Options for Reducing International Maritime Shipping Emissions: Opportunities and Constraints in an Era of Transformative Technologies

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Trade has potentially significant climate change impacts due to the transportation involved in moving goods. The main focus of climate change discussions has been carbon dioxide as a result of fossil fuel combustion. Yet, in the case of maritime shipping, black carbon particles represent another source of possible high-impact climate change. The international community, including the International Maritime Organization, has thus begun to take steps to limit emissions from the maritime sector. The most recent developments include an International Maritime Organization "Initial Strategy," which highlights, among other things, a target of reducing international maritime shipping's "total annual [greenhouse gas] emissions by at least 50% by 2050 compared to 2008."[1] While the Strategy specifically addresses only greenhouse gases, its adoption provides a timely opportunity to analyze possibilities for reducing ships' other climate-change-related emissions, in particular black carbon. This paper identifies technological and other opportunities for reducing such emissions, while also noting potential constraints on success.

Nature and Significance of International Maritime Shipping's Emissions

Ships' emissions cause harm in more ways than is commonly recognized. Emissions of fine particulate matter by shipping traffic from tens of thousands of trips per year through channels connecting the North Sea and Baltic Sea result in as many as 10,000 deaths annually from respiratory and cardiovascular diseases.[2] In China alone, ships' emissions contribute to 180,000 deaths per year.[3] One large cruise ship emits as much particulate matter per day as a million cars.[4]

All types of vessels engaged in international commerce use diesel engines for propulsion and shore-side auxiliary electric power, creating harmful emissions. Diesel engine emissions include carbon dioxide, black carbon, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Among these emissions, black carbon is of special interest because of its effects on public health, food production, and climate change.

Climate change science has been slow to give adequate attention to black carbon. Citation counts in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports provide a rough indicator of the increased interest in black carbon in the climate change science community. In the first IPCC Assessment Report, there was only one literature reference to black carbon. By the fifth report, there were more than a hundred. Because of a previous lack of data, it was only a few years ago that black carbon was included in models of Arctic region temperature changes—an omission that contributed to the early underestimated projections of ice melt in the region.[5]

Black carbon, an air pollutant emitted as tiny particulates that are narrower than a human hair, occurs together with organic carbon in the soot from marine diesel engines. Organic carbon is a global coolant because of its reflective capacity, and the ratio of black carbon to organic carbon in the soot is an important determinant of the net warming/cooling effect. However, diesel engines emit a high ratio of black carbon to organic carbon—around nine to one for such engines in maritime shipping.[6] Ships' diesel engines are thus unambiguously net global warming sources.[7]

Like many other carbon pollutants, black carbon is considered a global warming "aerosol" because some black carbon particles travel great distances as airborne matter. Other black carbon particulates fall to the ground as depositions in local and regional areas near their sources. Black carbon has a global warming potential on the order of thousands of times greater than carbon dioxide over 20 years.[8] Altogether, worldwide black carbon emissions—which total approximately a billion tons per year—account for roughly 55 percent as much as the total global warming impact of carbon dioxide.[9] As a public health problem, black carbon causes tens of thousands of deaths worldwide per year from lung cancer, heart disease, asthma, as well as brain development disorders in children and other respiratory and cardiovascular problems.[10] In addition, black carbon emissions threaten food production and destroy hundreds of millions of tons of rice and other crops per year worldwide due to particulate deposits on soil and plant leaves.[11]

From a climate change policy perspective, the central problem is that ships' emissions are expected to rise significantly in a business-as-usual scenario because of the increasing volume of traded goods and passengers on cruise ships. One frequently cited projection—made before the agreement in 2018 on the International Maritime Organization Initial Strategy—suggests that carbon dioxide emissions will increase by between 50 percent and 250 percent by 2050 compared with 2012.[12] Studies estimate that black carbon emissions from ships will triple by 2050 compared with 2004, even with recent fuel efficiency regulations in place.[13] The frequently cited statistic that shipping has been responsible for only 2 to 3 percent of global carbon dioxide emissions is therefore misleading and incomplete for analyses of future policy options. In business-as-usual projections, its share could be as high as 17 percent by 2050.[14]

Although the estimates of future global emission levels vary considerably, it is important to note that black carbon emissions will not be evenly distributed. The portions of black carbon emissions that accumulate on the ground tend to be more highly concentrated in populous coastal regions near heavily used shipping lanes and in major urban areas near seaports.[15] Policy makers should take into account this geographical variation as they asses policy options.

