air and rail transport appears to be a success story at the provincial/state level. This is a good example of a program that has funded several environmental initiatives within the province's maritime sector. It could inspire and serve as a model for similar programs in other provinces and states.

A detailed assessment of the success of the various aforementioned Canadian and U.S. programs in terms of return on investment would help to determine which ones should be maintained, renewed, and/or expanded, and/or replicated.

4) OPPORTUNITIES FOR INNOVATIVE FINANCING MECHANISMS TO FACILITATE INVESTMENTS THAT REDUCE THE ENVIRONMENTAL IMPACT OF THE MARITIME INDUSTRY

This chapter is organized into two sections: 1) initiatives being taken to increase awareness of and promote adherence to environmental goals; and 2) climate funding initiatives providing financing mechanisms available to pursue environmental goals.

4.1 AWARENESS INITIATIVES

Much of the focus in providing funding of sustainable projects/assets has been the development of criteria for what qualifies as sustainable. Some investors wish to have their funds only used for viable investments that also qualify as sustainable, environmentally friendly or climate mitigating (while still providing a return on investments). Clear criteria and transparency are required so that investors seeking to invest in sustainable or environmentally friendly ventures/assets can be assured that the investment vehicle being used is indeed following rigorous principles. Three such investment frameworks providing guidance relevant to the marine sector are 1) the Poseidon Principles, which largely address international shipping, 2) the EU Sustainable Finance Taxonomy Regulation, which addresses the European Union's domestic economy, including inland waterways; and 3) the Great Lakes Impact Investment Platform. The three frameworks are briefly described below.

4.1.1 POSEIDON PRINCIPLES

The Poseidon Principles establish a global framework to quantitatively assess and disclose whether financial institutions' lending portfolios are in line with climate goals set by the IMO, specifically a target trajectory of annual reductions in GHG intensity necessary to reduce total emissions by 50% by 2050 compared with 2008 levels. (Given the growth projections for international shipping, this corresponds to an 88% reduction in emissions intensity by 2050).

Launched in June 2019, the program has already had an impact. The program's 15 financing signatories have submitted the performance results of the shipping lines receiving loans.[xlix] Bhat and Mitchell (2021)[l] recently reviewed the Poseidon Principles report and interviewed some participants:

> "European signatories to the Principles have structured over US$1.2 billion in Poseidon-linked facilities that tie the cost of capital to GHG performance. The average reported alignment score is +1.2%, which means that the 2019 GHG emissions associated with signatories' shipping portfolios are on average 1.2% above the decarbonization trajectory set by the IMO. Individual scores ranged from –45% to +32%. The reporting financial institutions have tied the terms of their loans to the lender's GHG performance. As an example, the Antwerp-headquartered crude oil tanker company Euronav has secured a US$713 million loan package with specific emission requirements. Compliance over the first 12 months will be rewarded with a reduced interest coupon of five basis points."

The 5 basis points saving in Year 1 amounts to US$3.57 million.

4.1.2 EU SUSTAINABLE FINANCE TAXONOMY REGULATION

The European Union has developed a sustainable Finance Taxonomy Regulation. It establishes a classification system for domestic economic activities that can be considered as green for investment purposes, with the ultimate purpose of "aiming capital in that direction." For inland waterway vessels, it includes thresholds that must be met for companies to qualify to receive green loans. The proposed criteria is outlined in a spreadsheet-based taxonomy tool. The criteria presented for inland water transport vessels includes some very stringent components.[li] For example, vessels that are dedicated to the transport of fossil fuels or any blended fossil fuels are ineligible, even if they meet the efficiency criteria for marine vessels. The efficiency criteria for non-fossil-fuel transport vessels relate to EU's efficiency standards for heavy duty road vehicles (HDVs), more specifically: "Other inland waterway vessels are eligible if direct emissions per tkm CO2e emissions per tonne-kilometre (g CO2e/tkm) or per tonne nautical mile (g CO2e/tnm) are 50% lower than the average reference value defined for HDVs."[lii] The reference value for HDVs is set by government as a fleet-average emissions criterion for new-builds that is decreasing over time and is subject to ongoing revision.

4.1.3 GREAT LAKES IMPACT INVESTMENT PLATFORM

In collaboration with a multidisciplinary project team, the GSGP has developed the Great Lakes Impact Investment Platform to promote environmentally sustainable economic growth in the Great Lakes states and provinces. It features various investment products intended to deliver demonstrable environmental impacts while also aiming to generate competitive market-based financial returns. The Platform's goals include reduced emissions and nutrient inputs, and improved energy efficiency.

The Platform provides a framework to help maritime stakeholders access potential investors and track progress toward environmental goals. Maritime sector projects with a focus on energy efficiency and emissions reduction, for example, are being encouraged. Maritime could be added to the Platform's four existing themes: Forestry, Smart Water Systems, Agriculture, and Energy.

4.2 FUNDING INITIATIVES

Climate funding initiatives are gaining attention worldwide. The Organization for Economic Co-operation and Development lists 91 separate climate funding initiatives in a Climate Fund Inventory. However, none of the 91 listed programs is available to developed countries. Developed countries appear to have accepted that financing climate initiatives will be done via normal markets, or through green investment initiatives that depend on the type of awareness programs outlined in the previous section to verify the green attributes of the companies and/or projects under financial consideration.

4.2.1 RELEVANT FUNDING INITIATIVES

Nordic Investment Bank (NIB) is one example of a market-based financial institution with environmental criteria for its lending in the Baltic region and beyond. NIB is an international financial institution owned by Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway and Sweden. NIB lends to projects (mostly but not all to member countries) that foster:

- Pollution reduction
- Preventive measures
- Resource efficiency
- Development of clean technology
- Climate change mitigation.

4) OPPORTUNITIES FOR INNOVATIVE FINANCING MECHANISMS TO FACILITATE INVESTMENTS THAT REDUCE THE ENVIRONMENTAL IMPACT OF THE MARITIME INDUSTRY

NIB acquires the funds for its lending by borrowing on the international capital markets. Since 2008 the NIB has provided EUR 7.8 billion aimed at projects with a climate change mitigation component and EUR1.4 billion to projects with "positive effects on the Baltic Sea environment."

NIB is an example of governments collaborating to raise capital on the world stage and attaining favorable rates consistent with large public sector loans. NIB has used some of the bank's funds for government initiatives but has also funded specific private sector initiatives that meet public policy goals. In doing so, NIB is providing funds to the private sector at rates the private sector cannot attain by direct means. Whether more favorable rates are enough to motivate the Great Lakes St. Lawrence maritime's private sector to participate in public policy goals is unknown, but it is one possible approach to discuss with regional industry stakeholders.

Central Commission for the Navigation of the Rhine Findings: As noted in Section 2.1.1, the EU tasked the CCNR with exploring funding issues and solutions for the European inland waterways. In this section, the intermediate report for CCNR's Task A is addressed (i.e., the possible triggers and financial drivers to enable a positive investment decision by ship owners to invest in technologies contributing to zero-emission performance). The CCNR's key findings were:[liii]

- Only a very limited part of the IWT sector can finance the electrification of a vessel by its own means (existing capital and/or bank financing). There is a lack of financial capacity and incentives (i.e., the business case) do not currently exist to make greening the powertrain an economical choice for the ship owner/operator. There is no return on investment within the current framework conditions. It only adds costs that are paid by the clients (i.e., shippers/forwarders).
- One assessed possibility is to have vessel owners pay to retrofit vessels, and a new cleaner power/fuel source supplied on a pay-per-use basis by third parties that have raised the capital and made the larger investment.

