TECHNICAL BRIEF

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Estimating greenhouse gas emissions from U.S. maritime shipping: Potential benefits of a monitoring, reporting, and verification system

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INTRODUCTION AND BACKGROUND

The maritime shipping sector plays a critical role in the U.S. economy, with maritime shipping activities estimated to generate more than $40 billion in added value in 2022.[1] However, the reliance on fossil fuels for maritime transport presents environmental challenges. Ships burn fossil fuels such as heavy fuel oil, very-low sulfur fuel oil, marine gas oil, and liquefied natural gas (LNG), which emit greenhouse gases (GHGs) that drive climate change. The consequences of climate change—such as coastal flooding, more intense storms, and damage to infrastructure—impose growing economic costs on the United States, including $165 billion worth of damages in 2022 from climate- and weather-related disasters.[2] To reduce the climate impacts of the marine sector, the United States has committed to achieving net-zero GHG emissions from domestic and international shipping by no later than 2050.[3]

1 Bureau of Economic Analysis, *Marine Economy Satellite Account, 2022,* U.S. Department of Commerce (June 6, 2024), https://www.bea.gov/data/special-topics/marine-economy. Table 1 indicates that "transportation and warehousing, marine" activities generated $28.2 billion of added value in 2022 in chained 2017 dollars. Table 7 shows that the index for that category for 2022 was 140, compared with 100 for the 2017 base year. Therefore, in 2022, the value for maritime shipping activities is estimated to be approximately $40 billion. This captures activities within the U.S. Exclusive Economic Zone and along the U.S. coastline, as explained in Bureau of Economic Analysis, *Defining And Measuring the U.S. Ocean Economy,* U.S. Department of Commerce (2020), https://www.bea.gov/system/files/2021-06/defining-and-measuring-the-united-states-ocean-economy.pdf.

2 Adam B. Smith, "2022 U.S. Billion-Dollar Weather and Climate Disasters in Historical Context," *Beyond the Data* (blog), *National Oceanic and Atmospheric Administration*, January 6, 2023, https://www.climate.gov/news-features/blogs/beyond-data/2022-us-billion-dollar-weather-and-climate-disasters-historical#:~:text=Damages%20from%20the%202022%20disasters,Heat%20Wave%20(%2422.1%20billion).

3 U.S. Department of Energy, U.S. Department of Transportation, U.S. Environmental Protection Agency, and U.S. Department of Housing and Urban Development, *U.S. National Blueprint for Transportation Decarbonization* (2023), https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf. The U.S. has set a goal of a net-zero maritime shipping sector by no later than 2050. Additionally, the International Maritime Organization, of which the United States is a member state, recently adopted a goal of net-zero GHG emissions from ships by or around 2050. See: "2023 IMO Strategy on Reduction of GHG Emissions from Ships," International Maritime Organization, accessed October 29, 2024, https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx.

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Despite the importance of maritime shipping, there are significant gaps in the U.S. government's estimates of GHG emissions from marine vessels. Current estimates, listed in Table 1, rely on either fuel sales data, which overlook emissions from ships that refuel outside U.S. jurisdictions, or bottom-up modeling using Automatic Identification System (AIS) data that is limited to emissions within the U.S. Exclusive Economic Zone, leaving emissions from international voyages outside of that boundary unaccounted for. Official U.S. estimates of maritime shipping emissions range between 32 and 45 million tonnes (Mt) of carbon dioxide (CO_2) or carbon dioxide equivalent (CO_2e) in recent years, but these estimates are incomplete because they do not account for GHGs emitted outside of U.S. waters.[4] By contrast, the European Union has implemented a more comprehensive system for tracking maritime emissions. The EU Monitoring, Reporting, and Verification (MRV) system requires ships of 5,000 gross tonnage (GT) or more to report their fuel consumption and associated GHG emissions on all voyages to, from, and between ports in the European Economic Area.[5] The EU MRV covered voyages responsible for approximately 137 Mt CO_2e in 2022. This brief uses the International Council on Clean Transportation's (ICCT) Systematic Assessment of Vessel Emissions (SAVE) model to estimate the GHG emissions from ships that could be covered under a similar U.S. MRV program .[6]

Table 1

Estimates of emissions from U.S. maritime shipping

Category	Year	Value	Data source	Scope
Ships and boats	2022	45 Mt CO_2e	Fuel sales[a]	Domestic ships and boats
International bunker fuels	2022	32 Mt CO_2e	Fuel sales[b]	International ships, including commercial and military, but excluding fishing vessels
Commercial marine vessels	2020	39 Mt CO_2	AIS[c]	All vessel emissions in U.S. waters, extending out to the U.S. Exclusive Economic Zone (up to 200 nautical miles)

