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BACKGROUND AND CHALLENGES

The International Maritime Organization's (IMO) Fourth Greenhouse Gas study shows that shipping accounted for about 2.89% of global anthropogenic carbon dioxide (CO_2) emissions in 2018. Emissions are projected to grow by up to 50% by 2050 compared to 2018 levels under plausible long-term economic and energy scenarios (Faber et al., 2020). To support the United Nations' Sustainable Development Goal 13 (SDG 13), which calls for urgent action to combat climate change and its impacts, IMO has adopted mandatory measures to reduce greenhouse gas (GHG) emissions from international shipping under IMO's pollution prevention treaty (MARPOL). In 2018, IMO adopted an initial GHG strategy to reduce total annual GHG emissions from ships by at least 50% by 2050 compared to 2008 levels and to reduce ship carbon intensity by at least 40% by 2030 (Rutherford & Comer, 2018). The IMO will revise its initial GHG strategy in 2023 which could be strengthened in two main ways: aim for zero emissions by no later than 2050 and set interim reduction targets for 2030 and 2040.[1]

The People's Republic of China (China) and the United States (U.S.) and are among the 10 IMO states with the largest interest in providing international shipping services for decades,[2] whose bilateral trade is responsible for 2.5% of the global shipping carbon dioxide emissions and 4.8% of ship-related global premature deaths caused by air pollution (Liu et al., 2019). GHG emissions from ships post a growing concern in the two countries' national emissions inventories as well. ICCT estimated that CO_2 emissions from ships navigating within 12 nautical miles from shore could account for approximately 1% of China's national CO_2 emissions inventory[3], expected to grow if left unchecked while other sectors start to decarbonize (Mao & Meng, 2022; Mao & Rutherford, 2018). For the U.S., ICCT estimates that CO_2 emissions from ships navigating in the U.S. EEZ account for 0.6 % of the U.S.'s 2020 emission inventory, as recorded by the U.S. EPA (US EPA, 2022).

China and the U.S. are both major players at the IMO. The two countries have ratified IMO's MARPOL Annex VI which deals with air emissions from international shipping. Under MARPOL Annex VI, the U.S. applied for and received an IMO-designated Emission Control Area (ECA)

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[1] https://theicct.org/zero-emission-shipping-and-the-paris-agreement-why-the-imo-needs-to-pick-a-zero-date-and-set-interim-targets-in-its-revised-ghg-strategy/

[2] Membership of IMO is classified in three categories: Category (a) 10 States with the largest interest in providing international shipping services: China, Greece, Italy, Japan, Norway, Panama, Republic of Korea, Russian Federation, United Kingdom, United States. The other two categories are: Category (b) for 10 States with the largest interest in international seaborne trade and Category (c) for 20 States elected into the IMO Council but are not elected in Category (a) or (b). Sourced here: https://www.imo.org/en/OurWork/ERO/Pages/Council-Members.aspx

[3] In 2019, China emitted 10.7 billion tonnes of CO_2. This data is sourced from World Bank, available here: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?locations=CN

which extends roughly 200 nautical miles from its coastline, within which all ships need to comply with more stringent sulfur oxides (SO_X) standards, and ships built in 2016 and later need to comply with stricter nitrogen oxides (NO_X) emission standards than the rest of the world. China, however, implements a domestic version of an ECA within 12 nautical miles from its coastline. During the establishment of IMO's initial GHG Strategy, China led the proposal of the National Action Plan (NAP) for member states to voluntarily share their experiences on maritime decarbonization to inform IMO's GHG strategy revision which was later adopted officially. Later, the U.S. spearheaded a proposal co-sponsored by Costa Rica, Norway, and the United Kingdom, to IMO's 77th Marine Environment Protection Committee (MEPC 77) to achieve zero emissions from the international shipping sector by 2050 and to establish interim targets for 2030 and 2040 for both carbon intensity and absolute emissions (MEPC 77/7/15).

