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Decarbonizing Marine Shipping

A Primer

January 2021

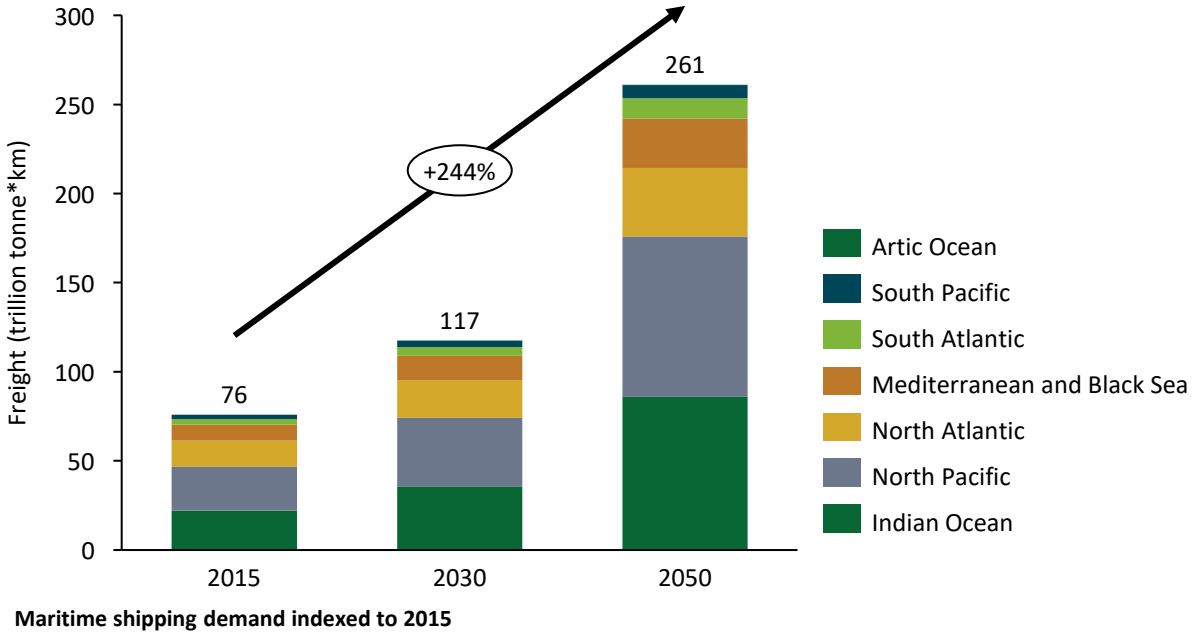
Maritime shipping handles about 80% of global trade by volume

Global shipping routes for world trade

Sources: shipmap.org; UNCTAD Review of Maritime Transport 2018, UNCTAD 2020 e-Handbook of Statistics

As the dominant form of trade, international shipping plays a vital role in the global economy. In 2019, an estimated 11.1 billion tonnes of goods were transported by sea across international waters.

Maritime shipping volume is expected to triple by 2050



Maritime shipping demand indexed to 2015

75%

Percent of global freight (tonne*km) will be moved by marine ships in 2050

Source: ITF Transport Outlook 2019.

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Environmental Impacts of Shipping

Shipping relies on one of the world's dirtiest fuels and has been slow in adopting measures to reduce pollution

Distillate Fuel **Heavy Fuel Oil**

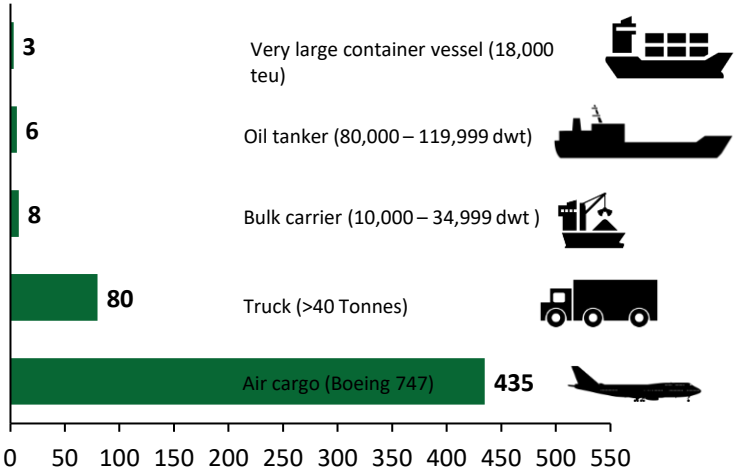
What is heavy fuel oil?
Heavy fuel oil (HFO) is a highly viscous oil product that is left over after the distillation of crude oil—it is literally the bottom of the barrel. It contains heavy compounds that are resistant to degradation along with high levels of sulfur and heavy metals. Put simply, heavy fuel oil is one of the world's dirtiest petroleum fuels, and almost all of it is used in the marine shipping sector.