Note: CO_2e emissions here include CO_2, CH_4, and N_2O, but exclude HFCs.
[a] U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Table 2-13* (2024), https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022.
[b] U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Table 3-116 (2024)*.
[c] Eastern Research Group, *Category 1 and 2 Commercial Marine Vessel 2020 Emissions Inventory, Table 9* (2022), https://www.epa.gov/system/files/documents/2023-01/2020NEI_C1C2_Documentation.pdf; Eastern Research Group, *Category 3 Commercial Marine Vessel 2020 Emissions Inventory, Table 3* (2022), https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/nonpoint/CMV/2020%20C3%20Marine%20Emissions%20Tool%20%20Documentation.pdf.

The United States has experience with an MRV program for aviation under the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Under this program, U.S. aircraft operators voluntarily

4 Note that the United States government abbreviates million tonnes (Mt) as million metric tons (MMT) in its publications.

5 The EU MRV's first reporting period began on January 1, 2018. Starting January 1, 2025, the MRV will expand to cover offshore vessels and will also require smaller ships than before to report their emissions, covering offshore vessels and general cargo vessels below 5,000 GT but above 400 GT, as explained in European Commission, *The EU ETS and MRV Maritime General Guidance for Shipping Companies* (July 4, 2024), https://climate.ec.europa.eu/document/download/31875b4f-39b9-4cde-a4e2-fbb8f65ee703_en?filename=policy_transport_shipping_gd1_maritime_en.pdf.

6 Naya Olmer et al., *Greenhouse Gas Emissions from Global Shipping, 2013–2015* (International Council on Clean Transportation, 2017), https://theicct.org/publication/greenhouse-gas-emissions-from-global-shipping-2013-2015/.

report their emissions, and all major U.S. operators are participating.[7] Unlike the EU shipping MRV data, which publicly reports ship-by-ship information, only aggregated aviation MRV data on the emissions of air transport between two countries are publicly available.[8] Additionally, all domestic emissions are excluded. Nevertheless, experience with the aviation MRV program could inform the development of a U.S. MRV system for maritime shipping.

Some of the ships that would be covered by a U.S. MRV system already report to the EU MRV system, and all report to the International Maritime Organization (IMO) Data Collection System (DCS). In the IMO DCS, ships 5,000 GT and above report their fuel consumption and CO_2 emissions for all voyages each year. Like the CORSIA MRV program, IMO DCS data are not publicly available, except for summaries of fuel consumption and emissions aggregated by ship type and size, preventing analyses of the GHG emissions of individual ships.

METHODS

VOYAGE-LEVEL EMISSIONS

ICCT's SAVE model joins AIS ship activity data from Spire with ship technical characteristics data from S&P Global to estimate fuel consumption and emissions, as shown in Figure 1.[9] ICCT's SAVE model uses methods consistent with the Fourth IMO Greenhouse Gas Study.[10] Emissions are reported in CO_2e based on 100-year global warming potentials from the Intergovernmental Panel on Climate Change Sixth Assessment report: 1 for CO_2, 29.8 for methane, and 273 for nitrous oxide.[11] The SAVE model also integrates a voyage identification module that maps the origin and destination points of a voyage to nearest ports, based on information provided by the World Port Index.[12] For this analysis, a voyage was considered to be covered under the U.S. MRV if the ship was 5,000 GT or above with an origin or destination in a U.S. port. Emissions were then aggregated voyage-by-voyage for each ship. Results were differentiated by inbound, outbound, and cabotage (between two U.S. ports) voyages, as well as by ship type; in-port emissions (at-berth plus at-anchor) were reported separately, consistent with EU MRV reporting methods.

7 U.S. Federal Aviation Administration, *Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) Frequently Asked Questions* (July 24, 2023), https://www.faa.gov/media/67966.

8 International Civil Aviation Organization, *CORSIA Central Registry (CCR): Information and Data for Transparency* (October 2023), https://www.icao.int/environmental-protection/CORSIA/Documents/CCR%20Info%20Data%20Transparency_PartIII_Oct2023_web.pdf.

