Marine Shipping Emissions Mitigation

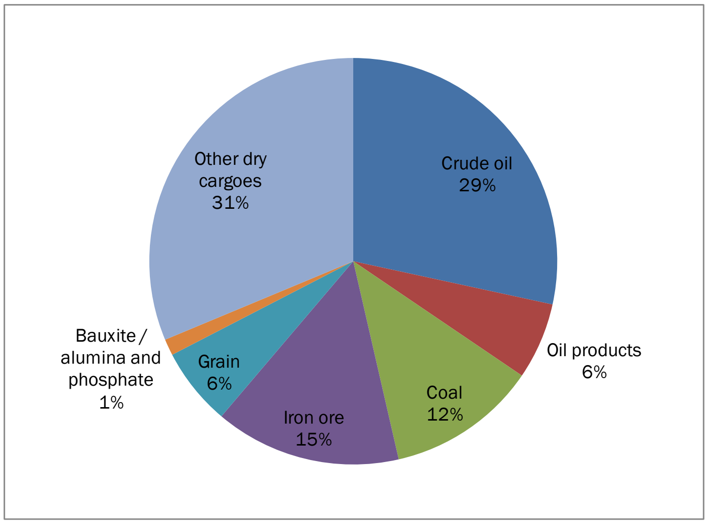
Quick Facts

- The global marine shipping sector is responsible for approximately 1.5 percent of global greenhouse gas emissions from anthropogenic sources.
- Under "business-as-usual" conditions, emissions from the global shipping fleet are expected to double by 2050.
- Shipping's greenhouse gas emissions could be curtailed through changes in operational practices, improving the fuel efficiency of ships, and burning lower-carbon fuels. Combined together, these changes could reduce shipping emissions by 62 percent below "business-as-usual" projections in 2050, which would mean emissions would stay at roughly current levels despite very large increases in shipping volume by mid-century.
- The international dimension of global shipping complicates policy efforts to reduce emissions. Working with and through transnational actors will be an essential step to forging meaningful, global regulations.

Background

Marine shipping—both domestic and international—plays a vital part in the globalized world, moving goods both within and between countries. Demand for global shipping has steadily risen to transport goods between markets as international trade has increased. From 2000 to 2007, the volume (in tons) of world merchandise exports increased an average of 5.5 percent per year (nearly twice as fast as world GDP), with over 80 percent of that trade volume moved via ship.[1,2] Figure 1 shows the composition of world seaborne trade in terms of ton-miles of shipping. While low-value, high-volume merchandise categories dominate the seaborne trade in terms of volume, the World Trade Organization (WTO) estimates that manufactured goods account for more than 70 percent of the total value of world merchandise trade.[3]

Figure 1: World seaborne trade by type as a percent of total ton-miles[4]