Heavy fuel oil is the primary fuel for the shipping sector
Although cleaner alternatives are available and technically viable, HFO accounts for more than 80% of the total fuel consumption in international shipping.

Sources:
Picture from Environmental Investigation Agency
HFO Free Arctic. https://www.hfofreearctic.org/hrf_faq/heavy-fuel-oil/. Accessed July 2019.
Lloyds Register Marine, N.D. "Global Marine Fuel Trends 2030."

Shipping accounts for about 2% of global GHG emissions (3% of global combustion emissions). Without intervention, emissions may grow by up to 50% by 2050.

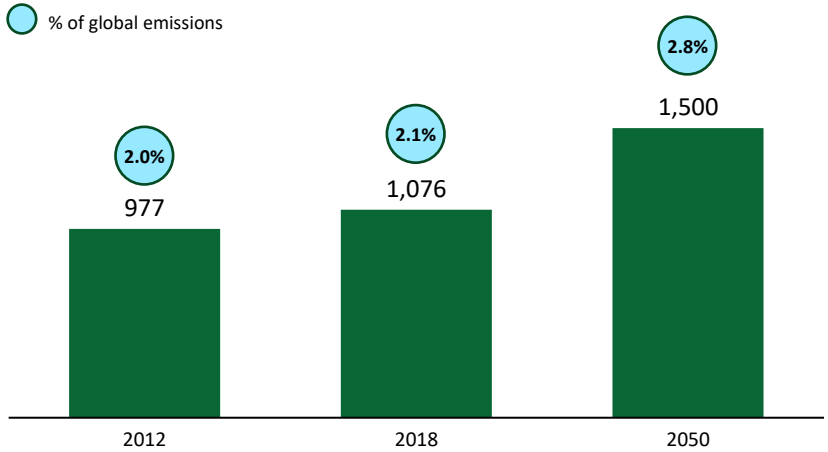
Shipping is the most efficient mode of transport on a per tonne*km basis.



Emissions from different modes of transport (g CO_2 / tonne*km)

Source: IMO Greenhouse Gas Study 2009.

But due to continued reliance on high-carbon fuels and the huge volume of goods moved, marine shipping is a major contributor to global GHG emissions.

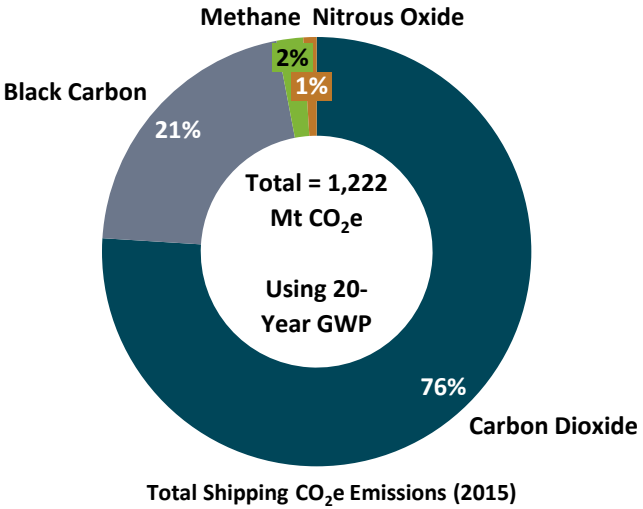


Historical and future shipping emissions under a BAU scenario (Mt CO_2e)

Source: IMO 4th Greenhouse Gas Study 2020, Climate Action Tracker. Future percent of global emissions based on average of "Post-COVID-19 current policies" scenarios from Climate Action Tracker. Does not include black carbon and 2050 estimate is CO2 only. 2050 is the high end of projections from the IMO's 4th Greenhouse Gas Assessment.