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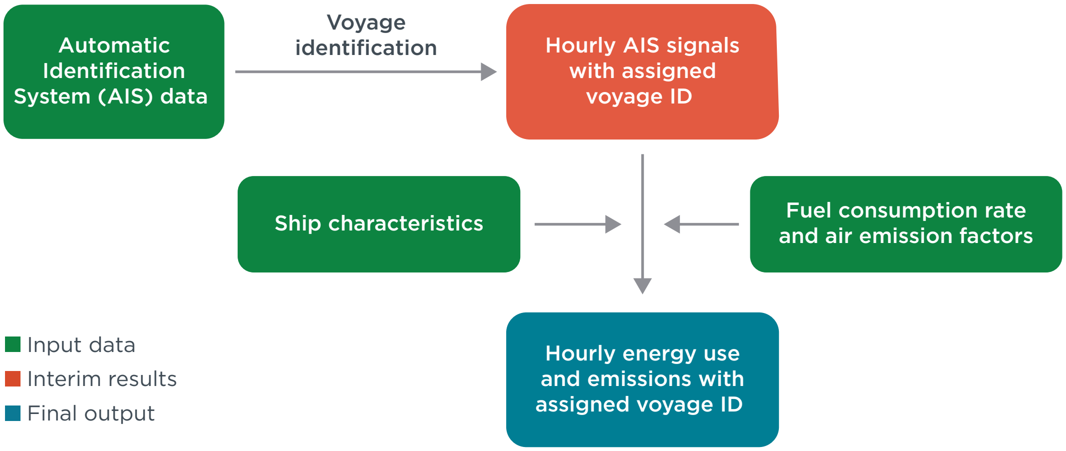
10 Jasper Faber et al., *Fourth IMO Greenhouse Gas Study 2020* (International Maritime Organization, 2020), https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf.

11 Intergovernmental Panel on Climate Change, *Sixth Assessment Report* (2023), https://www.ipcc.ch/assessment-report/ar6/.

12 National Geospatial-Intelligence Agency, *World Port Index 2019* (2019), https://msi.nga.mil/Publications/WPI.

Figure 1
Flowchart of the SAVE model methodology



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POTENTIAL REVENUES UNDER A U.S. GREENHOUSE GAS PRICING SYSTEM

In the European Union, a portion of the emissions covered by the EU MRV will be subject to GHG pricing under the EU Emissions Trading System (ETS). The scope includes 100% of in-port emissions, 100% of emissions for voyages between two member states, and 50% of emissions on inbound or outbound (i.e., "extra-EU") voyages. The total amount of emissions that must be paid for under the ETS increases over time. In 2025, 40% of emissions reported in 2024 are subject to the GHG price, rising to 70% of 2025 emissions in 2026, and 100% of emissions in 2027 and onward. In this briefing, we report the range of revenues that could be generated if U.S. MRV emissions were subject to a U.S. ETS with the same scope as the EU ETS. The EU ETS carbon price is approximately $70 per tonne of CO_2 as of September 2024.[13] We use the U.S. EPA estimated central value of $190 per tonne of CO_2 for 2020 emissions in constant 2020 dollars, or approximately $230 per tonne in September 2024.[14] We assume that the CO_2 price would also apply to CO_2e.

RESULTS

A U.S. MRV could cover approximately 11,100 ships, based on 2022 data, of which more than 6,300 (57%) reported to the EU MRV in 2022. As shown in Figure 2, approximately 103 Mt of CO_2e would have been covered by a U.S. MRV in 2022, including 43% from outbound voyages, 33% from inbound voyages, 14% from cabotage voyages, and 10% emitted in U.S. ports. This is much greater than official U.S. estimates of maritime shipping GHG emissions, which range from 32–45 Mt CO_2e. Approximately 80% of covered emissions are from international voyages, and 20% from domestic. Adding up 50% of the emissions from inbound and outbound voyages and 100% of

13 "European Electricity Prices and Costs: The Price of Emissions Allowances in Europe," Ember, accessed October 16, 2024, https://ember-climate.org/data/data-tools/european-electricity-prices-and-costs/.

14 U.S. Environmental Protection Agency, *EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* (2023), https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf, see table 4.1.1. Value in 2024 dollars was calculated using the U.S. Bureau of Labor Statistics Consumer Price Index Inflation Calculator (https://data.bls.gov/cgi-bin/cpicalc.pl) assuming $190 in January 2020, which yielded $232 by September 2024, which we have rounded to $230.

cabotage and in-port emissions equals 64 Mt CO_2e. If these emissions were subject to a GHG price ranging from $70 to $230 per tonne of CO_2e, the revenues could equal between $4.5 billion to $15 billion per year.