National Australia Bank (NAB) is one noteworthy example of financial innovation that includes the NAB's sustainability-linked loans. The Port of Newcastle is the first Australian port to obtain such loans (equivalent to approximately US$399 million). Lower debt margins structured into these loans incentivize the port to meet targets set across a range of five social and environmental metrics.

4.2.2 BLUE BONDS

Blue bonds are a relatively new financial instrument. They differ from classic bonds in that they are issued on the promise to use the funds raised for specific green, climate and/or social purposes. Roth et al. (2019)[liv] provides an overview of the blue bond market in a paper funded by the International Union for Conservation of Nature (IUCN). The paper refers to the Seychelles government announcing the world's first sovereign blue bond in October 2018. The US$15-million blue bond was launched by the Republic of the Seychelles with a maturity of 10 years and an annual interest payment of 6.5%. In January 2019, NIB issued a US$200-million equivalent blue bond to protect and rehabilitate the Baltic Sea. These two bonds are similarly designed in that they include green bonds, as well as social and sustainability bonds.

While it is difficult to predict the direction the blue bond movement will take, Roth et al. (2019) discusses two conceptual approaches:

> "Blue bonds that finance broader sustainable blue economy strategies of issuers (whether Small Island Development States or other). This could happen under the form of a green, social or sustainability bond, always complemented by, and vetted against, the Sustainable Blue Economy Financing Principles;
>
> and/or
>
> Blue bonds that finance specific, narrowly defined impact transactions borrowing, in particular from the Climate Bond Initiative taxonomy and screening criteria. Examples would be transactions focusing on blue carbon habitats (blue carbon bond), marine environments (marine protection or marine energy bond), or blue natural capital compatible coastal infrastructure investments (blue natural capital bonds)."

In relation to the specific goals of climate change, Roth et al. (2019) notes that:

> "Climate change has provided an impetus to develop new bond financing solutions. An early example of a climate change-focused taxonomy has been provided by the Climate Bond Initiative (CBI). It is applicable to blue bonds targeting investments in the areas of marine energy, water infrastructure, specifically including coastal conservation and restoration activities. Importantly, the CBI refers to work done by IUCN and others in terms of quantifying the climate mitigation (blue carbon) effect of such activities."

DLA Piper[lv] provides a brief overview of blue bonds in which it is concluded that the bonds can achieve strong financial returns, while contributing to meaningful environmental and social impacts on ocean-related economies.

> "Multilateral development banks have always led the way in supporting sustainable finance and it is expected that they would play a significant role in facilitating blue bonds issuances. As has been the case with other environmental, social and governance (ESG) labelled bonds, it is likely that the investment community will eagerly adopt blue bonds into the suite of sustainable finance products, driving greater investment into ocean economies, and supporting the health of our oceans."

www.portofnewcastle.com

4) OPPORTUNITIES FOR INNOVATIVE FINANCING MECHANISMS TO FACILITATE INVESTMENTS THAT REDUCE THE ENVIRONMENTAL IMPACT OF THE MARITIME INDUSTRY

4.3 KEY TAKEAWAYS

Transparency and incentive-based funding mechanisms such as those monitored by the Poseidon Principles show initial promise and should be monitored for ongoing effectiveness in attaining GHG reduction goals. While the Great Lakes St. Lawrence maritime sector is relatively small, the need for funds to meet GHG reduction goals will elevate the capital demands, and a structure that documents progress and offers incentives for meeting goals might be relevant. Such a program could be offered in isolation or might be more efficient and effective if it included the funders of companies in other competing modes that are seeking the same or similar goals.

Direct government incentives and market-based measures (such as carbon pricing) can also be used as alternatives or undertaken in concert to encourage private industry to invest in meeting public sector goals. In assessing the alternatives, it is important to recognize the need for harmonized measures across borders and across modes to ensure a level playing field is maintained. With a level playing field, modal competitive balance can be maintained, and shippers will bear the final costs. From both a carrier and shipper perspective, it is important to consider any distortions in the global playing field. For the Great Lakes St. Lawrence, steel industries and agriculture are the largest sectors affected by Great Lakes St. Lawrence domestic maritime sector costs. Shippers and/or government can also take an active role in risk mitigation. For example, the Canadian Wheat Board demonstrated a long-term commitment to the Great Lakes St. Lawrence maritime sector by purchasing one of several new Equinox vessels that Algoma Central Corporation ordered and contracting with Algoma to operate the vessel.

Green financing mechanisms are relatively new in the maritime sector. The brief overview presented in this report highlights a few promising awareness and funding initiatives but does not provide sufficient basis on which to make specific recommendations for the Great Lakes Saint Lawrence region. A dedicated study on this topic would be required to evaluate in more detail the success conditions of those tools and whether they could be replicated in the unique market of the Great Lakes St. Lawrence maritime sector.

Meanwhile, one possible short-term action to facilitate access to capital for projects that will reduce the environmental footprint of the Great Lakes St. Lawrence MTS would be to use an existing tool (i.e., the Great Lakes Investment Platform) and expand its scope to include maritime transportation.

Unsplash – Dylan McLeod

5) HIGH-LEVEL RECOMMENDATIONS AND CONCLUSION

Based on the current knowledge of the industry and the information provided in Sections 2 to 4, four high-level strategies are suggested with a set of recommendations and short-term actions that are collectively in line with the regional maritime strategy (see Annex 2). These high-level strategies are mainly aimed at governments and, in certain cases, also directed at industry stakeholders.

FOUR HIGH-LEVEL STRATEGIES

- **Promote research, development & demonstration**
- **Plan for the energy transition**
- **Incentivize green shipping**
- **Harmonize U.S. and Canadian governmental policies and regulatory approaches**

5.1 PROMOTING RESEARCH, DEVELOPMENT & DEMONSTRATION

Best management practices can reduce the industry's environmental footprint to a certain degree but, to go beyond that point, innovation is key to greening the maritime industry. Despite the progress made to date, there remains research gaps that need to be addressed. Therefore, the first high-level strategy suggested for governments is to **promote RD&D**, which can be done, in part, by **investing in research and green technology projects**. In the short-term, this could be accomplished by maintaining and/or renewing ongoing and successful Canadian and U.S. governmental programs focusing on marine mammal protection, clean marine technologies, biofouling, smart shipping, climate resilience, and pollution remediation.

Governments can also promote RD&D by **supporting existing local innovation centers and driving the creation of new business clusters, incubators and accelerators** to advance the development of innovative greener technologies for the maritime industry and the blue economy. Currently, there exists a broad range of models worldwide, some of which focus solely on marine transportation, while others have a broader scope. As can be observed on The Liquid Grid's Ocean Tech Innovation Ecosystem map,[lvi] the highest concentration of innovation hubs, clusters, incubators and accelerators are in northern Europe and, not surprisingly, this is where most of the innovation for the maritime industry is being achieved. Interesting examples in North America that could inspire a Great Lakes specific innovation cluster include Innovation Maritime, Washington Maritime Blue, Canada's Ocean Supercluster, and SeaAhead.