In addition to CO_2 and methane, ships also cause significant black carbon emissions which amplify the climate impact of the sector

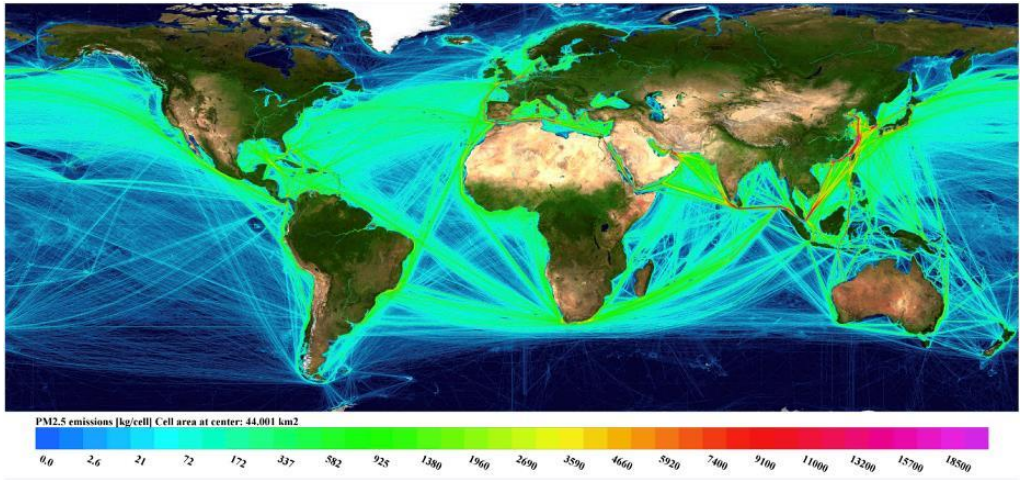
Black carbon is released from the burning of HFO and increases the shipping sector's greenhouse gas emissions by ~20%. Black carbon in the air and deposited on land and snow warms the earth by absorbing solar radiation. A combination of combusting dirty HFO and a lack of end-of-pipe exhaust treatment requirements have resulted in high rates of black carbon emissions from shipping.



Source: International Council on Clean Transportation. "Greenhouse gas emissions from global shipping, 2013–2015."

Emissions of particulate matter ($PM_{2.5}$) and other criteria pollutants from ships cause an estimated 64,000 deaths and 1.7 million cases of childhood asthma each year

70 percent of shipping traffic occurs within 400 km of the coastline with serious implications for human health. Emissions are concentrated in communities near ports, many of which are predominantly low-income.



Distribution of $PM_{2.5}$ emissions from shipping in 2015

52,500 deaths from cardiovascular disease

11,500 deaths from lung cancer

1.7 million cases of childhood asthma

Sources: Johansson, et al. 2017. "Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution."
Corbett, 2007. "Mortality from Ship Emissions: A Global Assessment"
Corbett, et al. 2018. "Cleaner fuels for ships provide public health benefits with climate tradeoffs."

Note: Estimates assume implementation of 2020 sulphur cap and a log-linear concentration-response function. Studies using linear response functions, which are more applicable at lower ambient pollution levels estimate higher mortality.