At home, both countries have taken regulatory actions to control criteria air pollutants and GHG emissions from shipping. Starting in 1999, the U.S. established the Marine Engine Rule, where the EPA regulated emissions from marine diesel engines applicable to different categories. Standards for the smaller marine engines[4] were improved in 2008, establishing Tier 3 and 4 emission standards and setting a sulfur cap to enable catalytic after-treatment methods.[5] Aside from federal regulations, California, home to the U.S.'s largest ports, has the Harbor Craft Regulation, which was recently updated by the California Air Resources Board (CARB) to require zero-emission options where feasible, and cleaner combustion Tier 3 and 4 engines on all other commercial harbor crafts.[6] CARB also implements fuel regulations for oceangoing vessels that are stricter than ECA, requiring the use of distillate fuel with no higher than 0.1% sulfur, and does not allow for alternatives of scrubbers. And for at port, or "at berth," emissions, California has required oceangoing vessels to use shore-side electricity while at-berth, which started in 2014 and will further expand the regulation by ship type in 2023, requiring 100% zero emission at berth compliance for all containerships that call California ports. In 2015, China enacted the country's first-ever marine engine emission standards which are equivalent to the U.S. Marine Engine Rule besides Tier 4. Between 2015 and 2016, China introduced, and upgraded the Domestic Emission Control Area (DECA). However, its then more stringent SO_X emission standards were grandfathered in 2020 which will likely be strengthened by 2025. The DECA system includes a mandate for certain vessels to use shore-side electricity while berthing in ports within DECA regions.

More recently, the two countries have raised their respective ambitions to cut GHG emissions across the entire economy. At the 75th UN General Assembly in September of 2020, Chinese President Xi Jinping announced that China's overall CO_2 emissions will peak by 2030 and that carbon neutrality will be reached before 2060 (Mao & Meng, 2022). The U.S. also updated its National Determined Contribution at COP26 to cut domestic emissions by 50%-52% from 2005 levels in 2030 and reach net-zero emissions by 2050.[7] Additionally, at COP26, the U.S. co-led the Global Methane Pledge with the European Union, which aims to cut economy-wide methane emissions by 30% by 2030 compared to 2020 levels. Historically, the two countries had successfully collaborated on cutting shipping emissions. Between 2008 and 2021, the U.S. Department of State and China's National Development and Reform Commission implemented the Eco-Partnerships program that incubated 45 subnational partners to achieve shared goals in clean air, clean water, and waste reduction (Szum, 2021). One such partnership was between the Port of Los Angeles and Shanghai Municipal Transportation Commission to deploy shore-based power to replace ships' fuel consumption at berth. In 2016, the Eighth Round of U.S.-China Strategic and Economic Dialogue (S&ED) was held, and the two countries launched the Green Ports and Vessels Initiative (GPVI) focusing on the development of emissions inventories for air pollutants and black carbon from ports and vessels.[8] The recent U.S.-China

[4] There are three engine size categories, Category 1 and 2 engines have smaller displacement and are seen mostly in the domestic fleet. Category 3 engines are seen mostly in the international fleet.

[5] https://dieselnet.com/standards/us/marine.php

[6] https://ww2.arb.ca.gov/news/carb-passes-amendments-commercial-harbor-craft-regulation

[7] https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/13/fact-sheet-renewed-u-s-leadership-in-glasgow-raises-ambition-to-tackle-climate-crisis/

[8] https://america.cgtn.com/2016/06/07/full-text-2016-china-u-s-strategic-and-economic-dialogue-strategic-fact-sheet

Glasgow Joint Declaration on Enhancing Climate Action in the 2020s is a healthy continuation of such bilateral collaborations with more concrete actions to come.[9] Earlier this year (2022), Port of Shanghai and Port of Los Angeles and C40 cities pledged to create the world's first transpacific green shipping corridor.[10]

GHG REDUCTION POTENTIAL

Technologies of different GHG reduction potential and technological readiness are available to help decarbonize international shipping. The Fourth Greenhouse Gas study identified 44 GHG abatement technologies which can be categorized into four major groups: energy-saving technologies, use of renewable energy, use of alternative fuels, and speed reduction (Faber et al., 2020). That study doesn't include battery-electric technology, which will be discussed here within the group of "alternative fuels".

Energy-saving technologies

The ICCT estimated the CO_2 reduction potentials of leading industry practices for international shipping. Two leading technologies that ships can use to reduce their energy use and emissions include air lubrication (5-15% reductions) and wind-assisted propulsion (2-15% reductions) (Comer, 2019; Comer et al., 2022; Wang & Lutsey, 2013). Few shipowners have voluntarily adopted these technologies because they are able to comply with existing energy efficiency regulations without investing in these solutions. However, if policies become more stringent, it will be more likely that shipowners will invest in these and other energy saving technologies. Policies that could be strengthened to make them more effective at reducing emissions include the IMO's Energy Efficiency Design Index (EEDI), which regulates the technical efficiency for ships built in 2013 and later and becomes more stringent over time, and the Energy Efficiency Existing Ship Index (EEXI), which regulates the technical efficiency for all existing vessels starting in 2023. Research has shown that accelerating the pace of efficiency improvements under the EEDI can reduce absolute emissions from the international shipping sector, leading to a 17% to 44% probability of cutting emissions in half by 2050, depending on future demand for shipping, even if no other policies were implemented (Comer et al., 2018). Pairing EEDI improvements with other measures such as slow steaming and using low or zero life-cycle fuels can lead to a complete decarbonization of the sector. In China where emissions from its domestic fleet are comparable to that of its international fleet and not regulated by IMO's EEDI or EEXI standards, there exists the need to enact similar policies so that energy-saving technologies could penetrate the domestic market as well. The ICCT estimated that energy efficiency standards, if introduced in 2025, could cut CO_2 emissions from China's coastal shipping by 5% in 2030 compared with 2019 levels (Mao & Meng, 2022).