5.2 PLANNING OF ENERGY TRANSITION

The second high-level strategy is to **prepare for the energy transition by assessing the feasibility and economic impacts of options for the fuel(s) and energy source(s) of the future**. In the next few years, federal, state, and provincial governments, along with the maritime industry, should focus on assessing the physical limitations and economic impacts of different candidate fuels for the region's fleets. It will also be important to assess the feasibility of implementing green ammonia and/or green hydrogen plants (the most promising alternatives to fossil fuels to date) to resupply international vessels and the domestic fleet. The planning for the necessary landside infrastructure must be done in lockstep with the planning and introduction of vessel modifications and new propulsion systems to eventually accommodate new alternative fuels.

5.3 INCENTIVIZING GREEN SHIPPING

The third high-level strategy is to **incentivize green shipping**. Implementing new technologies and beyond-compliance best practices can represent risks and significant costs for private companies. This can slow the pace of innovation. Leadership is required to green the industry, especially when those investments can potentially lead to an economic and competitive disadvantage. Incentive frameworks to counter these drawbacks are increasingly being used at different levels of governance around the world to encourage investment in sustainable shipping and to reward innovators, frontrunners and early adopters of new technologies.

Continued political support and publicity for tools, such as the Great Lakes Commission's Blue Accounting tool that uses Green Marine's performance indicators and published results to benchmark and highlight the industry's achievements beyond compliance, are an example of important **non-financial incentives** for port authorities and maritime companies by **increasing public awareness of the industry's commitment to environmental sustainability**.

Yet, an arguably even more effective way to incentivize green shipping is through reduced fees for greener companies, and some of the most advanced ports in terms of environmental sustainability have begun implementing such reward mechanisms. In the near-term, regional ports and government agencies could therefore **focus on recognizing and rewarding leadership, initiative and innovation** in sustainable transportation. This can be done by implementing differentiated government charges (i.e., reward- and/or incentive-based discounted service fees or taxation schemes) and port fee structures that recognize and encourage higher levels of environmental performance, thereby making the cleanest technologies and operations more competitive and attractive. Such incentives, ideally with similar eligibility criteria by all Canadian and U.S. port authorities, would attract greener ship owners to participate and adopt green measures given the opportunity of cumulative savings. This approach could even be used to incentivize technology developers and suppliers to provide more efficient technologies and maritime stakeholders to purchase cleaner-operating machinery and equipment.

Another way for federal, state and provincial governments to incentivize green shipping over the short term is by **expanding government policies and funding programs** to support the maritime industry's efforts to reduce its environmental impact, especially in terms of GHG emissions and underwater noise, two priority issues requiring significant investment in technology and innovation. For GHGs, governments could first assess existing programs in terms of return on investment and other elements in order to identify the most successful models. Based on this assessment, the next step would be to maintain, renew, expand and/or replicate programs deemed successful. For underwater noise, governments are encouraged to develop and implement programs incentivizing ship owners to upgrade or renew their fleet with quiet vessel technologies and noise monitoring equipment.

Finally, as mentioned in Section 4, a first step to **facilitate access to capital for projects that will reduce the environmental footprint of the region's MTS** would be to expand the Great Lakes Impact Investment Platform to include a theme on maritime transportation. Monitoring emerging awareness initiatives and sustainable funding mechanisms, such as blue bonds, NIB's low-rate loans, and the Poseidon Principles, and evaluating their replicability in the maritime sector for the Great Lakes St. Lawrence region should also be considered.

5) HIGH-LEVEL RECOMMENDATIONS AND CONCLUSION

5.4 HARMONIZING U.S. AND CANADIAN GOVERNMENTAL POLICY AND REGULATORY APPROACHES

The Great Lakes St. Lawrence region is highly integrated, both physically and economically, with a regulatory landscape that is equally complex, involving multiple levels of governance and jurisdictions spanning two countries, eight states, two provinces and hundreds of municipalities. Policies, legislation and regulations inevitably affect the entire MTS. For successful implementation of environmental protection measures, the fourth high-level strategy is the **harmonization of U.S. and Canadian governmental policy and regulatory approaches**. In the near term, governments could focus on **coordinating their approaches to address the issues of biofouling, stormwater management, and climate change adaptation and resilience.**

Industry stakeholders would benefit from coordinated policies. For example, they could facilitate the advancement of hull grooming and cleaning capture technologies by creating a larger market with standardized requirements and clearing the way for testing in designated areas within the MTS region. Governments could also develop a holistic binational approach to align and advance stormwater management by ports and terminal operators with harmonized standards to achieve better overall water quality for the region. Governments could also coordinate their approaches to support ports and the Seaway to ensure the sustainability and resilience of assets.

5.5 CONCLUDING REMARK ON OPPORTUNITIES TO IMPROVE ENVIRONMENTAL PERFORMANCE IN THE GREAT LAKES AND ST. LAWRENCE MARITIME SYSTEM

Much has been accomplished in recent years to address important environmental issues in the region's MTS. There is clearly a renewed interest and a sense of urgency to push further and faster to build a green economy that includes an environmentally sustainable maritime sector. The series of strategies and recommendations outlined in this report are intended to highlight opportunities that exist to improve environmental performance in the region's MTS, both in the short term and in the long run.

The role of federal, state and provincial government decision-makers will continue to be critically important as policies, programs and initiatives are designed and implemented to help the region's maritime industry reduce its environmental footprint, while also increasing the overall competitiveness of the region's MTS. Equally important will be the continued collaboration within all sectors of the maritime industry to meet the challenges ahead and take the necessary steps to further build a regional MTS that is both environmentally and economically sustainable. Success will ultimately help support the region's economic competitiveness, create jobs, and improve environmental health for the benefit of the region and its population.

Unsplash – Chris Pagan

6) REFERENCES

i "Strategy for the Great Lakes-St. Lawrence River Maritime Transportation System," *Great Lakes St. Lawrence Governors & Premiers*, updated January 2019, accessed July 16, 2021, https://gsgp.org/media/2otm2bho/final-regional-mts-strategy-january-2019.pdf

ii Ibid

iii Kim, Y. & Ross, L. 2019. Ports: An industry guide to enhancing resilience. Resilience Primer. *Four Twenty Seven Inc. and Resilience Shift*, UK. 52 pages, https://www.resilienceshift.org/wp-content/uploads/2019/10/RP-Ports_Final_Pages.pdf

iv "Great Lakes-St. Lawrence River shipping," *Chamber of Marine Commerce*, accessed July 16, 2021, https://www.marinedelivers.com/great-lakes-st-lawrence-shipping/

v "Environment," *Chamber of Marine Commerce*, accessed July 16, 2021, https://www.marinedelivers.com/environment/

vi Carmen Hsieh, C. & Felby, C. 2017. Biofuels for the marine shipping sector. An overview and analysis of sector infrastructure, fuel technologies and regulations. *IEA Bioenergy*. 86 pages, http://task39.sites.olt.ubc.ca/files/2013/05/Marine-biofuel-report-final-Oct-2017.pdf

vii "Fourth IMO Greenhouse Gas Study," *International Maritime Organization*, 2020, accessed July 16, 2021, https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf

viii "Pathway to net zero, 2020 Climate Report," *Glencore*, 2020, accessed July 16, 2021, https://www.glencore.com/dam/jcr:c1e7faf7-1928-4251-819e-aa8918be42ba/2020-climate-report--.pdf

ix "ESG Company Overview," *Valero*, updated November, 2020, accessed July 16, 2021, https://www.valero.com/sites/default/files/valero-documents/Valero%20ESG%20Deck_11_10_2020%20FINAL.PDF

x Rantanen, A., Berg, N., & Kanto, E. 2019. Digitalization as a tool to reduce GHG emissions in maritime transport. *Finnish Transport and Communications Agency. Traficom Research Reports* 28/2019, ISBN 978-952-311-361-9, 38 pages + annexes.