Shipping has numerous other environmental impacts

Ocean Pollution

Oil Spills

Dumping

Scrubber discharge

Wildlife and Habitat Impacts

Wildlife strikes

Ballast water / invasive species

Noise pollution

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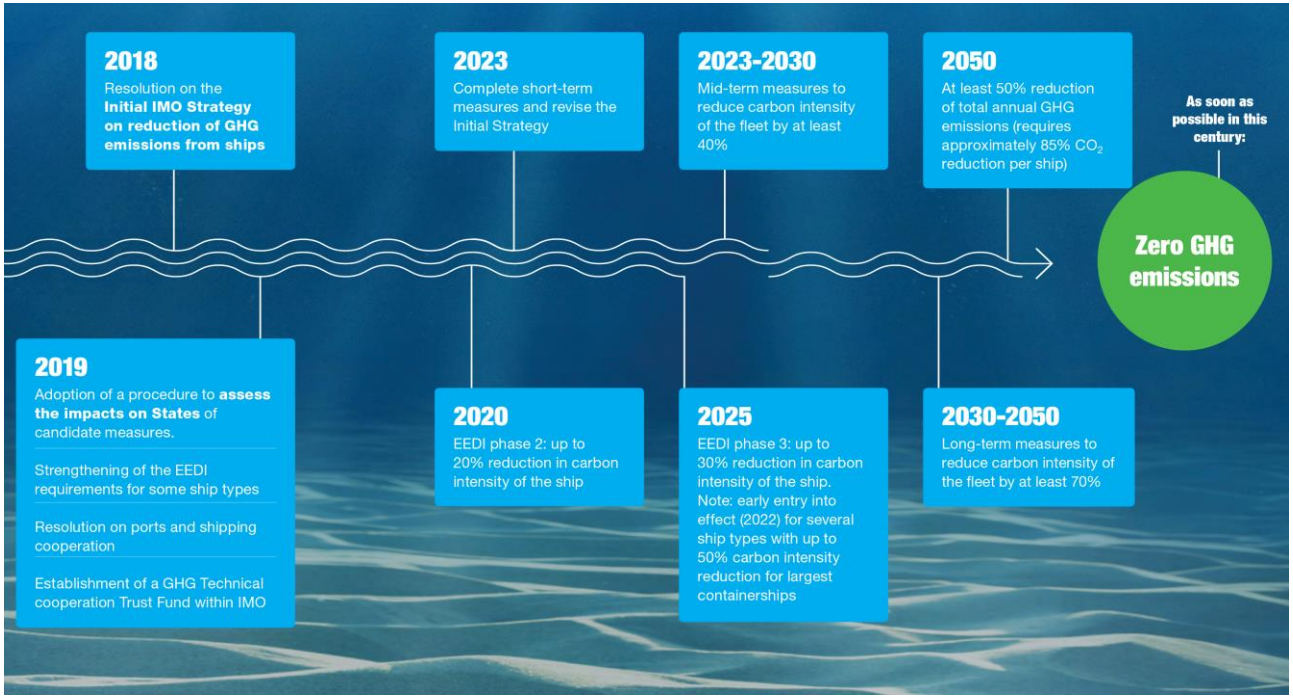
Policy Landscape

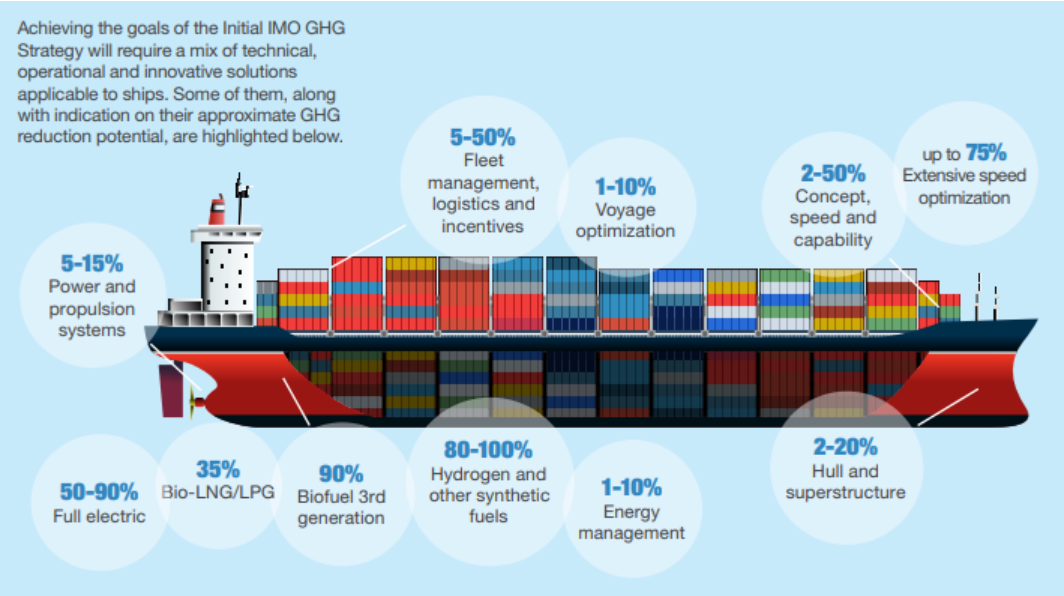
The International Maritime Organization's (IMO) initial GHG targets at least a 50% reduction in emissions by 2050 from a 2008 baseline



Timetable of IMO action to reduce GHG emissions from ships

Source: IMO Action to Reduce Greenhouse Gas Emissions from International Shipping

Decarbonizing the shipping sector will require a mix of different operational strategies and technical approaches



There is no silver bullet for decarbonizing the shipping sector. The use of green hydrogen or other synthetic fuels can completely reduce GHG emissions, but currently faces significant technical and cost barriers. Other operational strategies such as speed optimization (slowing down the speed of ships to be more efficient) can reduce emissions but will not lead to full decarbonization.