Figure 2

Million tons of CO_2e emissions that would have been covered by a U.S. monitoring, reporting, and verification system in 2022, summarized by voyage type

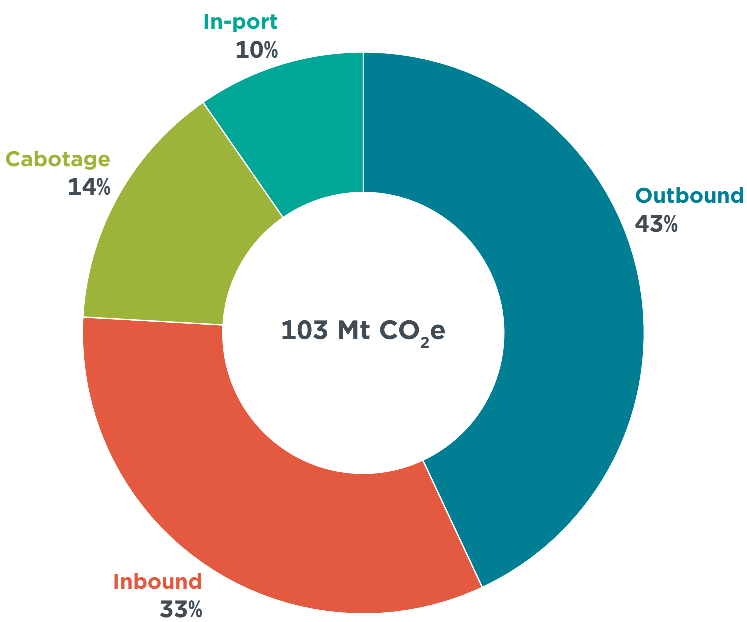

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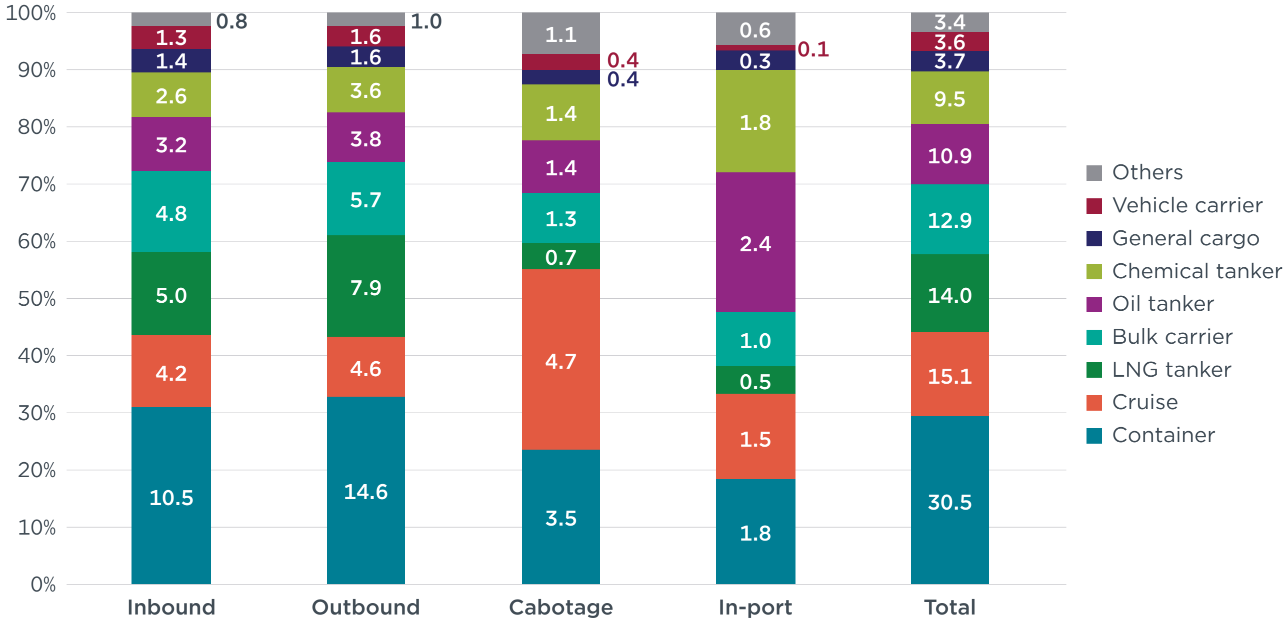
Figure 3 shows the breakdown of emissions by ship type within each voyage type (inbound, outbound, cabotage, in-port), in addition to the share of total emissions by ship type. Container ships were responsible for the most emissions in 2022, accounting for more than 30 Mt CO_2e, and were also responsible for the largest share of emissions of inbound and outbound voyages. Cruise ships were the second-highest emitting ship type, with 15 Mt CO_2e of total emissions. Notably, cruise ships were the highest emitters for cabotage voyages. Tankers transporting LNG were the third-highest emitters in most voyage types (14 Mt CO_2e), but the second-highest emitters for outbound voyages, reflecting U.S. exports of LNG. Together, container ships, cruise ships, and LNG tankers accounted for 58% of total emissions. Bulk carriers ranked fourth in total emissions (13 Mt CO_2e) and in cabotage voyages (1.3 Mt CO_2e). Other important ship types include oil tankers, which emitted 11 Mt CO_2e in total, and chemical tankers, with emissions of about 10 Mt CO_2e.