Opportunities and Constraints

Maritime Shipping Technologies

Numerous potential technological and operational solutions are available for reducing emissions from shipping below business-as-usual projections:[16]

- Emission control equipment for diesel engines, e.g. diesel particulate filters;
- Alternative propulsion systems, e.g. liquefied natural gas, electricity, wind;
- Operations, e.g. speed reduction;
- Port facilities, e.g. harbor-side electricity sources as substitutes for on-board auxiliary diesel engines; and
- Monitoring systems for regulatory compliance enforcement.

International technology transfers from leading countries to the rest of the world have a great potential to reduce black carbon emissions.[17] Currently, there is an unusually large gap between technological leaders and laggards in the international maritime shipping industry, including regional and national patterns among the leaders and laggards. Firms in northern Europe deserve attention for their leadership in many categories. The first electric-powered ferry is in service between Denmark and Sweden. German firms continue to be world leaders in the development of wind power on large ocean-going vessels. The world's largest container shipping firm, A.P. Moeller-Maersk of Denmark, jointly with IBM, is leading the first pilot project testing the potential of “blockchain” electronic tracking systems to improve the efficiency of the antiquated paper-based logistical documentation systems.[18] The potential policy relevance of such “distributed ledger systems” is their use for monitoring compliance with regulations to reduce emissions. Altogether, these developments indicate that the industry is still in the early stages of an era of disruptive technologies—with transformative implications for industry economics, management, and regulation.

Industry Economics

More than 50,000 sea-going vessels are currently in operation, with about 40 percent owned by firms in Greece, Japan, China, Germany, and Singapore.[19] These numbers include container ships, cruise ships, tankers, large ferries, and other types of sea-going vessels. In specific sectors, the patterns among leading firms and countries vary greatly. For instance, in the container sector, the principal operators own about half the ships they operate and charter the other half. Among them, three of the top four are A.P. Moeller-Maersk (Denmark), MSC (Switzerland), and CMA GCM (France)—the other is COSCO (China Ocean Shipping Company) (China). Together, the three top firms account for almost 40 percent of the world’s container ship capacity.[20] On the positive side, these three firms happen to be based in countries that have taken leadership positions on climate change issues. The industry’s demand for new technologies is thus increasing and offering new economic opportunities for their manufacturers—and some firms in the financial and insurance sectors are advocating more sustainable industry practices for their maritime industry clients.[21]

International Maritime Organization Politics and Policies

The International Maritime Organization's willingness to tackle climate-change-related emissions has been underwhelming.[22] Members of the Organization took more than two decades to agree on the "Initial Strategy" noted above. With respect to black carbon, they met on and off for five years before agreeing on a definition in 2005 and, as of early 2019, after many years studying black carbon measurement methods and reporting protocols, the Organization's Subcommittee on Pollution Prevention and Response of the Marine Environment Protection Committee was still studying the issues. On the other hand, International Maritime Organization members have recently adopted fuel efficiency and ship design regulations, thereby revealing a willingness to address emissions issues with new policies.[23] These positive developments became possible in part because Scandinavian and other progressive European members have assumed leadership roles on climate change issues in the Organization.

A number of International Maritime Organization regulations concerning fuels, ship design, and operations aim to reduce greenhouse gas emissions. Organization members adopted efficiency standards in 2011 in the form of amendments to the International Convention for the Prevention of Pollution from Ships. The regulations include an Energy Efficiency Design Index for new ships and the associated methods of calculation and certification as well as a requirement for a Ship Energy Efficiency Management Plan for all ships. The fuel efficiency regulations are mandatory, tangible, and in force—and will evolve over time. These efforts highlight that the International Maritime Organization is more progressive than the International Civil Aviation Organization in addressing climate change issues. Among the reasons for the differences between the two organizations is the greater U.S. interest and influence in the latter.

World Trade Organization (WTO) Agreements

The International Maritime Organization does not have a monopoly on international shipping policy making. World Trade Organization (WTO) agreements can, either directly or indirectly, help to reduce emissions from maritime shipping. WTO agreements on subsidies, services, goods, technical standards, trade-related intellectual property rights, and trade-related investment measures are particularly relevant to reducing emissions from the shipping industry.[24]

Numerous studies address the issue of fossil fuel subsides and the topic has emerged in recent WTO discussions.[25] Diesel fuels, among many other fossil fuels, are widely subsidized around the world—such subsidies are thus candidates for action at the WTO. In addition, regulators treat international maritime diesel fuels, like international aviation fuels, as international "bunker fuels" excluded from sales taxes.[26]

The WTO disputes cases that the European Community and Japan brought against Korea's shipbuilding as General Agreement on Tariffs and Trade subsidy cases; Korea's case against the European Community reminds us that subsidy issues extend to the ships themselves as well as to the diesel fuel that powers them.[27] One could argue that shipbuilding subsidies create an oversupply of large ships with current-generation technologies that undermine investments in more fuel efficient, advanced technologies that could reduce carbon emissions.