Speed reduction

There is a cubic relationship between ship speed and fuel consumption. To speed up, a ship needs to consume much more fuel. The opposite is also true: slowing down can greatly reduce fuel consumption, with concomitant reductions in air pollutants and GHGs (California Air Resources Board, 2018). Cutting back the speed would inevitably increase time needed to travel the same distance and, at some point, may require using more ships to maintain transport supply. However, research has shown that even accounting for these factors, a 10% reduction in speed can result in voyage-level emissions reductions of about 19%. Even greater emissions reductions are possible at slower speeds (Faber et al., 2013).

Many U.S. ports have favored vessel speed reduction (VSR) zones within their jurisdictions. The Port of Los Angeles launched its voluntary VSR program in 2001 which incentivizes ocean-going vessels to

9 https://www.state.gov/u-s-china-joint-glasgow-declaration-on-enhancing-climate-action-in-the-2020s/

10 https://www.c40.org/news/la-shanghai-green-shipping-corridor/

reduce their cruising speeds to less than 12 knots.[11] In 2019, the port achieved a 91% participation rate within 20 nautical miles and an 87% participation rate within 40 nautical miles.[12] Port of Long Beach, Port of New York and New Jersey, and Port of San Diego offered similar programs, who have been tracking the effectiveness of these programs through annual emissions inventories. In 2016, VSR accounted for 2670 tons of carbon dioxide equivalent (CO_2e) in Port of San Diego; in 2017, VSR resulted in 58,964 tons of CO_2e reduction in Port of Long Beach; in 2018, VSR generated 15,626 tons of CO_2e reduction for Port of New York and New Jersey. CARB estimated that if all ships were to travel for less than 12 knots within 40 nautical miles of ports, GHG emissions within boundary could be cut by 29% (International Transport Forum, 2018). China on the other hand has not yet adopted such voluntary programs, and the IMO has little appetite for any mandatory limits on vessel speeds yet.

Low and zero emission fuels

Alternative fuels for maritime shipping show the highest potential to decarbonize international shipping, yet questions remain on how to evaluate their GHG reduction potentials. The ICCT proposes that three criteria should be used to determine if a new fuel is "sustainable":

- Low CO_2e emissions, not just low CO_2: This ensures that GHGs, especially those with high global warming potentials (GWPs), such as methane, nitrous oxide, and black carbon, are taken into account to ensure the sustainability of alternative fuels are fully captured.
- Low GWP20 emissions, not just low GWP100: This encourages action to reduce pollutants that contribute the most to near-term warming, which are important to reduce to avoid exceeding the Paris Agreement temperature goals.
- Low life cycle (well-to-wake) emissions, not just low direct (tank-to-wake) emissions: This ensures that the adoption of alternative fuels would not displace emissions elsewhere but delivers true economy-wide reductions.

The following fuels and energy sources can have low life-cycle emissions and score well against the three principles outline above:

- **Renewable electricity**

  So far, passenger ferries have seen the most progress towards electrification, and several battery-electric ferries are already on the water, mostly in Europe. Denmark's electric ferry (e-ferry) Ellen, in service since 2019, carries by far the world's largest battery system of 4.3 megawatt hours (MWh) which can power a one-way route of 22 nautical miles (Mao et al., 2021). China also has a growing number of battery-powered passenger and cargo ships in operation, including the world's largest battery-powered cruise ship, the Yangtze River Three Gorges 1, which is 100 meters long. It is equipped with a 7,500-kilowatt-hour (kWh) battery[13]. In addition, in 2021, Lianyungang Port put into use China's first battery-driven tugboat, which is 35.5 meters long with a total battery capacity of about 5,000 kWh[14]. With range limitations and charging speed constraints, batteries will be mostly applicable to smaller vessels plying shorter routes or less frequent longer routes. The ultimate GHG reduction potential of battery-electric ships depends entirely on the GHG intensity of the electricity. Sourced renewably and with additional capacity, battery-electric ships could be close to zero emissions on a life cycle basis. On shore power is a readily developed technology that can work on literally all existing ships and cut at-berth ship tailpipe emissions to zero and well-to-wake emissions to zero if sourced renewably with additional capacity (Eastern Research Group & Energy & Environmental Research Associates, 2017).