Source: IMO Action to Reduce Greenhouse Gas Emissions from International Shipping

Decarbonizing shipping in line with the Initial IMO Strategy involves a combination of short-, mid-, and long-term measures

The Initial IMO Strategy on reduction of GHG emissions from ships outlined a series of short-, mid-, and long-term measures to reduce GHG emissions and called for "a program of follow-up actions" to be decided on before the adoption of a revised strategy in 2023. Short-term measures focus on operational efforts such as slow-steaming, while zero emission vessels (ZEVs) are a long-term measure necessary to achieve full decarbonization. The measures are summarized below, and a full list can be found here.

Short-term measures

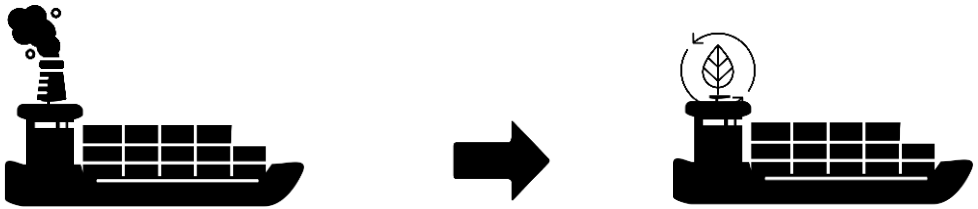
- Improve the Energy Efficiency Design Index (EEDI) for new ships and Ship Energy Efficiency Management Plan (SEEMP)
- Develop technical and operational energy efficiency measures for both new and existing ships
- Establish an Existing Fleet Improvement Program
- Consider the use of speed optimization
- Consider and analyze measures to address emissions of methane
- Encourage the development and update of national action plans to develop policies and strategies to address GHG emissions from shipping

Mid-term measures:

- Implementation program for the effective uptake of alternative low-carbon and zero-carbon fuels
- New/innovative emission reduction mechanisms, possibly including Market-based Measures (MBMs)
- Development of a feedback mechanism to share lessons learned

Long-term measures:

- Develop zero-carbon fuels to allow full decarbonization of the shipping sector
- Encourage the adoption of other new and innovative emission reduction mechanisms



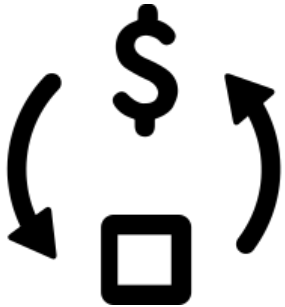
Financial tools can provide incentives to reduce emissions and direct revenues to help speed decarbonization of the shipping sector

Proposed IMO Research & Development Surcharge

A group of international shipowner associations representing over 90% of the world merchant fleet has proposed the creation of an International Maritime Research and Development Board (IMRB) to accelerate ZEV technology. The proposal would levy a mandatory ~$2/tonne surcharge on fuel oil purchased to contribute toward an R&D fund, raising $USD 5 billion over a 10-year period. While far short of what is required for full decarbonization, this proposal shows the progress that is being made at the IMO.

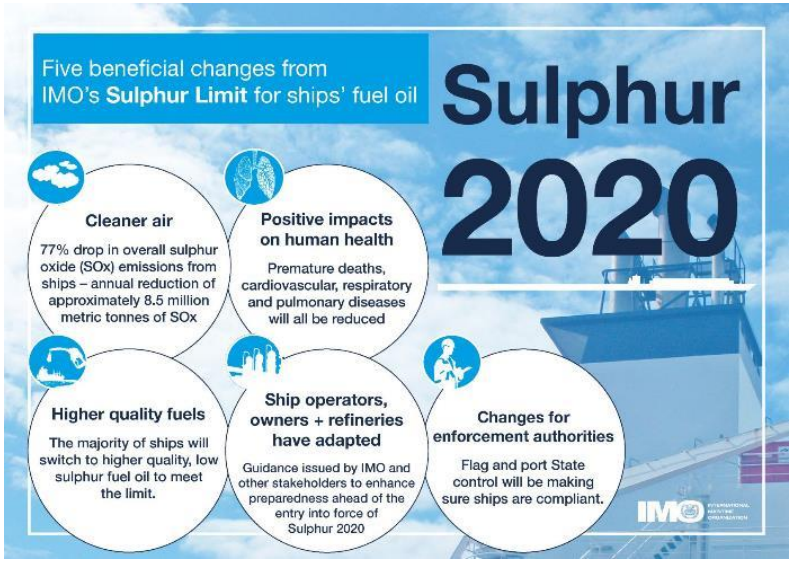
European Union Emissions Trading System (EU ETS)