The WTO services agreement, the General Agreement on Trade in Services, explicitly includes "maritime transport services." But liberalization commitments in the industry have lagged behind those in other services sectors. The General Agreement on Trade in Services negotiations on maritime services were temporarily suspended and then restarted in 1994 before its entry into force at the time of the establishment of the WTO in 1995. Negotiations ended again temporarily and restarted in 2000 as part of the new round of the General Agreement on

Trade in Services. Several proposals and some commitments have emerged since then. WTO members have yet to address issues such as restrictions on foreign equity ("commercial presence") in freight transport services and auxiliary services and access to port services. Some 63 members, not including the United States, have made "maritime transport" commitments. Some of the commitments—and their absence in some cases—are relevant to the topic of this paper because they affect international technology transfer. Along with the protectionist policies of many other countries, the United States Jones Act is a prominent example of maritime shipping protectionism. The Act reserves domestic trade between U.S. ports to ships that are built in the United States and are owned and crewed by U.S. citizens. The Jones Act is a conspicuous exception to the trade liberalization principles of the General Agreement on Trade in Services. One of the consequences of the Jones Act is that the United States-based shipping industry has been a laggard in efficiency and technological change.

The Agreement on Trade-Related Investment Measures concerns goods and makes explicit that some General Agreement on Trade in Services articles apply to international investments. The Agreement creates an issue in international investments and technological advances in seaports. Standard seaport legal and managerial arrangements are increasingly international joint ventures and/or long-term contracts with a local governmental agency as owner of the port land, and a foreign and/or local corporation as owner and operator of port facilities. This arrangement creates the potential for local content requirements that inhibit international investor participation and international technology transfer. Port infrastructure expansion plans in the 21st Century Maritime Silk Road portion of China's One Belt One Road initiative are pertinent, as are India's and South Korea's plans for port expansions.[28] Plans for major port expansions will create opportunities for addressing carbon emissions at large and create long-term transport infrastructure facilities. For the purposes of this paper, the key questions are: Will these countries, and their public and private sector partners, install equipment and adopt regulations to limit carbon emissions? If so, what will such measures look like? When and how will they be enacted? Will these ports become international leaders or laggards in addressing maritime shipping climate change issues? Will there be local content restrictions affecting equipment choices?

In Europe, port authorities follow regulations by the European Union and by Norway to track the emissions of ships entering their ports. This is the initial step in a long-term regulatory development process that includes reporting and verification of emissions, fuel consumption, distance travelled, and cargo carried—all already in effect since 2018.[29]

Other regional issues concern maritime shipping in the Arctic.[30] The Arctic sea ice melt could increase trans-Arctic international maritime freight traffic, which will have significant implications on traffic from China and South Korea through the Arctic region on the way to Northern Europe. Oil and gas exploration and cruise ship traffic are also expected to increase in the region. A cruise ship with 1,500 people on-board traveled from Anchorage, Alaska, to New York City via the Arctic Ocean in 2016 and a similar voyage took place in 2017. Therefore, two key questions are: How much and how soon will Arctic shipping traffic increase, and with what effects on emissions?

United States Climate Change and Trade Politics

The United States was one of only four International Maritime Organization members that "reserved" their position on the adoption of the Initial Strategy to limit greenhouse gases.[31] More generally, the turmoil and hostility exhibited by the current U.S. presidential administration toward the international global trade and investment regime—and the international climate change regime—clearly pose constraints on international cooperation.[32] The International Maritime Organization has avoided the conflict between (a) the trade policy principle of non-discrimination among countries and (b) the climate change policy principle of *common but differentiated responsibilities* among countries. The International Maritime Organization's policies impose obligations on ships and ship owners, not national governments. This approach also partially circumvents regulatory enforcement and other legal issues created by the system of "flag of convenience" whereby ships are registered in a country other than the home country of the ship owner. With some exceptions, major ports are not in "flag of convenience" countries. This is important because the International Maritime Organization's regulations are typically enforced by port authorities and by national navies with jurisdictions in the adjacent coastal areas.

At the same time, new opportunities are arising for policymaking to address trade and climate change issues more actively—even in the absence of United States leadership. National and local governments, as well as regional organizations are developing innovative solutions to reduce emissions from the shipping industry. The ports of Los Angeles and Long Beach, for instance, became world leaders in reducing black carbon emissions by offering financial incentives to vessels that reduce their speed as they approach the harbors.[33]

Policy Recommendations

Trade and climate change policies at multiple levels of governance can incentivize more rapid and widespread uptake of technological solutions. International trade and investment policies can affect the development of climate change friendly—or climate change unfriendly—technologies through several roles.