- **Green hydrogen and its derivatives**

  Electrolyzing water with 100% renewable electricity produces close to zero GHG emissions.

[11] https://kentico.portoflosangeles.org/getmedia/0e57c1fd-0997-424a-92f3-547f31713b11/VSR-Instruction-Guidelines-2020

[12] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10119QQ.pdf

[13] https://baijiahao.baidu.com/s?id=1729169782936067197&wfr=spider&for=pc

[14] https://www.sohu.com/a/486516973_155167

Transported in a cryogenic or compressed gaseous state, via pipeline, trucks or ships, hydrogen can be pumped into ships with fuel cell stacks and converted into electricity, producing nothing but water. ICCT has analyzed the technical feasibility of a U.S.-China zero-emission shipping corridor powered by liquid hydrogen fuel cells and concluded that 99% of existing traffic can be fulfilled by adding one more refueling stop along the way (Mao et al., 2020). The additional refueling stop, if positioned in the Aleutian Islands of the U.S., could enable 25% of the otherwise unfulfilled traffic, bringing huge opportunities for producing and selling green hydrogen using local renewable energy to supply the additional demand (Georgeff et al., 2020, 2022). Using renewably produced hydrogen, a series of liquid fuels could be made with close to zero or net-zero emissions. For example, ammonia produced by combining H2 and N2, or e-NH3, can be burned in internal combustion engines with aftertreatment, or fed into fuel cells onboard ships; carbon-based fuels, such as methanol, can be produced by combining H2 and biogenic or directly captured CO_2 and burned in internal combustion engines. Depending on a fuel's energy density, it could be more applicable to specific shipping segments than others. Using hydrogen directly would be the most straightforward but for long-range deep-sea shipping where refueling is not readily available, hydrogen-derivatives could be preferred.

- **Advanced biofuels**

  The sustainability of biofuels is more dependent on its feedstock than the conversion technology, and different from fuels mentioned above, should include indirect land-use change emissions (Zhou et al., 2020). The ICCT found that advanced liquid biofuels made from wastes can deliver 70%-100% life cycle GHG emission reductions compared with existing marine fuels (Ibid.) from cradle to grave.

  Penetration of alternative fuels is different for different fuel types. To help meet the EU's climate neutrality goal by 2050 and an interim target of at least 55% net GHG reduction by 2030, relative to 1990 levels (Fit for 55), the EU proposes to set a maximum limit on the life cycle GHG content of energy used by ships calling at EU ports starting in 2025 under its FuelEU maritime initiative (EU Commission, 2021; Transport & Environment, 2021). The current life cycle GHG intensity requirements include a 13% reduction in GHG intensity by 2030 relative to 2020, and up to a 75% reduction by 2050; however, this regulation is still being negotiated and it is likely that these targets will be strengthened, including 100% reduction by 2050[15]. The U.S. and China have yet to adopt such policies. However, in the aspirational document of the U.S. pledge to achieve net-zero by 2050, "carbon-free hydrogen" and "sustainable biofuel" have been identified to help the shipping sector achieve decarbonization.[16] China has developed an experimental small hydrogen fuel cell-powered passenger ship, which is 13.9 meters long and hybrid powered by 70kW fuel cells and 86kWh lithium batteries. The ship has a designed speed of 18km/h, a endurance of 180km and a capacity of 10 passengers[17]. In addition, in the government's 2021-2035 hydrogen energy development plan, it has been decided to promote the pilot of hydrogen-powered ships[18]. China will follow up its carbon neutral pledge by releasing sectoral targets ("N+1" framework) which could include a separate target for its shipping sector. The ICCT estimated that with low-carbon fuel regulations phased in like the EU proposal, China's coastal shipping can be expected to achieve deep reduction (50%-87%) by 2060 (Mao & Meng, 2022).