In July 2020, European lawmakers agreed to include international carbon emissions from the maritime sector in the EU carbon market. They also called for binding targets for shipping companies to reduce the annual average CO_2 emissions of all ships by at least 40% by 2030 compared to 2018 levels. The implementation details are still being negotiated, but under discussion is the establishment of a “Maritime Transport Decarbonization Fund” to recycle $1-3.5 billion EUR annually from EU ETS revenues into supporting decarbonization actions and innovation.

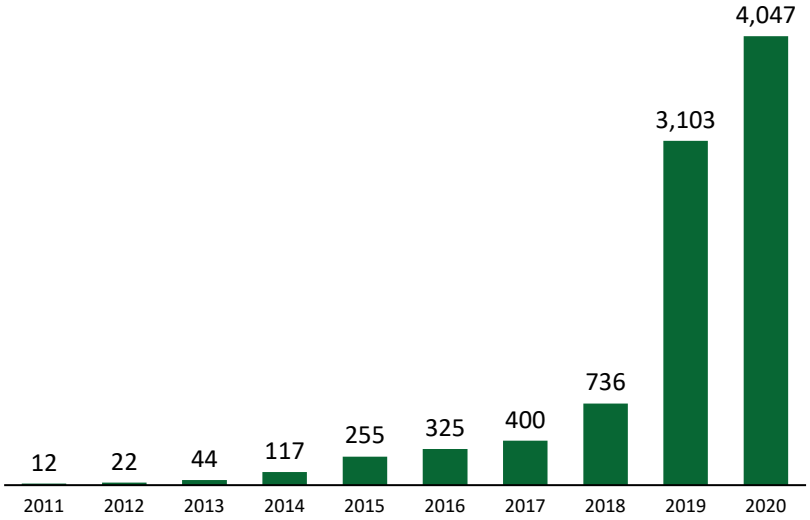


The IMO's new Sulphur Limit, implemented in 2020, will reduce SO_x emissions by up to 77%, preventing acid rain and reducing human health impacts

HFO contains high concentrations of sulphur, a harmful element that causes damage to human health. The IMO Sulphur limit reduced the maximum allowable sulphur content in shipping fuel from 3.5% to 0.5%, except for ships that use scrubbers. The policy has caused an exponential uptick in the number of ships with scrubbers to circumvent having to buy more expensive low-sulphur fuel. Marine conservation groups are concerned about this pattern because scrubbers generate contaminated washwater, which is sometimes dumped overboard.



Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

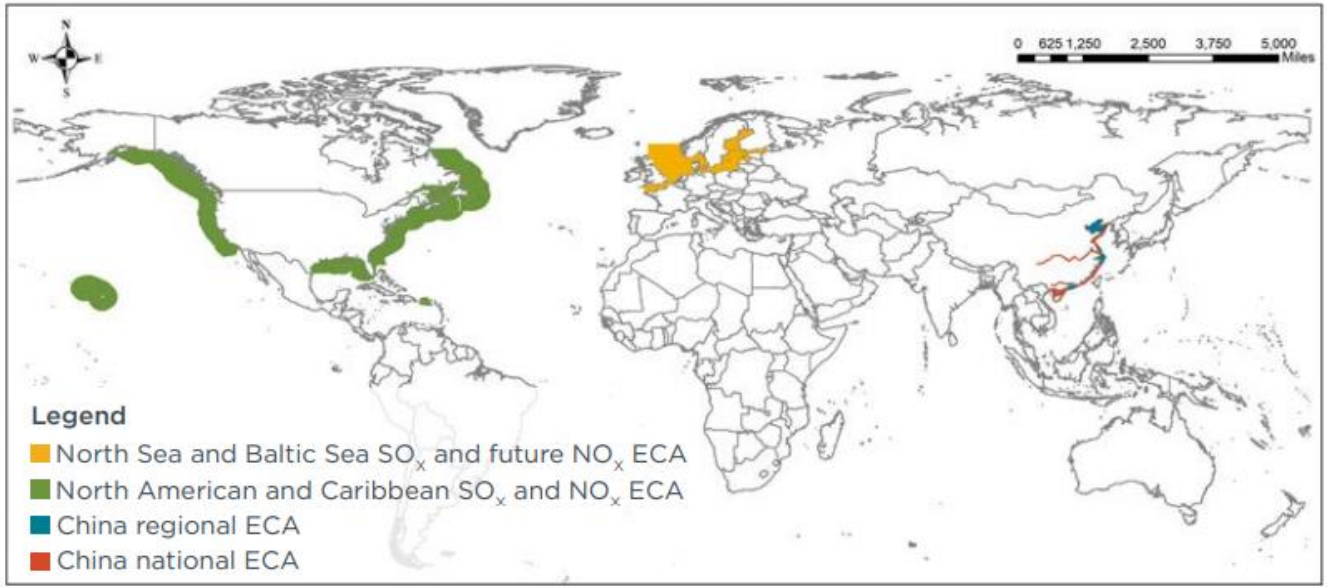


Number of ships with scrubbers

Source: ICCT (data from DNV GL Alternative Fuels Insight Platform)

Emissions Control Areas (ECAs) are a key tool for addressing localized air pollution

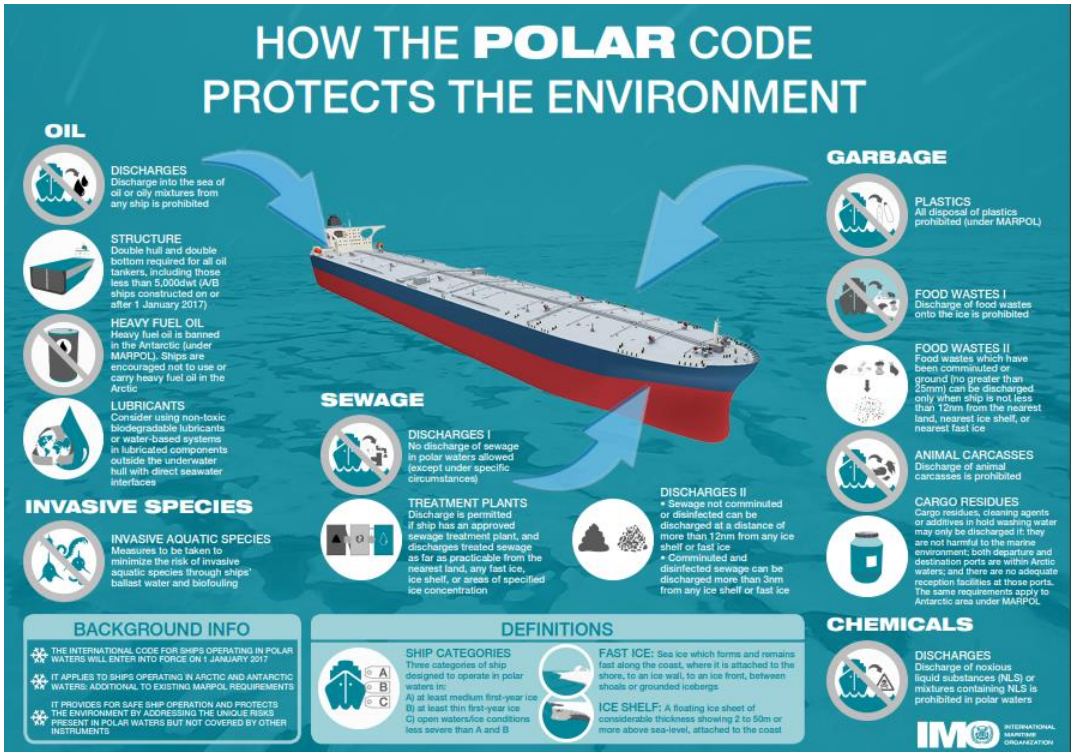
ECAs are zones near the coast of certain geographies where stricter restrictions are established to minimize pollution from targeted substances such as SO_x, NO_x, VOCs, and ozone depleting substances. The largest ECAs are off the coast of North America and in the North and Baltic Seas. China has three regional ECAs and a national ECA that are not regulated by the IMO and efforts are underway to move towards an IMO-approved ECA.