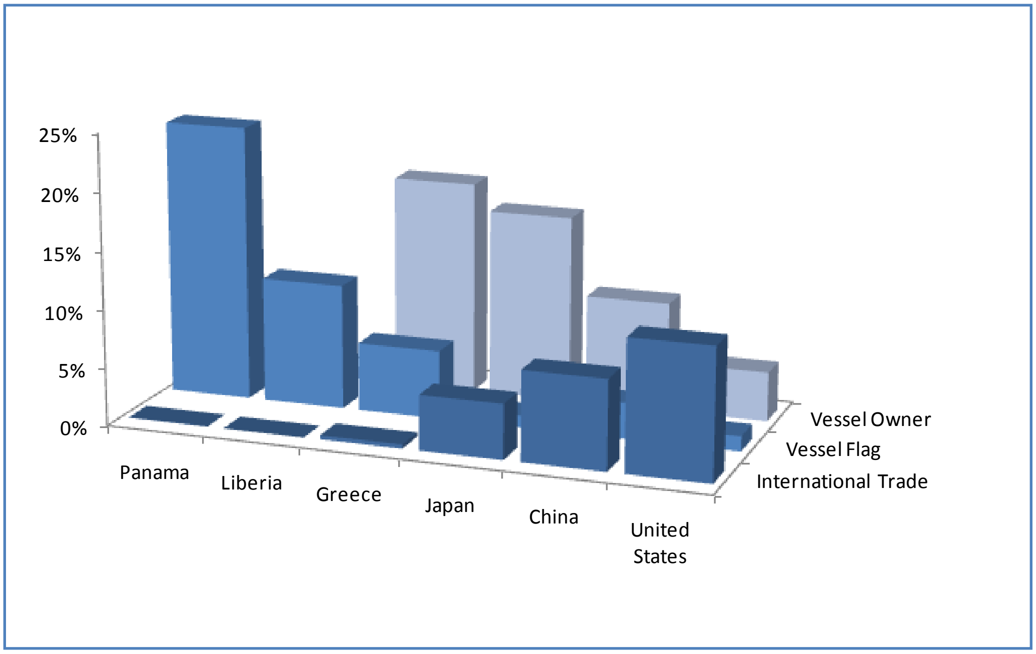


Greenhouse gas (GHG) emissions from shipping have increased in tandem with this rise in demand. While information about global shipping is less readily available than for other transport sectors, it is estimated that shipping accounts for 1.5 percent of global anthropogenic GHG emissions each year.[5] International shipping—movement of goods between countries—comprises nearly 85 percent of these emissions. The remaining share of emissions results from domestic activities, such as recreational boating, and movement of goods within a country's own borders.[6]

There are a number of strategies that could help address GHG emissions from marine shipping. Shipping-related GHG emissions can be mitigated by increasing efficiency (i.e., decreasing fuel consumption per ton-mile) and using less GHG-intensive fuels or power sources.[7] Operational measures, such as speed reduction, offer a large and near-term mitigation option, while improving the energy efficiency of new ships and switching to alternative fuels present longer-term options. Despite the emission reduction options available, demand for shipping is growing so rapidly that even aggressive action to exploit all available mitigation strategies is likely only to slow the growth in GHG emissions from the global shipping fleet, perhaps limiting absolute emissions from shipping to roughly current levels despite very large increases in ton-miles of shipping.[8]

The global nature of marine shipping complicates efforts to mitigate emissions from the sector. Ownership of the international shipping fleet is especially complex—a ship owned by a company incorporated in Greece could be registered to fly a Panamanian flag, yet move goods from India to Italy. These political realities greatly complicate assignment of responsibility for GHG emissions from international shipping and must be taken into account when designing policies to address emissions from international shipping. Figure 2 below illustrates the differences between marine vessel ownership, vessel registration, and the value of trade shipments.

Figure 2: Comparison of International Trade (Percent of Global Value of Merchandise Trade), Vessel Flag (Percent of Global Deadweight Tons, DWTs), and Vessel Owner (Percent of Global DWTs) by Country



Description

Strategies for reducing GHG emissions from global marine shipping can be broken down into three categories: operational changes that reduce fuel consumption, technological advances that improve ship fuel efficiency, and alternative fuels with lower net lifecycle GHG emissions. These three avenues to mitigating emissions are discussed below.

- **Operations**
  Modifying operational practices of the global shipping fleet could reduce emissions across the entire sector. Immediate reductions in GHG emissions are available from all ships by reducing speed. For example, decreasing speed by 3 knots (3.5 miles per hour) for a typical container ship at average speed reduces the resistance of the ship's hull against the water by 50 percent, thus requiring less energy (and thus less fuel consumption and associated GHG emissions) to propel the ship.[9] However, reducing speed would also reduce shipping capacity since any given vessel would supply fewer ton-miles of transport service since it could cover fewer miles in a given period of time. To maintain current shipping supply with reduced average speeds, more frequent trips or increased ship utilization (i.e. load factors) would be required. Despite this, most studies conclude the net effect of decreasing speed could reduce GHG emissions. Other operational strategies can mitigate reduced shipping capacity from slower speeds; these include increased port efficiency and faster loading techniques, improved routing, decreased turnaround times, and streamlined maintenance.

- **Ship Efficiency**
  Technological options for more efficient new ships include larger ship sizes, hull and propeller optimization, more efficient engines, and novel low-resistance hull coatings. For example, a single large ship with the same cargo capacity as two smaller ships not only weighs less in total, but also has less hull-area in contact with the water, thereby reducing resistance and lowering the energy required for propulsion. As such, building larger ships could increase the fuel efficiency of the global fleet; however, some practical limitations to increasing ship size exist, including, for example, canal sizes, harbor depths, and port cargo handling equipment. Further gains can be made by optimizing hull and engine design. Currently ships use diesel engines that operate efficiently within a narrow range of speeds. Replacing those engines with a series of smaller diesel-electric engines would allow for more efficient engine operation at a greater range of speeds. Ships could also make use of combined-cycle diesel engines that transform waste heat into useable energy.[10] The most advanced efficiency technologies involve novel hull coatings (such as special polymers or air bubbles) that reduce hull resistance against the water.