- **Port infrastructure and onshore power supply**

  Transitioning ships off fossil fuels necessitates concurrent infrastructure and energy transformation at the world's ports and along the world's major trade corridors. China is home to many of the world's largest ports, including the world's single largest, Port of Shanghai. The U.S. is home to the largest seaport complex in the Western Hemisphere, the San Pedro Port Complex including the Ports of Los Angeles and Long Beach. These facts make China and the U.S. uniquely well positioned to lead in accelerating port and landside infrastructure at a pace commensurate with a 1.5C decarbonization pathway for the global shipping industry.

[15] https://www.europarl.europa.eu/doceo/document/TRAN-AM-731663_EN.pdf

[16] https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

[17] https://www.xianjichina.com/special/detail_469619.html

[18] https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220323_1320038.html?code=&state=123

RECOMMENDATIONS FOR THE U.S.

Eliminate in-port emissions in all major trading ports with a focus on those in Clean Air Act nonattainment areas by 2030

Require ships that call on U.S. ports to report their fuel consumption and emissions in a public database starting in 2024

Retrofit or replace the Jones Act fleet with zero-emission vessels between 2024 and 2032

Ban scrubbers in U.S. waters by 2024

For U.S. specifically, we recommend the following actions to decarbonize shipping:

- **Eliminate in-port emissions in all major trading ports with a focus on those in Clean Air Act nonattainment areas by 2030**

  California recently updated its at-berth regulation to require zero emission for ship at-berth operations in ports between 2023 and 2027, depending on the ship type.[19] Additionally, the California Air Resources Board recently approved updates to its Commercial Harbor Craft Regulation that will require short-run ferries (< 3 miles) to be zero emission by 2025, and there are proposals for zero in-port operations by no later than 2035 (Barry, Rose and Hubbell, 2021). The U.S. should develop and implement a national plan that eliminates in-port shipping emissions for both ocean-going vessels, Great Lakes ships, and harbor craft by no later than 2030 for major U.S. ports and those located in "non-attainment" areas, which do not meet U.S. National Ambient Air Quality Standards. All U.S. ports should aim to be zero-emissions by no later than 2035.

- **Require ships that call on U.S. ports to report their fuel consumption and emissions in a public database starting in 2024**

  Since 2019, the International Maritime Organization requires most ships to report their fuel consumption and emissions each year to its Data Collection System; however, this database is not public. Since 2018, the European Union requires most ships to report their fuel consumption and emissions on voyages to or from and EU port to its Monitoring Reporting and Verification (MRV) system. This is a public database where each ship is identified. The U.S. should establish its own MRV system for all ships that call on U.S. ports, including both international and domestic shipping. This will enable the U.S. to quantify shipping emissions more accurately and to develop strategies to eliminate emissions from ships.

- **Retrofit or replace the Jones Act fleet with zero-emission vessels between 2024 and 2032**

  The U.S. Jones Act fleet is used for domestic transportation. There are approximately 130 Jones Act vessels, including ocean-going and Great Lakes ships. Many are more than 40 years old, and the oldest ocean-going Jones Act vessel still in service was built in 1963[20], and the oldest Great Lakes Jones Act vessel still operating was built in 1942.[21] These ships are built in America, owned by Americans, and crewed by Americans and, therefore, any investments made in updating these ships directly benefit Americans. Additionally, because these ships are engaged in domestic transportation, the air pollution reduction benefits and associated health benefits accrue over time to Americans. According to ABB, the Jones Act fleet is a great candidate for electrification.[22]

- **Ban scrubbers in U.S. waters by 2024**

  Scrubbers work by spraying seawater to reduce sulfur emissions (Osipova et al., 2021). The resultant washwater is acidic and contains polycyclic aromatic hydrocarbons, heavy metals,

[19] https://ww2.arb.ca.gov/news/california-approves-updated-berth-regulation-expanding-efforts-cut-pollution-ships-california

[20] https://www.cato.org/blog/old-ships-still-abundant-jones-act-fleet

[21] https://www.mlive.com/news/2018/07/2_oldest_freighters_on_great_l.html

[22] https://new.abb.com/news/detail/67966/the-path-to-a-carbon-free-maritime-industry-investments-and-innovation

and other pollutants, and is discharged overboard, which worsens water quality (Comer et al., 2020). California already requires ships to use fuels that have less than 0.1% sulfur content in California waters, rather than scrubbers. In the rest of the U.S., approximately 150 million tonnes of scrubber washwater is discharged in U.S. territorial seas each year, the most of any country (Osipova et al., 2021). Scrubber systems should be banned as a means of compliance with clean fuel standards in all U.S. waters, including at U.S. ports. Thirty nations already ban scrubber systems in national waters, including China. A nationwide ban on scrubbers would improve water quality and air quality, as ships using cleaner fuels emit less total air pollution than scrubber-equipped ships burning high-sulfur heavy fuel oil (Comer et al., 2020). To comply with this ban, ships would simply need to use low sulfur fuels, which they usually already carry onboard and which they can use in their existing engines. Indeed, ships that are not equipped with scrubbers routinely switch between high sulfur and low sulfur fuels when they enter Emission Control Areas. Therefore, no delay in implementing such a ban is needed.