One is the familiar role of governments committing to non-discrimination principles and providing market access through liberalization of tariffs and the removal of non-tariff barriers. The International Technology Agreement or the Environmental Goods Agreement negotiations, for example, aim to reduce trade barriers through liberalization. These agreements could reduce tariffs on diesel particulate filters, batteries, and other climate change friendly equipment for ships.

Another role is to prohibit—or allow—subsidies for particular fuels or technologies; for example, fossil fuel subsidies versus clean energy subsidies. Issues about reducing the former and increasing the latter have long been on the trade and climate change agenda, without a resolution to date. Carbon intensive bunker fuel used in shipping is a good candidate for such measures.

A third role is to use trade as a basis for sanctions or rewards ("sticks" or "carrots") to induce compliance with regulations. This approach could be a core feature of "climate change clubs" to incentivize participation in the "club" and compliance with its rules and it could be used in the context of a regulatory framework for limiting shipping emissions.[34]

These policy roles, in combination with the multiple levels of governance and the several types of technological changes that are emerging, create a broad range of opportunities. At the local level, port authorities around the world can follow the examples of ports in Europe and North America to provide more energy efficient and cleaner energy services for ships and, at the same time, require them to follow more energy efficient operational practices. At the bilateral and regional levels, free trade agreements can include tariff reductions on diesel particulate filters and other equipment that reduce emissions. At the plurilateral level, the International Maritime Organization can advance energy efficiency and emission reduction measures by improving regulatory monitoring and enforcement procedures. At the multilateral level, WTO members can make agreements on subsidies and local contents more supportive of climate change action. However, additional analytic work is required in order to quantify the potential impacts of such policies and to prioritize negotiating agendas and venues. The following four sets of policy issues emerge concerning technologies that can reduce emissions: diesel particulate filters, electric propulsion, port auxiliary electric power sources, and "blockchain" logistical management systems.

Diesel Particulate Filters

Although tens of millions of diesel particulate filters are in use in motor vehicles around the world, the number of current marine applications is quite small. While some ferries and tugboats—such as the ones in the port of Los Angeles—are outfitted with diesel particulate filters, these filters are much smaller than the ones needed for container ships, tankers, cargo ships, and other large vessels.[35] Scaling up for such large vessels is a major technological challenge.

An elementary trade policy issue for diesel particulate filters concerns how they should be classified for customs purposes. Although this may seem an esoteric technological and legal question, it can have significant consequences. Among the many potential classification issues about marine diesel particulate filters is how they are different from filters made for vehicles and the scale of their application. Clarity about future tariff rates for large marine filters may be problematic. For instance, in a United States International Trade Commission decision in response to an inquiry about a Japanese-made particulate filter for automobiles, the Commission ruled that such filters were *not* a "part of motor vehicles" with a duty rate of 2.5 percent, but were classified as "other" under "ceramic wares for laboratory, chemical or other technical uses" (6909.19.5095), with a 4 percent duty.[36]

Policy Recommendation: The World Customs Organization, International Organization for Standardization, and World Trade Organization should undertake analyses to clarify tariff classification and tariff rate issues concerning maritime diesel particulate filters.

Electric Propulsion

Two technological developments have promising applications for electric marine propulsion—one is on-board solar, and the other is storage batteries that are charged by land-based electric sources. The former is in principle a climate-change-friendly alternative to diesel fuel. The latter could be a clean energy alternative, depending on the source of electricity, with solar or wind at one extreme, and coal at the other.

Policy Recommendation: There should be a certification process that verifies the climate-change-friendliness of the electricity source used to charge a ship's batteries.

Auxiliary Electric Power Sources in Ports

As with the electric power sources used to charge ships' electric propulsion systems, the sources of electricity used as alternatives to a ship's diesel-powered auxiliary engines must be climate-change-friendly.

Policy Recommendation: There should be a certification process that verifies the climate change friendliness of the electricity source used as an alternative to a ship's auxiliary engine.