xi Gustafsson, M., Hellström, M., & Wahlström. I. 2019. Driving Emission Out of Shipping, A race against time. White Paper. *Åbo Akademi, PBI Research Institute*, 18 pages.

xii Lind, M., Bergmann, M., Bjørn-Andersen, N., Robert, W., Haraldson, S., Watson, R., Andersen, T. Michaelides, M., Evmides, N., Gerosavva, N., Karlsson, M., Holm, H., Olsson, E., Zerem, A., Herodotou, H., Ferrus, G., Gimenez, J., Arjona, J., Marquez, M., Rygh, T., Voskarides, S., & Gonzales, A. 2019. Substantial value for shipping found in PortCDM testbeds. *Sea Traffic Management,* 13 pages.

xiii "Empowering the modern maritime economy," *The St. Lawrence Seaway Management Corporation*, 2021, accessed July 16, 2021, https://greatlakes-seaway.com/wp-content/uploads/2021/07/slsmc_ar2021_en.pdf

xiv Karaarslan, S, Quispel, M., Dahlke-Wallat, F., Friedhoff, B., & Martens, S. 2020. Study on Financing the Energy Transition Towards a Zero-Emission European IWT Sector, Intermediary overall study report. *EICB, Rebel, Panteia Research to Progress, pro Danube Management GMBH.* Written for the Central Commission for the Navigation of the Rhine, 38 pages.

xv "E-navigation," *International Maritime Organization*, accessed July 16, 2021, https://www.imo.org/en/OurWork/Safety/Pages/eNavigation.aspx

xvi "Agreement between the ports of Montreal and Trois-Rivières," *Port of Montreal*, December 3, 2020, accessed July 16, 2021, https://www.port-montreal.com/en/the-port-of-montreal/news/news/press-release/entente-trois-rivieres-en

xvii Agility and resilience through tech: a lifeline for distribution logistics," *Port of Montreal*, accessed July 16, 2021, https://www.port-montreal.com/en/the-port-of-montreal/news/news/resilience-en

xviii "Supply chain performance," *Vancouver Fraser Port Authority*, updated July 13, 2021, accessed July 16, 2021, https://www.portvancouver.com/port-dashboard/supply-chain-performance/

xix "PortXchange," *Port of Rotterdam*, accessed July 16, 2021, https://www.portofrotterdam.com/en/port-forward/portxchange

xx "About," *NxtPort*, accessed July 16, 2021, https://www.nxtport.com/about

6) REFERENCES

xxi Carmen Hsieh, C. & Felby, C. 2017. Biofuels for the marine shipping sector.

xxii Karaarslan, S, Quispel, M., Dahlke-Wallat, F., Friedhoff, B., & Martens, S. 2020. Study on Financing the Energy Transition.

xxiii Chen, R., Qin, Z., Han, J., Wang, M., Taheripour, F., Tyner, W., O'Connor, D., & Duffield, J. 2018. Life cycle energy and greenhouse gas emission effects of biodiesel in the United States with induced land use change impacts. *Bioresource Technology*, 251, 249-258

xxiv "Oceanbird," accessed July 16, 2021, https://www.oceanbirdwallenius.com/

xxv "Sulphur limit in ECAs - increased risk of PSC deficiencies and detentions," *DNV*, published March 12, 2019, accessed July 19, 2021, https://www.dnv.com/news/sulphur-limit-in-ecas-increased-risk-of-psc-deficiencies-and-detentions-142911

xxvi Congbiao Sui, de Vos, P., Stapersma D., Visser, K., & Ding, Y. 2020. Fuel Consumption and Emissions of Ocean-Going Cargo Ship with Hybrid Propulsion and Different Fuels over Voyage. *J. Mar. Sci. Eng.* 8, 588.

xxvii Pavlenko, N., Comer, B., Zhou, Y., Clark, N. & Rutherford, D. 2020. The climate implication of using LNG as a marine fuel. Working Paper 2020-02. *International Council on Clean Transportation*, 24 pages + annexes

xxviii "List of jurisdictions restricting or banning scrubber wash water discharges," *Britannia P&I*, published 27 January, 2020, accessed July 16, 2021, https://britanniapandi.com/2020/01/list-of-jurisdictions-restricting-or-banning-scrubber-wash-water-discharges/

xxix "Climate change indicators: Great lakes water levels and temperatures," *United States Environmental Protection Agency*, accessed July 16, 2021, https://www.epa.gov/climate-indicators/great-lakes

xxx "St. Lawrence Seaway shipping delayed by high water on the Great Lakes," *MLive Media Group*, published February 27, 2020, accessed July 16, 2021, https://www.mlive.com/news/2020/02/st-lawrence-seaway-shipping-delayed-by-high-water-on-the-great-lakes.html

xxxi "Environmentally Acceptable Lubricants," *United States Environmental Protection Agency*, EPA 800-R-11-002, November 2011, 27 pages, https://www3.epa.gov/npdes/pubs/vgp_environmentally_acceptable_lubricants.pdf

xxxii "Invasive species & marine shipping," *Clear Seas*, accessed July 16, 2021, https://clearseas.org/en/invasive-species/?gclid=EAIaIQobChMIyPD6zfeD7wIVgZqGCh1rRgwuEAAYASAAEgImwPD_BwE

xxxiii "Ballast water and the Great Lakes-St. Lawrence Seaway System," *Transport Canada*, updated December 23, 2015, accessed July 19, 2021, https://tc.canada.ca/en/ballast-water-great-lakes-st-lawrence-seaway-system

xxxiv "L'économie circulaire, une priorité," *Recyc-Québec*, accessed July 16, 2021, https://www.recyc-quebec.gouv.qc.ca/entreprises-organismes/mieux-gerer/economie-circulaire

xxxv "Getting to zero: reduce the use of plastic drinking water bottles onboard ships by 2025," *IMPA SAVE*, accessed July 16, 2021, https://www.impasave.org/plastics

xxxvi "Seabin Project," accessed July 16, 2021, https://seabinproject.com/

xxxvii "National Trade Corridors Fund," *Transport Canada*, last modified June 19, 2019, accessed July 16, 2021, https://tc.canada.ca/en/programs/funding-programs/national-trade-corridors-fund

xxxviii "Contribution Program for the Centre of Excellence for the Marine Transportation of Oil and Liquified Natural Gas (LNG)," *Transport Canada,* accessed July 16, 2021, https://tc.canada.ca/en/disclosure-transfer-payments-under-5-million#contribution-program-for-the-centre-of-excellence

xxxix "Quiet Vessel Initiative," *Transport Canada*, updated July 17, 2020, accessed July 16, 2021, https://tc.canada.ca/en/programs/quiet-vessel-initiative

xl "Transportation Assets Risk Assessment (TARA) Program," *Transport Canada*, updated February 11, 2021, accessed July 16, 2021, https://tc.canada.ca/en/programs/transportation-assets-risk-assessment-tara-program

xli "SPTP projects," *Transport Canada,* updated December 18, 2017, accessed July 16, 2021, https://tc.canada.ca/en/programs/sptp-projects