RECOMMENDATIONS FOR CHINA

Release a workplan for the Chinese shipping industry to peak emissions by 2025

Release a timetable for decarbonizing China's river fleet by the 15th five-year planning (2026), and for China's coastal fleet by the 16th five-year planning (2031)

Eliminate in-port emissions within DECA, starting with major seaports in 2030 with a target for zero emission by 2050

Include the shipping industry into the national ETS system, as soon as possible

For China specifically, we recommend the following actions to decarbonize shipping:

- **Release a workplan for the Chinese shipping industry to peak emissions by 2025**

  As one of the world's largest shipbuilding nations, China can play a global leadership role in curbing ship emissions. Under its N+1 policy framework to implement 2060 carbon neutrality, China could direct its shipping industry to peak emissions by 2025, a goal already set for its steel industry. As the world's largest shipbuilding country, China's ambition in producing green steel could attract emerging orders for well-to-wake zero-emission vessels. China's existing leadership in auto electrification can be leveraged for battery-powered ships and with its steel industry's decarbonization transition, massive demand for green hydrogen could be leveraged to support hydrogen fuel cell powered ships.

- **Release a timetable for decarbonizing China's river fleet by the 15th five-year planning (2026), and for China's coastal fleet by the 16th five-year planning (2031)**

  In China, actionable policies are often implemented with measurable targets every five years. For the domestic shipping industry, a pathway to decarbonization by 2060 needs to be researched and released ahead to guide the industry with a smoother transition. The river fleet and coastal fleet needs to be treated separately as they present different challenges in technological and operational changes. It is recommended that a combination of energy efficiency standards and low-carbon fuel regulations be included in those pathways to deliver immediate results and pave the way for long term results.

- **Eliminate in-port emissions within DECA, starting with major seaports in 2030 with a target for zero emission by 2050**

  Ports are emission hotspots in the international goods movement chain, where ship and truck traffic are concentrated and often congested. Almost all port-side mobile and stationary equipment can be electrified with existing technology, including shore power for ships' energy requirement while at berth. Although the life cycle GHG reduction would be dependent on carbon intensity of the grid, the direct emission reduction in ports' jurisdiction would yield immediate environmental and public health benefits to local communities and while mitigating climate impact at the same time. Major sea ports within DECA should start transitioning to zero-emissions by 2030 and commit to net-zero emission by 2050.

- **Include the shipping industry into the national ETS system, as soon as possible**

  The shipping industry was not included in China's initial national ETS market. However, it has been included in regional ETS markets like Shanghai. The inclusion of the shipping industry provides incentives for zero-emission fuels and propulsion technologies and associated infrastructure to help transition the industry to a decarbonized future.

OPPORTUNITIES FOR COLLABORATION

Given the common challenges and opportunities facing the U.S. and China to decarbonize the shipping industry, we first propose a venue for future collaborations to take place which is the concept of a green shipping corridor. A shipping corridor is an existing trading route between the U.S. and China where goods movement takes place on a regular basis. Stakeholders on a shipping corridor include cargo owners, shipping/logistics companies, ports, and fuel suppliers. Demand and supply can be secured along a shipping corridor so that efforts to deploy low/zero emission technologies could be coordinated. Public-private partnerships are likely already in place so that initiatives to move towards collaboration on sustainability would be less difficult to establish. There's already a U.S.-China shipping corridor, the one between Port of Shanghai and Port of Los Angeles, which announced its ambition to launch zero-carbon fueled ships by 2030 under the C40 network of nearly 100 world-leading cities to collaboratively combat the climate crisis.