Figure 3

Million tons of CO_2e emissions that would have been covered by a U.S. monitoring, reporting, and verification system in 2022, summarized by ship type for each voyage type



Note: The values in the figure represent Mt of CO_2e emissions for that ship type. The "other" category includes refrigerated bulk carriers, ferries, offshore supply vessels, other liquids tankers, and service vessels.

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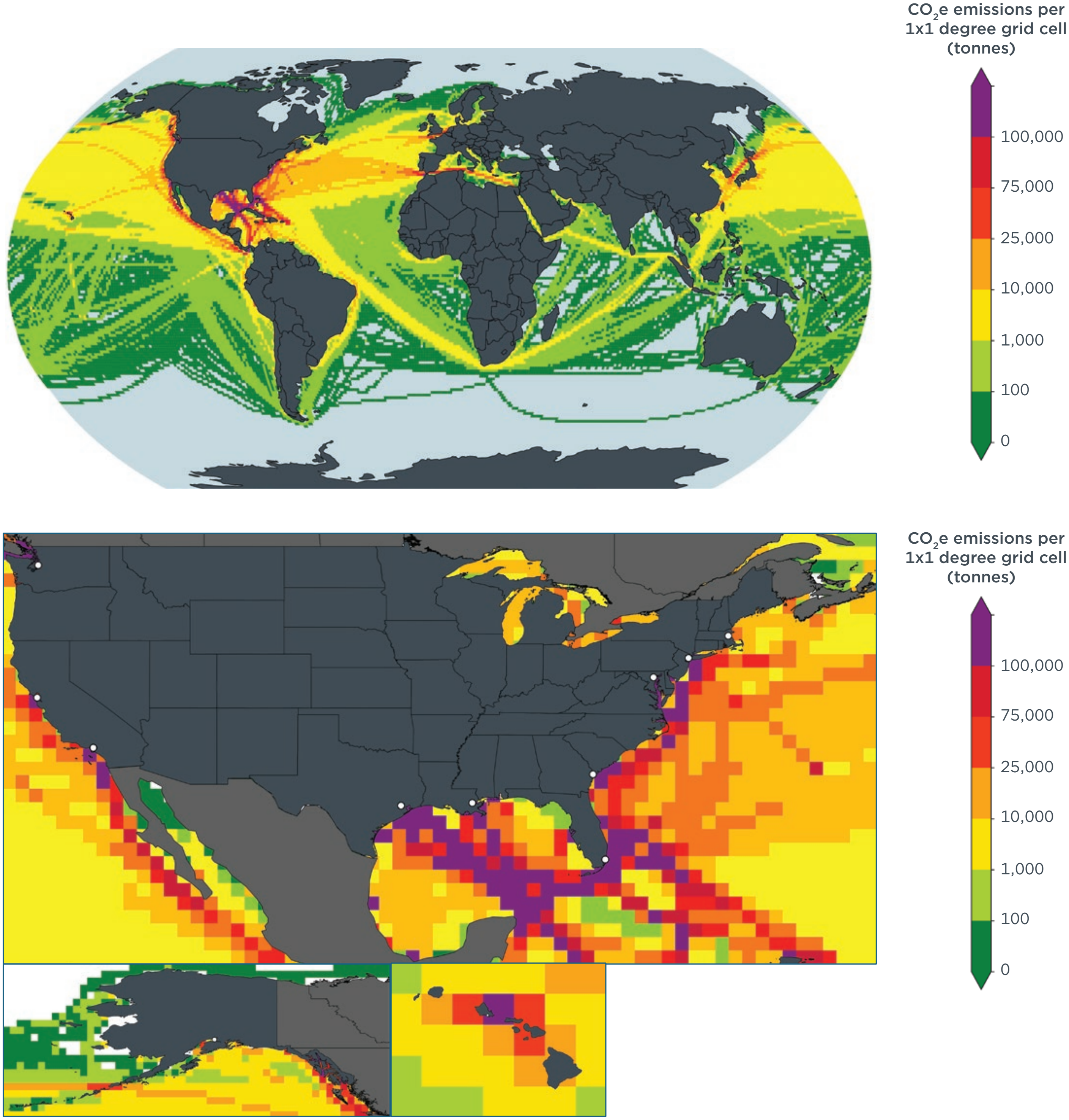
Figure 4 maps the distribution of CO_2e emissions for voyages that would be covered by a U.S. MRV in 2022. As shown, there are higher concentrations of emissions along the California, Texas, Louisiana, Florida, Georgia, and New York/New Jersey shorelines compared with other areas. California is a major container ship hub; Texas and Louisiana export oil and gas via tankers, as well as agricultural products by bulk carriers; Florida is a cruise ship hub and handles cargo; Georgia handles large amounts of container cargo, and the port of New York/New Jersey is the busiest port on the U.S. East Coast. We observe high emission intensities on voyages that connect the United States with East Asia, Europe, and South America.