6) REFERENCES

xlii "Clean Transportation System – Research and Development Program," *Transport Canada*, updated April 27, 2021, accessed July 16, 2021, https://tc.canada.ca/en/programs/clean-transportation-system-research-development-program

xliii "Ontario building fully electric ferries for Wolfe and Amherst Islands," *Ontario Ministry of Transportation*, published March 16, 2018, accessed July 16, 2021, https://news.ontario.ca/en/release/48665/ontario-building-fully-electric-ferries-for-wolfe-and-amherst-islands

xliv "Programme d'aide gouvernementale à l'amélioration de l'efficacité du transport maritime, aérien et ferroviaire," *Ministère des Transports du Québec*, accessed July 16, 2021, https://www.transports.gouv.qc.ca/fr/aide-finan/programmes-aide/Pages/Programme-aide-amelioration-efficacite-maritime-aerien-ferroviaire.aspx

xlv "Programme visant la réduction ou l'évitement des émissions de gaz à effet de serre par le développement du transport intermodal," *Ministère des Transports du Québec*, accessed July 16, 2021, https://www.transports.gouv.qc.ca/fr/aide-finan/programmes-aide/Pages/Programme-reduction-evitement-ges.aspx

xlvi "Turkish-built tanker series for Canada," *The Motor Ship*, published May 7, 2019, accessed July 16, 2021, https://www.motorship.com/news101/ships-and-shipyards/turkish-built-tanker-series-for-canada

xlvii "SmartWay," *United States Environmental Protection Agency*, accessed July 16, 2021, https://www.epa.gov/smartway

xlviii "Ports Initiative," *United States Environmental Protection Agency,* accessed July 16, 2021, https://www.epa.gov/ports-initiative

xlix "Annual Disclosure Report 2020," *Poseidon Principles*, published December 2020, accessed July 19, 2021, 39 pages, https://www.poseidonprinciples.org/wp-content/uploads/2020/12/Poseidon-Principles-Annual-Disclosure-Report-2020.pdf

l Bhat, S. & J. Mitchell, "A Year at Sea: The Poseidon Principles and the Possibilities of Sectoral Decarbonization," *Global Maritime Forum*, published January 5, 2021, accessed July 19, 2021, https://www.globalmaritimeforum.org/news/a-year-at-sea-the-poseidon-principles-and-the-possibilities-of-sectoral-decarbonization

li "Sustainable finance: TEG final report on the EU taxonomy, Excel tool - TEG report on EU taxonomy," *European Commission*, published March 9, 2020, accessed July 19, 2021, https://knowledge4policy.ec.europa.eu/publication/sustainable-finance-teg-final-report-eu-taxonomy_en

lii "Inland freight water transport", *Viridad*, accessed July 19, 2021, https://tool.viridad.eu/economic_activities/69/mitigation

liii Karaarslan, S, Quispel, M., Dahlke-Wallat, F., Friedhoff, B., & Martens, S. Study on Financing the Energy Transition.

liv Roth, N., Thiele, T. & von Unger, M. 2019. Blue Bonds: Financing Resilience of Coastal Ecosystems, Key Points for Enhancing Finance Action. A technical guideline prepared for IUCN GMPP by 4Climate, Global Ocean Trust and Silvestrum. *Blue Natural capital Financing Facility*, 70 pages.

lv Joywin Mathew, "Shades of blue in financing: Transforming the ocean economy with blue bonds," *DLA Piper Sustainable Finance Series*, published January 12, 2021, accessed July 19, 2021, https://www.lexology.com/library/detail.aspx?g=220c2b67-22a2-480b-8891-d598349524fd

lvi "Ocean Tech Innovation Ecosystem", *The Liquid Grid*, updated June 6, 2021, accessed July 19, 2021, https://theliquidgrid.com/ocean-tech-innovation-ecosystem/

ANNEX 1A) LIST OF RECOMMENDED ACTIONS FOR THE INDUSTRY AND GOVERNMENTS

RECOMMENDED ACTIONS		
Environmental Performance Objective	Recommended actions[1]	Targeted stakeholders
Air quality & climate change Reduction of GHG emissions and other air pollutants (SOx, NOx, PM)	SHORT-TERM	
	Carry out a regional GHG inventory for the GLSL maritime industry and set aspirational targets based on this reference	State & Provincial Governments
	Assess current impact by carrying out detailed annual emissions inventories (GHG and other air pollutants) and set ambitious reduction targets based on this data (with a reference year)	Industry (all sectors)
	Carry out energy efficiency audits to identify areas for improvement and to implement an Energy Efficiency Management Plan[2] to improve energy efficiency of operations (e.g., select or upgrade machinery (waste heat recovery systems, engine repower, variable speed pumps and fans, smart controls, etc.), clean hull and maintain coatings)	
	Electrify vehicles, equipment, and machinery	
	Begin transition toward smart shipping by: 1) installing digital equipment to reduce paper use; 2) using an IT technology to standardize and transfer digital data from ship to shore, 3) create a data sharing platform and begin developing tools	State & Provincial Governments, Industry (all sectors), partners
	Carry out a pilot project on voyage optimization with a sample of ship owners to assess feasibility and benefits for the region (considering port planning, at-sea response to weather information, speed and routing optimization, carrying capacity/ utilization to reduce ballast legs, reduced idling, etc.)	
	Install charging stations for electric vehicles	Industry (ports, terminals, shipyards, Seaway)
	Assess the economics and environmental benefits of installing shore power in ports, including for self-unloading vessels (including potentially a review of the economics of previous government-assisted shore power installations in Canada and in the U.S.)	Industry (ports, ship owners)
	Ensure an active technological watch on alternative fuels and carbon capture technologies	
	Monitor real-time fuel consumption	Industry (ship owners)
	Carry out pilot projects with alternative fuels	
	Ensure appropriate treatment of closed-loop scrubber "bleed-off" water	
Climate change Adaptation and resilience	SHORT-TERM	
	Assess the impacts, vulnerability, and risks of climate change on infrastructure	State & Provincial Governments, Industry (ports, terminals, shipyards, Seaway)
	Develop and adopt a Climate Change Action Plan[2] with concrete measures to promote adaptability and resilience of assets	Industry (ports, terminals, shipyards, Seaway)
	New projects: Design new sustainable, adapted and resilient infrastructure through a risk-informed and multi-criteria-based framework	
	Limit shoreline erosion by adhering to voluntary slowdowns in sensitive areas within the GLSL region	Industry (ship owners)
Water quality Reduction of vessel incidental discharges	SHORT-TERM	
	Implement an integrated bilge treatment system on new-builds and adopt a similar approach on existing vessels	Industry (ship owners)
	Adopt a modernization program for oily water separators including all related control and verification equipment	
	Avoid discharging treated bilge water in sensitive areas and/or adopt a zero-discharge policy	
	Eliminate oil-to-water interfaces wherever feasible	
	LONG-TERM	
	Foster stewardship and collaboration between port reception services and/or pump and haulout providers and their customers and facilitate user feedback with the equipment manufacturers and suppliers	Industry (ports, ship owners)
Biodiversity Protection of marine mammals	SHORT-TERM	
	Adhere to all voluntary measures (slowdowns, rerouting, etc.) implemented in designated areas of the region where marine mammals are at risk	Industry (ship owners)
	Incorporate applicable quiet vessel technologies during retrofits and/or construction of new vessels	
	Monitor underwater noise with hydrophones (e.g., construction, dredging, vessels, etc.)	Industry (seaports, ship owners)
	Develop smart shipping solutions to better target and manage voluntary slowdown and area avoidance zones along the Estuary and Gulf of St. Lawrence	Federal or State & Provincial Governments
	MEDIUM-TERM	
	Set underwater noise reduction targets and develop an action plan to meet these targets	Industry (seaports, ship owners)