The U.S. and China could expand this type of collaboration to other existing shipping routes between the two countries, with harmonized policy frameworks and financial support on both sides. Since ports handle international trade as well as domestic trade, benefits of such international collaboration can spill over to benefit domestic shipping as well. The ultimate target of **U.S.-China Green Shipping Corridors** should be to explore a feasible way as soon as possible for decarburizing the U.S.-China bilateral trade no later than 2050 in order to contribute to IMO's GHG strategy to be strengthened in 2023. Interim goals should be set for 2025, and 2030, including the overall CO_2e reduction target and the number of decarbonized corridors, to make sure progress is on track. To support these goals, we identify the following areas for collaboration under the **U.S.-China Green Shipping Corridors**:

- **Build and deploy zero-emission vessels**

  Ship classification societies of both countries could collaborate on harmonized protocols to certify and label qualified zero-emission vessels and provide financial incentives for zero-emission vessels to join the two countries' registry or subsidize the construction of these ships in each country. The U.S. and China could start by targeting their domestic fleets, including tugs, pilot boats, ferries, and regional cargo ships, and then expand to larger ships that travel longer distances, including deep sea vessels that can sail along green shipping corridors.

- **Deploy zero life-cycle emission marine fuels**

  The two countries could work on harmonized protocols to certify sustainable marine fuel and provide financial incentives to deploy the production, distribution and sales of these fuels to ships servicing a targeted green shipping corridor. These fuels should have zero or near-zero life cycle GHG emissions and should not contribute to global deforestation.

- **Showcase zero-emission ports**

  The two countries could collaborate on eliminating in-port emissions by initiating a paired zero-emission port project, for which the pair is the two end ports of a targeted green shipping corridor. Each country can decide its own technology pathway. However, the countries should ensure that shore power connections are available at all terminals, and they should use the same electrical frequency so that shore-power-equipped ships can plug in at all U.S. and China ports where shore power is available.

- **Create zero-emission ocean shipping corridors**

  The Chinese Port of Shanghai and the U.S. Port of Los Angeles and Port of Long Beach have already announced a collaborative initiative to use zero-emission vessels between these ports. The U.S. and China could create other port partnerships and clarify the year by which zero-emission vessels will begin sailing these routes and set targets for the proportion of trade moved by zero-emission vessels along these corridors over time.

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REFERENCES

1. Barry, J., Rose, M., and Hubbell, D. (2021). *'All Aboard: All Aboard: How The Biden-Harris Administration Can Help Ships Kick Fossil Fuels'*. Pacific Environment and Ocean Conservancy, Washington D.C., 2021.

2. California Air Resources Board. (2018). *Technology Assessment: Ocean-Going Vessels*. 147.

3. Comer, B. (2019). Rotors and bubbles: *Route-Based Assessment Of Innovative Technologies To Reduce Ship Fuel Consumption And Emissions*. 19.

4. Comer, B., Chen, C., & Rutherford, D. (2018). *Relating Short-Term Measures To Imo's Minimum 2050 Emissions Reduction Target*. International Council on Clean Transportation. https://theicct.org/publication/relating-short-term-measures-to-imos-minimum-2050-emissions-reduction-target/

5. Comer, B., Douglas, S., & Elise, G. (2022). *Decarbonizing Bulk Carriers With Hydrogen Fuel Cells And Wind-Assisted Propulsion: A Modeled Case Study Analysis*. International Council on Clean Transportation. https://theicct.org/publication/hydrogen-and-propulsion-ships-jan22/

6. Comer, B., Georgeff, E., & Osipova, L. (2020). *Air Emissions And Water Pollution Discharges From Ships With Scrubbers*. International Council on Clean Transportation. https://theicct.org/publication/air-emissions-and-water-pollution-discharges-from-ships-with-scrubbers/

7. Eastern Research Group, & Energy & Environmental Research Associates. (2017). *Shore Power Technology Assessment At U.S. Ports*.

8. EU Commission. (2021). *Proposal For A Regulation Of The European Parliament And Of The Council Amending Regulation (EU) 2019/631 As Regards Strengthening The CO_2 Emission Performance Standards For New Passenger Cars And New Light Commercial Vehicles In Line With The Union's Increased Climate Ambition*. https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf

9. Faber, J., Hanayama, S., Zhang, S., Pereda, P., Comer, B., Hauerhof, E., Schim van der Loeff, W., Smith, T., Zhang, Y., Kosaka, H., Adachi, M., Bonello, J.-M., Galbraith, C., Gong, Z., Hirata, K., Hummels, D., Kleijn, A., Lee, D., Liu, Y., … Yuan, H. (2020). *Fourth IMO*

Greenhouse Gas Study. International Maritime Organization. https://docs.imo.org/

10. Faber, J., Nelissen, D., Hon, G., Wang, H., & Tsimplis, M. (2013). *Regulated Slow Steaming In Maritime Transport*. International Council on Clean Transportation. https://theicct.org/publication/regulated-slow-steaming-in-maritime-transport/