- Alternative Fuels
  Currently, ships generally burn an inexpensive, carbon-intensive fuel known as heavy, or residual, fuel oil. Replacing heavy fuel oil with less carbon-intensive marine diesel oil or liquefied natural gas could result in GHG reductions in the near to medium term. Other options include alternative energy sources, such as wind power (from sails) or biofuels. Longer-term opportunities include powering ships with solar photovoltaic cells and hydrogen fuel cells.

Environmental Benefit / Emission Reduction Potential

Applying the full range of mitigation strategies described above could reduce GHG emissions from global shipping by as much as 62 percent below "business-as-usual" (BAU) projections in 2050, which would mean global marine shipping emissions would be at roughly today's level at mid-century despite an expected doubling in shipping volume. Without intervention, analysts project emissions from global shipping to more than double by 2050. Table 1 and Figure 3 summarize the emission reduction potential for the global shipping sector.

Operational changes, such as reducing ship speeds, optimizing ship turnaround times by streamlining port logistics, and tailoring shipping routes to real-time weather and ocean current conditions are already expected to produce significant efficiency gains under "business as usual" due to non-climate-related factors, such as rising fuel prices. With additional support through policy interventions, incremental operational changes could reduce GHG emissions by an estimated 27 percent below BAU projections by 2025.

Advances in shipping technology hold the potential for additional GHG reductions. Larger ships are more efficient than smaller ones. For example, doubling the size of a vessel could increase energy efficiency by as much 30 percent.[11] Such changes in ship design and propulsion could further reduce GHG emissions by 17 percent below BAU projections for mid-century.

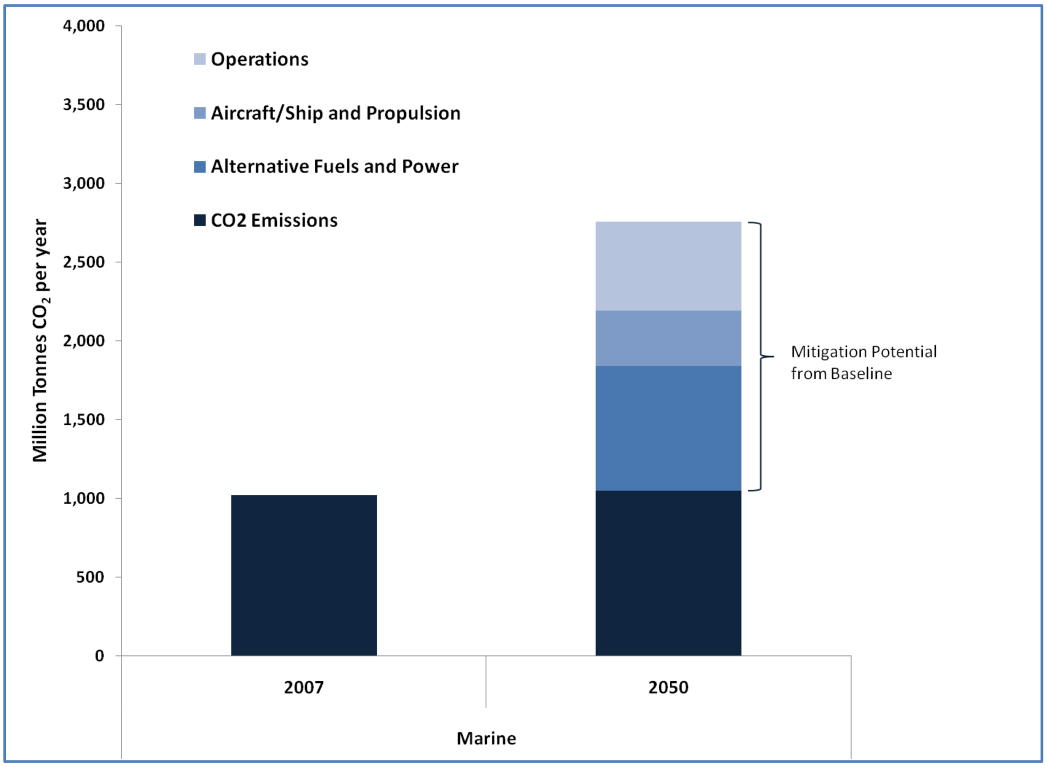
Only a small degree of switching to alternative fuels is projected under "business as usual." Replacing heavy fuel oil with modified diesel oil, a slightly less carbon-intensive fuel, could reduce CO_2 emissions by 4 to 5 percent.[12] Shifting to liquefied natural gas could reduce GHG emissions by as much as 15 percent.[13] When combined with other alternative fuel sources, such as wind power (sails) or biofuels, switching to alternative fuels could yield reductions of 38 percent below BAU GHG emissions projections by 2050.