ANNEX 1A) LIST OF RECOMMENDED ACTIONS FOR THE INDUSTRY AND GOVERNMENTS (CONTINUED)

RECOMMENDED ACTIONS (CONTINUED)		
Biodiversity Prevention of introduction and spreading of aquatic invasive species via biofouling	SHORT-TERM	
	Apply environmentally friendly anti-fouling paint or other coatings with effective lifespan	Industry (ship owners)
	Use biofouling resistant materials for pipes and unpainted equipment and apparatus	
	Conduct regular inspection and cleaning of hull and other submerged surfaces	
	Use Marine Growth Prevention Systems to prevent aquatic organisms from settling in internal or niche areas (e.g., sea chests, propeller thrusters, keels, rudders)	
Waste management Reduction of waste production	SHORT-TERM	
	Implement the 3RV principle (reduce, reuse, recycle, and valorize) - Don't just recycle!	Industry (all sectors)
	Carry out annual waste inventories (i.e., total volumes) and characterizations (i.e., identification of waste types)	
	Develop a Waste Management Plan[2] with reduction targets (e.g., for plastics, single use items) and reuse/recycling/valorization targets (e.g. recyclables, dunnage/lining/packaging material) and sustainable purchasing practices (e.g., local, less packaging, reusable and/or recyclable products)	
	Improve synergy and coordination between ship owners and ports to facilitate ship waste management upon arrival at berth	Industry (ports, ship owners)
Community impacts Reduction of nuisances	SHORT-TERM	
	Implement a Nuisance Mitigation Plan[2] for construction work and regular operations (e.g., for noise, dust emissions, traffic)	Industry (ports, terminals, shipyards, Seaway)
	Monitor air quality, noise and dust emissions in critical areas	Industry (ports)

1. The **short-term actions (1-3 years)** recommended in this table can help quickly and significantly reduce the impacts of the maritime industry of the region.
For more detail on best management practices and other actions that can be undertaken by ship owners, please refer to Green Marine's Ship owners program (https://green-marine.org/certification/scope-and-criteria/).

2. **All management plans should minimally include:**
   a) Objectives
   b) Roles & responsibilities
   c) Action plan with a set of concrete actions (measures and best management practices) to implement over a specific timeline and with measurable targets, where relevant
   d) Monitoring activities.

ANNEX 1B) LIST OF RECOMMENDED ACTIONS FOR SHIP OWNERS

RECOMMENDED ACTIONS FOR SHIP OWNERS

Environmental Performance Objective	Recommended actions[1]
Air quality & climate change Reduction of GHG emissions and other air pollutants (SOx, NOx, PM)	SHORT-TERM
	Assess current impact by carrying out detailed annual emissions inventories (GHGs and other air pollutants) and set reduction targets based on this data (with a reference year).
	Carry out energy efficiency audits to identify areas for improvement and to implement an Energy Efficiency Management Plan[2] to improve energy efficiency of operations (e.g., select or upgrade machinery (waste heat recovery systems, engine repower, variable speed pumps and fans, smart controls, etc.) and clean hull and maintain coatings)
	Begin transition toward smart shipping by: 1) installing digital equipment to reduce paper use; 2) using an IT technology to standardize and transfer digital data from ship to shore, 3) create a data sharing platform and begin developing tools; 4) Monitor real-time fuel consumption
	Carry out a pilot project on voyage optimization with a sample of ship owners to assess feasibility and benefits for the region (considering port planning, at-sea response to weather information, speed and routing optimization, carrying capacity/utilization to reduce ballast legs, reduced idling, etc.)
	With ports, assess the economics and environmental benefits of installing shore power in ports (including potentially a review of the economics of previous government-assisted shore power installations in Canada and in the U.S.)
	Ensure an active technological watch on alternative fuels
	Assess the economics and environmental benefits of installing shore power in ports, including for self-unloading vessels (including potentially a review of the economics of previous government-assisted shore power installations in Canada and in the U.S.)
	Ensure an active technological watch on alternative fuels and carbon capture technologies
	Monitor real-time fuel consumption
	Carry out pilot projects with alternative fuels
	Ensure appropriate treatment of closed-loop scrubber "bleed-off" water
Climate change Adaptation and resilience	SHORT-TERM
	Limit shoreline erosion by adhering to voluntary slowdowns in sensitive areas within the GLSL region
Water quality Reduction of vessel incidental discharges	SHORT-TERM
	Implement an integrated bilge treatment system on new-builds and adopt a similar approach on existing vessels
	Adopt a modernization program for oily water separators including all related control and verification equipment
	Avoid discharging treated bilge water in sensitive areas and/or adopt a zero-discharge policy
	Eliminate oil-to-water interfaces wherever feasible
	LONG-TERM
	Foster stewardship and collaboration between port reception services and/or pump and haulout providers and their customers and facilitate user feedback with the equipment manufacturers and suppliers
Biodiversity Protection of marine mammals	SHORT-TERM
	Adhere to all voluntary measures (slowdowns, rerouting, etc.) implemented in designated areas of the region where marine mammals are at risk
	Incorporate applicable quiet vessel technologies during retrofits and/or construction of new vessels
	Monitor vessel underwater noise with hydrophones
	MEDIUM-TERM
	Set underwater noise reduction targets and develop an action plan to meet these targets
Biodiversity Prevention of introduction and spreading of aquatic invasive species via biofouling	SHORT-TERM
	Apply environmentally friendly anti-fouling paint or other coatings with effective lifespan
	Use biofouling resistant materials for pipes and unpainted equipment and apparatus
	Conduct regular inspection and cleaning of hull and other submerged surfaces
	Use Marine Growth Prevention Systems to prevent aquatic organisms from settling in internal or niche areas (e.g., sea chests, propeller thrusters, keels, rudders)

ANNEX 1B) LIST OF RECOMMENDED ACTIONS FOR SHIP OWNERS (CONTINUED)

RECOMMENDED ACTIONS FOR SHIP OWNERS (CONTINUED)	
	SHORT-TERM
Waste management Reduction of waste production	Implement the 3RV principle (reduce, reuse, recycle, and valorize) - Don't just recycle!
	Carry out annual waste inventories (i.e., total volumes) and characterizations (i.e., identification of waste types)
	Develop a Waste Management Plan[2] with reduction targets (e.g., for plastics, single use items) and reuse/recycling/valorization targets (e.g. recyclables, dunnage/lining/packaging material) and sustainable purchasing practices (e.g., local, less packaging, reusable and/or recyclable products)
	Improve synergy and coordination between ship owners and ports to facilitate ship waste management upon arrival at berth

1. The **short-term actions (1-3 years)** recommended in this table can help quickly and significantly reduce the impacts of the maritime industry of the region.
For more detail on best management practices and other actions that can be undertaken by ship owners, please refer to Green Marine's Ship owners program (https://green-marine.org/certification/scope-and-criteria/).