11. Georgeff, E., Mao, X., & Rutherford, D. (2022). *Scaling U.S. Zero-Emission Shipping: Potential Hydrogen Demand At Aleutian Islands Ports*. International Council on Clean Transportation. https://theicct.org/publication/marine-us-aleutians-hydrogen-jun22/

12. Georgeff, E., Mao, X., Rutherford, D., & Osipova, L. (2020). *Liquid Hydrogen Refueling Infrastructure To Support A Zero-Emission U.S.–China Container Shipping Corridor*. International Council on Clean Transportation. https://theicct.org/publication/liquid-hydrogen-refueling-infrastructure-to-support-a-zero-emission-u-s-china-container-shipping-corridor/

13. International Transport Forum. (2018). *Reducing Shipping Greenhouse Gas Emissions: Lessons from Port-Based Incentives*. https://www.itf-oecd.org/sites/default/files/docs/reducing-shipping-greenhouse-gas-emissions.pdf

14. Liu, H., Meng, Z.-H., Lv, Z.-F., Wang, X.-T., Deng, F.-Y., Liu, Y., Zhang, Y.-N., Shi, M.-S., Zhang, Q., & He, K.-B. (2019). *Emissions And Health Impacts From Global Shipping Embodied In US–China Bilateral Trade*. Nature Sustainability, 2(11), 1027–1033. https://doi.org/10.1038/s41893-019-0414-z

15. Mao, X., Georgeff, E., Rutherford, D., & Osipova, L. (2021). *Repowering Chinese Coastal Ferries With Battery-Electric Technology*. International Council on Clean Transportation. https://theicct.org/publication/repowering-chinese-coastal-ferries-with-battery-electric-technology/

16. Mao, X., & Meng, Z. (2022). *Decarbonizing China's Coastal Shipping: The Role Of Fuel Efficiency And Low-Carbon Fuels*. International Council on Clean Transportation. https://theicct.org/publication/china-marine-decarbonizing-chinas-coastal-shipping-role-of-fuel-efficiency-and-low-carbon-fuels-factsheet-en-jun22/

17. Mao, X., & Rutherford, D. (2018). *NO_x Emissions From Merchant Vessels In Coastal China: 2015 And 2030*. International Council on Clean Transportation. https://theicct.org/publication/nox-emissions-from-merchant-vessels-in-coastal-china-2015-and-2030/

18. Mao, X., Rutherford, D., Osipova, L., & Comer, B. (2020). *Refueling Assessment Of A Zero-Emission Container Corridor Between China And The United States: Could Hydrogen Replace Fossil Fuels?* International Council on Clean Transportation. https://theicct.org/publication/refueling-assessment-of-a-zero-emission-container-corridor-between-china-and-the-united-states-could-hydrogen-replace-fossil-fuels/

19. Osipova, L., Georgeff, E., & Comer, B. (2021). *Global Scrubber Washwater Discharges Under Imo's 2020 Fuel Sulfur Limit*. International Council on Clean Transportation. https://theicct.org/publication/global-scrubber-washwater-discharges-under-imos-2020-fuel-sulfur-limit/

20. Rutherford, D., & Comer, B. (2018). *The International Maritime Organization's Initial Greenhouse Gas Strategy*. International Council on Clean Transportation. https://theicct.org/publication/the-international-maritime-organizations-initial-greenhouse-gas-strategy/

21. Szum, C. (2021). Capturing the legacy of the U.S.-China EcoPartnerships program. *Environmental Progress & Sustainable Energy*, *40*(5), e13640. https://doi.org/10.1002/ep.13640

22. Transport & Environment. (2021). *Draft FuelEU Maritime proposal. Quantifying the risks of a climate and environmental disaster in the making*. https://www.transportenvironment.org/sites/te/files/publications/2021_06_TE_analysis_Draft_FuelEU_Maritime_proposal.pdf

23. US EPA. (2022). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* (EPA 430-R-22-003). https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020

24. Wang, H., & Lutsey, N. (2013). *Long-Term Potential For Increased Shipping Efficiency.* International Council on Clean Transportation. https://theicct.org/publication/long-term-potential-for-increased-shipping-efficiency/

25. Zhou, Y., Pavlenko, N., Rutherford, D., Osipova, L., & Comer, B. (2020). *The Potential Of Liquid Biofuels In Reducing Ship Emissions*. International Council on Clean Transportation. https://theicct.org/publication/the-potential-of-liquid-biofuels-in-reducing-ship-emissions/