Table 1: Global GHG Emissions Abatement for Marine Shipping Sector

Category	**Measures**	**Reductions from "Business as Usual" in 2050 (%)**
Operations	Speed reduction, optimized routing, reduced port time	27**
Ship Design and Propulsion	Novel hull coatings, propellers, fuel efficiency optimization, combined cycle operation, multiple engines	17
Alternative Fuels	Marine diesel oil (MDO), liquefied natural gas (LNG), mind power (sails)	38
Total Reduction from BAU Emissions in 2050		**62**

*** These reductions could be met by 2025*

Figure 3: Global GHG Mitigation Potential from the Marine Shipping Sector



Cost

The costs of achieving GHG reductions from marine transportation through the options described above are uncertain in many cases. One study estimated that a price on carbon of $36 to $200 per metric ton of CO_2 would be needed to induce ships to reduce travel speed;[14] other researchers have calculated that prices in a narrower range of $50 to $100 per ton may induce such behavioral change.[15] The costs of researching and developing novel shipping technologies or implementing optimized routing schemes are highly uncertain.

There is also little known about the cost of switching ships to lower-carbon fuel. Currently, ships can buy fuel from anywhere around the world, bunker it in their holds, and thereby circumvent reporting requirements on how much or what type of fuel they use. On average, heavy fuel oil costs $0.95 per gallon. This low price makes it difficult for other fuels to compete against heavy fuel oil. Liquefied natural gas, modified diesel oil and biodiesel, for example, are 20, 70 and 480 percent more expensive, respectively.

Current Status of Shipping Emissions Mitigation Efforts

The global shipping sector has been slow to mitigate its GHG emissions. As mandated by the Kyoto Protocol, the International Maritime Organization (IMO) has formed a working group to address emissions from global shipping. To date, the organization has introduced a number of voluntary initiatives—such as the Energy Efficiency Design Index –which aim to improve the fuel efficiency of newly built ships.

Technological advances in the sector have also been slow to take hold. One study found that shipping fuel efficiency has undergone little overall change in the past 20 to 30 years.[16] Against this backdrop, there exist a few success stories. For example, a small number of ships operate using hydrogen fuel cell technology.[17] While limitations exist, it has been argued that fuel cells are best suited for a few large vehicles that are operated by a small but highly trained crew of workers—such as those vehicles used in international shipping.[18]

Obstacles to Further Deployment of Shipping Emissions Mitigation Strategies

- **International Jurisdiction**
  The international dimension of global shipping complicates the mitigation of emissions from the sector. To date, no paradigm exists for assigning the emissions from a transnational voyage to an individual country. Countries that engage in relatively little international trade (e.g., Panama) own and flag the majority of the international shipping fleet. In addition, international vessels enjoy a great deal of flexibility regarding the country in which they register and thus which nation's flag they fly onboard, and the flag a vessel flies often determines the regulations it faces. Currently ships choose flags in large part in order to minimize fuel and regulatory compliance costs. Effective GHG emission reduction efforts must avoid creating incentives for vessels to adopt certain flags in an attempt to escape GHG reduction policies.

- **Lack of Basic Sector Information**
  Policymakers require a better understanding of the mechanics of international shipping. Effectively regulating GHG emissions from the sector requires better knowledge of current practices—such as fuel use, costs, and technological advancements. Current policymaking is limited by a lack of primary information about the activities of the global shipping fleet.

Policy Options to Promote Shipping Emissions Mitigation Strategies

- **Carbon Price**
  Coordinated policies to ensure that international shipping firms face a carbon price associated with their GHG emissions would spur operational changes to reduce emissions and investments in more fuel-efficient vessels/engines and alternative fuels. In addition, a carbon price linked to the carbon price(s) applied to other economic sectors would promote GHG emission reductions from marine transport to the extent that they are cost-effective compared to equivalent emission reductions from other economic sectors.