2. **All management plans should minimally include:**
   a) Objectives
   b) Roles & responsibilities
   c) Action plan with a set of concrete actions (measures and best management practices) to implement over a specific timeline and with measurable targets, where relevant
   d) Monitoring activities.

ANNEX 1C) LIST OF RECOMMENDED ACTIONS FOR PORTS AND THE SEAWAY

RECOMMENDED ACTIONS FOR PORTS AND THE SEAWAY

Environmental Performance Objective	Recommended actions[1]
Air quality & climate change Reduction of GHG emissions and other air pollutants (SOx, NOx, PM)	SHORT-TERM
	Assess current impact by carrying out detailed annual emissions inventories (GHG and other air pollutants) and set ambitious reduction targets based on this data (with a reference year)
	Carry out energy efficiency audits to identify areas for improvement and to implement an Energy Efficiency Management Plan[2] to improve energy efficiency of operations (e.g., select or upgrade machinery (waste heat recovery systems, engine repower, variable speed pumps and fans, smart controls, etc.), clean hull and maintain coatings)
	Electrify vehicles, equipment, and machinery
	Begin transition toward smart shipping by: 1) installing digital equipment to reduce paper use; 2) using an IT technology to standardize and transfer digital data from ship to shore, 3) create a data sharing platform and begin developing tools
	Carry out a pilot project on voyage optimization with a sample of ship owners to assess feasibility and benefits for the region (considering port planning, at-sea response to weather information, speed and routing optimization, carrying capacity/utilization to reduce ballast legs, reduced idling, etc.)
	Install charging stations for electric vehicles
	Assess the economics and environmental benefits of installing shore power in ports, including for self-unloading vessels (including potentially a review of the economics of previous government-assisted shore power installations in Canada and in the U.S.)
	Ensure an active technological watch on alternative fuels and carbon capture technologies
Climate change Adaptation and resilience	SHORT-TERM
	Assess the impacts, vulnerability, and risks of climate change on infrastructure
	Develop and adopt a Climate Change Action Plan[2] with concrete measures to promote adaptability and resilience of assets
	New projects: Design new sustainable, adapted and resilient infrastructure through a risk-informed and multi-criteria-based framework
Water quality Reduction of vessel incidental discharges	LONG-TERM
	Foster stewardship and collaboration between port reception services and/or pump and haulout providers and their customers and facilitate user feedback with the equipment manufacturers and suppliers
Water and soil quality Prevention of spills and stormwater management	SHORT-TERM
	Raise awareness and train employees on the use of spill kits, proper clean-up procedure and spill reporting for minor spills. When applicable, train on maintenance and monitoring of stormwater treatment equipment
	Identify site-specific potential pollution sources (e.g., areas, equipment, activities) and associated pollutants, and determine/identify prevention measures to limit the risk of water and land contamination
	Adapt stormwater management practices to ensure adequate stormwater treatment (e.g. adequate treatment equipment (favoring green technologies where applicable) and maintenance procedures, water quality monitoring waste water (sampling and analysis))
Biodiversity Protection of marine mammals	SHORT-TERM
	Seaports - Monitor underwater noise with hydrophones (e.g., construction, dredging)
	MEDIUM-TERM
	Seaports - Set underwater noise reduction targets and develop an action plan to meet these targets
Waste management Reduction of waste production	SHORT-TERM
	Implement the 3RV principle (reduce, reuse, recycle, and valorize) - Don't just recycle!
	Carry out annual waste inventories (i.e., total volumes) and characterizations (i.e., identification of waste types)
	Develop a Waste Management Plan[2] with reduction targets (e.g., for plastics, single use items) and reuse/recycling/valorization targets (e.g. recyclables, dunnage/lining/packaging material) and sustainable purchasing practices (e.g., local, less packaging, reusable and/or recyclable products)
	Improve synergy and coordination between ship owners and ports to facilitate ship waste management upon arrival at berth
Community impacts Reduction of noise and dust emissions	SHORT-TERM
	Implement a Nuisance Mitigation Plan[2] for construction work and regular operations (e.g., for noise, dust emissions, traffic)
	Monitor air quality, noise and dust emissions in critical areas

1. The **short-term actions (1-3 years)** recommended in this table can help quickly and significantly reduce the impacts of the maritime industry of the region. For more detail on best management practices and other actions that can be undertaken by ship owners, please refer to Green Marine's Ship owners program (https://green-marine.org/certification/scope-and-criteria/).
2. **All management plans should minimally include:** a) Objectives b) Roles & responsibilities c) Action plan with a set of concrete actions (measures and best management practices) to implement over a specific timeline and with measurable targets, where relevant d) Monitoring activities.

ANNEX 1D) LIST OF RECOMMENDED ACTIONS FOR TERMINALS OPERATORS AND SHIPYARDS

RECOMMENDED ACTIONS FOR TERMINALS OPERATORS AND SHIPYARDS

Environmental Performance Objective	Recommended actions[1]
Air quality & climate change Reduction of GHG emissions and other air pollutants (SOx, NOx, PM)	SHORT-TERM
	Assess current impact by carrying out detailed annual emissions inventories (GHG and other air pollutants) and set ambitious reduction targets based on this data (with a reference year)
	Carry out energy efficiency audits to identify areas for improvement and to implement an Energy Efficiency Management Plan[2] to improve energy efficiency of operations (e.g., select or upgrade machinery (waste heat recovery systems, engine repower, variable speed pumps and fans, smart controls, etc.), clean hull and maintain coatings)
	Electrify vehicles, equipment, and machinery
	Begin transition toward smart shipping by: 1) installing digital equipment to reduce paper use; 2) using an IT technology to standardize and transfer digital data from ship to shore, 3) create a data sharing platform and begin developing tools
	Carry out a pilot project on voyage optimization with a sample of ship owners to assess feasibility and benefits for the region (considering port planning, at-sea response to weather information, speed and routing optimization, carrying capacity/utilization to reduce ballast legs, reduced idling, etc.)
	Install charging stations for electric vehicles
Climate change Adaptation and resilience	SHORT-TERM
	Assess the impacts, vulnerability, and risks of climate change on infrastructure
	Develop and adopt a Climate Change Action Plan[2] with concrete measures to promote adaptability and resilience of assets
	New projects: Design new sustainable, adapted and resilient infrastructure through a risk-informed and multi-criteria-based framework
Water and soil quality Prevention of spills and stormwater management	SHORT-TERM
	Raise awareness and train employees on the use of spill kits, proper clean-up procedure and spill reporting for minor spills. When applicable, train on maintenance and monitoring of stormwater treatment equipment
	Identify site-specific potential pollution sources (e.g., areas, equipment, activities) and associated pollutants, and determine/identify prevention measures to limit the risk of water and land contamination
	Adapt stormwater management practices to ensure adequate stormwater treatment (e.g. adequate treatment equipment (favoring green technologies where applicable) and maintenance procedures, water quality monitoring waste water (sampling and analysis))
Waste management Reduction of waste production	SHORT-TERM
	Implement the 3RV principle (reduce, reuse, recycle, valorize)
	Carry out annual waste inventories (i.e., total volumes) and characterizations (i.e., identification of waste types)
	Develop a Waste Management Plan2 with reduction targets (e.g., for plastics, single use items) and reuse/recycling/valorization targets (e.g. recyclables, dunnage/lining/packaging material) and sustainable purchasing practices (e.g., local, less packaging, reusable and/or recyclable products)
Community impacts Reduction of noise and dust emissions	SHORT-TERM
	Implement a Nuisance Mitigation Plan[2] for construction work and regular operations (e.g., for noise, dust emissions, traffic)