Figure 4

Global and near-U.S. CO_2e emissions for voyages that would have been covered by a U.S. monitoring, reporting, and verification system in 2022



Notes: White dots in the U.S. map represent the location of major ports. Alaska and Hawaii are not to scale.

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MODEL VALIDATION AND FUTURE IMPROVEMENTS

To validate our model, we used the same methodology to estimate the CO_2 emissions that would be covered by the EU MRV for 2022, and we compared our estimates with emissions reported under the EU MRV for that year, as shown in Table 2. For 2022, ships reported only CO_2 emissions; thus, we did not estimate CO_2e emissions for this comparison. We estimated 19% fewer emissions from inbound voyages than the EU MRV, 20% lower outbound emissions, 25% higher cabotage emissions, and 45% lower in-port emissions. However, in total, we estimated that 124 Mt CO_2 would be covered by the EU MRV, compared with reported emissions of 137 Mt CO_2, a difference of about 10%.[15] While there are some inconsistencies in the split of emissions among the three voyage types, the total emissions compare reasonably well. It is likely that some of the cabotage emissions should instead be categorized as from inbound or outbound voyages. For example, we noticed that in some cases the voyage identification algorithm codes a voyage as a round-trip cabotage voyage when it should be an outbound voyage followed by an inbound voyage. Future work can improve the split across the categories.

Table 2
Comparison of ICCT-estimated emissions with reported EU monitoring, reporting, and verification emissions for 2022

	ICCT-estimated emissions (Mt CO_2)	EU MRV-reported emissions (Mt CO_2)
Inbound	39	48
Outbound	35	44
Cabotage (Intra-EU)	45	36
In EU port	5	9
Total	**124**	**137**

CONCLUSIONS

We estimate that a U.S. MRV would cover 103 Mt of CO_2e from ships on voyages to, from, or between U.S. ports in 2022. Our estimates are much larger than official U.S. estimates of maritime emissions of 32–45 Mt CO_2e because we included emissions from voyages that occurred outside of U.S. waters. Approximately 80% of U.S. MRV emissions are from international voyages, while the remaining 20% are from domestic. Emission concentrations occur along the coasts, near major port cities, and along key international shipping routes. The data also reveal that container ships, cruise ships, and LNG tankers together account for 58% of total emissions.

If the United States levied a fee on 50% of international voyage emissions and 100% of cabotage and in-port emissions, it could generate between $4.5 billion and $15 billion annually, depending on the GHG price.

Implementing a U.S. MRV program would address several crucial needs. Such a system would fill data gaps in current maritime emissions estimates, align U.S. practices with the European Union, which has already established an MRV program, and set

15 EU MRV 2022 Public Emission Report, Version 222, dataset, September 4, 2024, https://mrv.emsa.europa.eu/#public/emission-report.

a precedent for other nations considering similar initiatives. Furthermore, it would enable the United States to effectively monitor progress toward both domestic and international climate objectives, including the ambitious target of achieving net-zero GHG emissions from maritime shipping by 2050. Given that more than half of ships that would have reported to a U.S. MRV program in 2022 were already reporting to the EU MRV the same year, compliance with a U.S. MRV program should be manageable for shipowners.

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