- **Assignment of Emissions to Home and Destination Port Nations**
  Overcoming the intricacies of ship ownership and flagging practices to regulate emissions could be accomplished by assigning responsibility for shipping emissions between origin and destination ports. Thus, the emissions from a ship moving goods from China to the United States would be the joint responsibility of those two trading nations, not the ship owner or flag state. Provisions would be needed to account for multi-stop trips and to incorporate the principle of common but differentiated

responsibilities of developed and developing nations to mitigate GHG emissions. This would allow nations to address their share of emissions from marine transportation appropriately.

- **Targeted Government Sponsored Research and Development and Technology Transfer**
  The slow speed of technological advancement in global shipping could be enhanced through government support of research and development (R&D). While the United States does not manufacture a large number of ships, many component parts originate in the United States. Combining those improvements with increased international collaboration and technology transfer could help facilitate R&D across multiple countries.

- **Increased Government Spending on Infrastructure**
  Enhancing port efficiency has the same impact as expanding global shipping capacity, thereby decreasing the number of trips needed to move the same volume of goods. Accommodating larger, more efficient ships would require expanding ports via dredging. Government spending could also focus on improving cargo-handling technology in order to enable faster loading and unloading times. Better integrating ports with land transportation networks could also help alleviate delays.

Related Business Environmental Leadership Council (BELC) Company Activities

- BP
- Cummins
- Lockheed Martin
- Royal Dutch/Shell
- United Technologies

Related Pew Center Resources

Climate TechBook *Biofuels Overview*

McCollum, David, Gregory Gould, and David Greene, *Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies*, Prepared for the Pew Center on Global Climate Change, 2009.

Further Reading / Additional Resources

International Marine Organization (IMO), *Prevention of Air Pollution from Ships - Second IMO GHG Study 2009 - Update of the 2000 IMO GHG Study - Final report covering Phase 1 and Phase 2*, 2009.

United Nations Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2009*, 2009.

MARINTEK (2000). Study of Greenhouse Gas Emissions from Ships. Final Report to the International Maritime Organization. Trondheim, Norway, Performed by Norwegian Marine Technology Research Institute (MARINTEK) for the International Maritime Organization.

Eyring, V., H. W. Köhler, et al. (2005). "Emissions from international shipping: 2. Impact of future technologies on scenarios until 2050." J. Geophys. Res. 110.

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[1] World Trade Organization (WTO), *International Trade Statistics 2008*.

[2] United Nations Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2008*, 2008.

[3] UNCTAD, 2008.

[4] UNCTAD, *Review of Maritime Transport 2009*, 2009, see Table 5. Grain includes wheat, maize, barley, oats, rye, sorghum, and soya beans. Manufactured goods are included under other dry cargoes.

[5] McCollum, David, Gregory Gould, and David Greene, *Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies,* Prepared for the Pew Center on Global Climate Change, 2009. Unless otherwise noted, all facts, tables, and figures in this document are drawn from this Pew Center report.

[6] The rise of alternative modes of transport, such as trucking and rail, has curtailed the use of domestic shipping to transport goods within country. See McCollum et al. 2009, page 4.

[7] A ton-mile is a standard unit used to describe shipping volumes; it refers to the transport of one ton of cargo one mile.

[8] International Maritime Organization (IMO), *Updated Study on Greenhouse Gas Emissions from Ships*, 2008.

[9] MARINTEK, *Study of Greenhouse Gas Emissions from Ships: Final Report to the International Maritime Organization*, 2000. Performed by Norwegian Marine Technology Research Institute (MARINTEK) for the International Maritime Organization.

[10] Ibid.

[11] Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, 2000.

[12] MARINTEK, 2000.

[13] IMO, 2008.

[14] Corbett, J., H. Wang, et al., "The Impacts of Speed Reductions on Vessel-Based Emissions for International Shipping," *Proceedings of the 88th Annual Meeting of the Transportation Research Board*, 2009.

[15] McCollum et al. 2009.

[16] Faber, J., B. Boon, et al., *Aviation and Maritime Transport in a Post 2012 Climate Policy Regime*, Netherlands Environmental Assessment Agency, 2007.

[17] Eyring, V., H. W. Köhler, et al., "Emissions from International Shipping: 2. Impact of Future Technologies on Scenarios until 2050," *Journal of Geophysical Research*, 2005.

[18] Farrell, A. E., D. W. Keith, et al., "A Strategy for Introducing Hydrogen into Transportation," *Energy Policy* 31(13): 1357-1367, 2003.