1. The **short-term actions (1-3 years)** recommended in this table can help quickly and significantly reduce the impacts of the maritime industry of the region.
For more detail on best management practices and other actions that can be undertaken by ship owners, please refer to Green Marine's Ship owners program (https://green-marine.org/certification/scope-and-criteria/).

2. **All management plans should minimally include:**
   a) Objectives
   b) Roles & responsibilities
   c) Action plan with a set of concrete actions (measures and best management practices) to implement over a specific timeline and with measurable targets, where relevant
   d) Monitoring activities.

ANNEX 1E) LIST OF RECOMMENDED ACTIONS FOR GOVERNMENTS

RECOMMENDED ACTIONS FOR GOVERNMENTS		
Environmental Performance Objective	Recommended actions[1]	Targeted stakeholders
Air quality & climate change Reduction of GHG emissions and other air pollutants (SOx, NOx, PM)	SHORT-TERM	
	Carry out a regional GHG inventory for the GLSL maritime industry and set aspirational targets based on this reference	State & Provincial Governments
	Begin transition toward smart shipping by: 1) installing digital equipment to reduce paper use; 2) using an IT technology to standardize and transfer digital data from ship to shore, 3) create a data sharing platform and begin developing tools	State & Provincial Governments (along with the industry and partners)
	Carry out a pilot project on voyage optimization with a sample of ship owners to assess feasibility and benefits for the region (considering port planning, at-sea response to weather information, speed and routing optimization, carrying capacity/ utilization to reduce ballast legs, reduced idling, etc.)	
	LONG-TERM	
	Where relevant, assess the feasibility of greening the electric grid	Federal or State & Provincial Governments
Climate change Adaptation and resilience	SHORT-TERM	
	Assess the impacts, vulnerability, and risks of climate change on infrastructure	State & Provincial Governments (along with the industry)
Biodiversity Protection of marine mammals	SHORT-TERM	
	Develop smart shipping solutions to better target and manage voluntary slowdown and area avoidance zones along the Estuary and Gulf of St. Lawrence	Federal or State & Provincial Governments

ANNEX 2) HIGH-LEVEL STRATEGIES AND RECOMMENDATIONS

HIGH-LEVEL STRATEGIES	HIGH-LEVEL RECOMMENDATIONS	SHORT-TERM ACTIONS	TARGETED STAKEHOLDER
1. Promote RD&D	Invest in research and green technology RD&D projects	Maintain/renew ongoing and successful governmental programs focusing on marine mammal protection, clean marine technologies, biofouling, smart shipping, climate resilience, and pollution remediation (e.g., Transport Canada's Clean Transportation System RD&D program, Contribution Program for the Centre of Excellence for the Marine Transportation of Oil and LNG, and Quiet Vessel Initiative, as well as SDTC, NRC, and the U.S. META programs) and advertise them to the region's maritime stakeholders	Federal and State/Provincial governments
	Support existing innovation centers and drive the creation of new business clusters, incubators and accelerators	Support local organizations such as Innovation maritime and develop a cluster organization in the Great Lakes St. Lawrence region such as Washington Maritime Blue in the Western U.S.	
2. Plan for the energy transition	Assess the feasibility and plan for the fuel(s) and energy source(s) of the future	Assess physical limitations and economic impacts of different candidate fuels for Great Lakes St. Lawrence vessel owners	Federal and State/Provincial governments and industry (ship owners)
		Assess the feasibility of a green ammonia and/or green hydrogen plant of the scale necessary to resupply international vessels and the domestic fleet (and any potential land-based usage)	
		Start planning for the necessary landside infrastructure (e.g., for refueling) and vessel modifications/new design to eventually accommodate new fuels and propulsion systems	Federal, State/Provincial governments, and industry (all sectors)
3. Incentivize green shipping	Recognize and reward initiative and innovation in sustainable transportation	Implement differentiated government charges and port fee structures that recognize and encourage higher levels of environmental performance	Federal, State/Provincial governments and industry (ports)
	Expand government policies and funding programs to support the maritime industry's efforts to reduce GHGs and underwater noise	Assess each program's success in terms of return on investment (e.g., GHG reduction achieved per dollar invested) to identify the most successful models	Federal and State/Provincial governments
		Maintain, renew, expand and/or replicate existing successful programs (e.g., Quebec's PETMAF program, NTCF, duty removal, DERA's National Grants Program)	
		Develop and implement programs to incentivize ship owners to upgrade or renew their fleet with quiet vessel technologies and noise monitoring equipment	
	Facilitate access to capital for projects that will reduce the environmental footprint of the Great Lakes St. Lawrence Maritime Transportation System	Expand the Great Lakes Investment Platform and evaluate the replicability of emerging sustainable funding mechanisms in the maritime sector for the Great Lakes St. Lawrence region	
4. Harmonize U.S. and Canadian governmental approaches	Coordinate federal, state/provincial governmental approaches in terms of bi-national environmental issues (i.e., stormwater management, climate adaptation/resilience and other system-wide issues)	Biofouling - Facilitate advancement of hull grooming and cleaning capture technologies (e.g., permitting testing is designated areas, policies)	Federal and State/Provincial governments
		Stormwater management - Develop a holistic, binational approach to align and advance ports and terminal operators' stormwater management to help improve water quality of port waters (e.g. establish harmonized stormwater quality standards for the Great Lakes St. Lawrence region). This will require an in-depth analysis of the different regulatory frameworks and identify gaps and areas for improvement.	
		Infrastructure - Support ports, waterways and lock systems with infrastructure susceptible to be damaged by climate change-related disturbances	

DERA: Diesel Emissions Reductions Act
GHG: Greenhouse gas
LNG: Liquid natural gas
META: Maritime Environmental and Technical Assistance
NRC: Natural Resources Canada
NTCF: National Trade Corridors Fund
RD&D: Research, development, and demonstration
PETMAF: Government assistance program to improve the efficiency of maritime, air and rail transport (French acronym PETMAF for Programme d'aide à l'amélioration de l'efficacité du transport maritime, aérien et ferroviaire) by using more efficient transport equipment as well as equipment using low GHG energy emitting sources.
SDTC: Sustainable Development Technology Canada