"Blockchain" Electronic Information Systems

Commonly defined as "distributed ledger" systems, "blockchain" systems for international maritime logistical management might create opportunities for developing and sharing data for regulatory compliance, including compliance with emissions regulations. Interest in "blockchain" applications in maritime shipping is rapidly growing, with potentially transformative implications for the entire industry and its supporting sectors and customers worldwide.[37]

"Blockchain" systems are pertinent to this paper's focus on trade policies to the extent that the systems' development and implementation will depend on internationally traded goods and services as well as technology transfers. Several possible systems are in the early stages of development. Danish shipping company A.P. Moeller-Maersk and U.S. computer information technology firm IBM are developing the most commonly noted system, with the participation of 22 national governments in the European Union and a total of more than 90 governmental agencies, shipping companies, supply firms, and non-governmental organizations.[40] Several key questions emerge in the context of this paper's focus: How soon and how widely will "blockchain" technology be deployed? Will it be adaptable to monitoring applications for regulatory compliance with emission reductions? How can international trade, investment, and technology transfer policies contribute to its deployment and success? Alas, it would be premature to answer such questions at this early stage, but the questions are likely to be on policy makers' agendas, perhaps for many years to come.

Policy Recommendation: "Blockchain" development and testing projects should involve explorations of the potential for "blockchain" maritime logistical systems to include monitoring for verification of compliance with emission reduction regulations. The exploration should include inputs from maritime legal, accounting, and insurance experts; as well as shipping, shipbuilding, equipment manufacturing, and information technology experts; and of course governmental port, customs, and regulatory agencies—all as contributors to an International Maritime Organization-sponsored regulatory monitoring and enforcement project.

An inescapable implication of the evolving technologies and policies noted in this paper is that the international maritime shipping industry is entering a new era of transformative technological changes. Though many of the issues and proposals of this paper are outside traditional trade policymaking concerns, they indicate new emerging issues as a result of technological transformation. International trade, investment, and technology transfer policies are inextricably interlinked with technological transformations—and thus facilitate or hinder efforts to curtail global climate change. The shipping industry needs innovative analysis and policy making to increase the odds for positive outcomes that will mitigate climate change. Much of the panoply of international institutions involved in trade, investment, and technology transfer issues should be in an anticipatory and planning mode as the technological transformations proceed. The entire international trade community will need to focus on the future in order to play a constructive role in addressing climate change issues and be prepared to deal with fundamentally new issues.

Notes

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[29] European Commission, "Climate Action: Reducing emissions from the shipping sector," accessed January 22, 2018, https://ec.europa.eu/clima/policies/transport/shipping_en. On its own initiative, Norway has created sub-national regional restrictions; Norwegian fjords will become the world's first maritime zero carbon emission zones by 2026. See Norwegian Centres of Expertise, "Norwegian parliament adopts zero-emissions regulations in the fjords," NCE Maritime CleanTech, accessed May 3, 2018, https://maritimecleantech.no/2018/05/03/norwegian-parliament-adopts-zero-emission-regulations-fjords/.

[30] Bryan Comer, Naya Olmer, Xiaoli Mao, Biswajoy Roy, and Dan Rutherford, Prevalence of heavy fuel oil and black carbon in Arctic shipping, 2015-2025, (Washington, DC: ICCT, 2017), https://www.theicct.org/sites/default/files/publications/HFO-Arctic_ICCT_Report_01052017_vF.pdf.

[31] In addition to the US, others voting against the IMO's April 13, 2018, "Initial Strategy" included Brazil, India and Saudi Arabia.

[32] The U.S. administration included several types of foreign-built vessels in its special tariff in 2018.

[33] OECD/International Transport Forum, Decarbonizing Marine Transport (Paris: OECD, 2018).

[34] Thomas Brewer, *Arctic Black Carbon from Shipping* (Geneva: ICTSD, 2015), https://www.tradeandclimate.net 23.

[35] Joe Kush, "Diesel Particulate Filter Experience on Marine Engines" (ICCT Marine Black Carbon Workshop, Ottawa, Canada, September 2014), https://www.theicct.org/sites/default/files/MECA%20Marine%20DPF%20Experience%20Sept%202014.pdf.

[36] United States International Trade Commission Rulings And Harmonized Tariff Schedule (US ITC), "Ruling NY N013892," July 20, 2007.

[37] On "blockchain" in general, see for instance, Dan Tapscott and Alan Tapscott, Blockchain Revolution*: How the Technology Behind Bitcoin and Other Cryptocurrencies Is Changing the World* (New York: Portfolio/Penguin, 2016) and UK Government Chief Science Adviser, *Distributed Ledger Technology: beyond block chain* (London: UK, Office for Science, 2016). On the specific application of blockchain technology to international maritimeshipping issues, see The Maritime Executive, "Maersk's Blockchain Solution: Ready, Set Go!," *The Maritime Executive*, August 9, 2018, https://www.maritime-executive.com/article/maersk-s-blockchain-solution-ready-set-go.