Map of existing and proposed ECAs

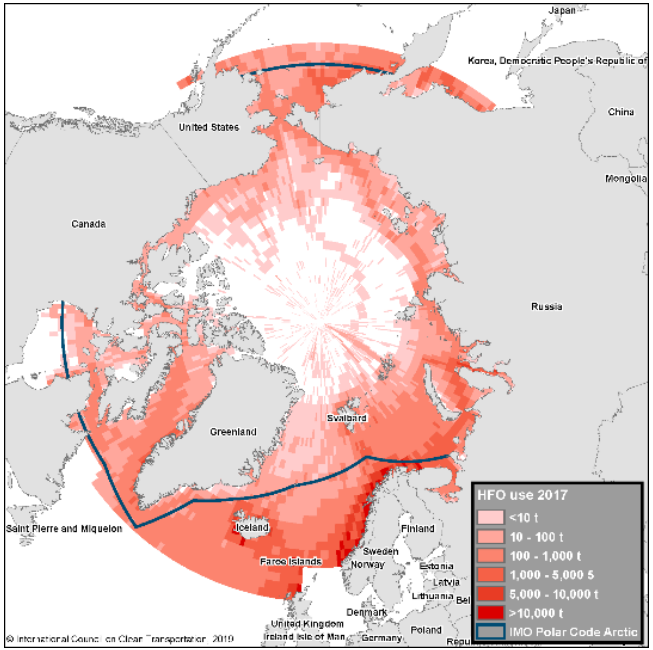
Source: ICCT 2019

The Polar Code, which entered into force in 2017, provides requires more stringent environmental measures for activities in polar waters



Source: http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx

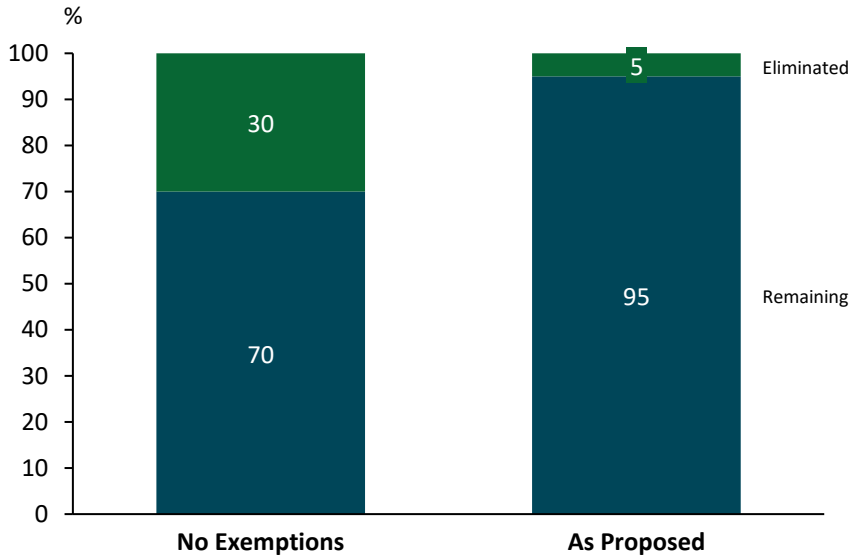
The IMO's draft HFO ban in Arctic waters would begin applying to some ships in 2024, but offers many exemptions and waivers



HFO Use in the Arctic, 2017

Source: ICCT

An HFO ban in the Arctic could significantly reduce spill risk and black carbon emissions, but many ships would be exempt from the currently proposed draft HFO ban until July 1, 2029.



Reduction in BC emissions with HFO ban is implemented with no exemptions or as currently proposed

Source: The International Maritime Organization's proposed Arctic heavy fuel oil ban: Likely implications and opportunities for improvement

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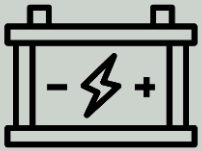
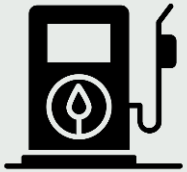
Key Opportunities and Barriers

Short-term opportunities can reduce shipping emissions, but are limited by costs, operational constraints, and slow ship turnover

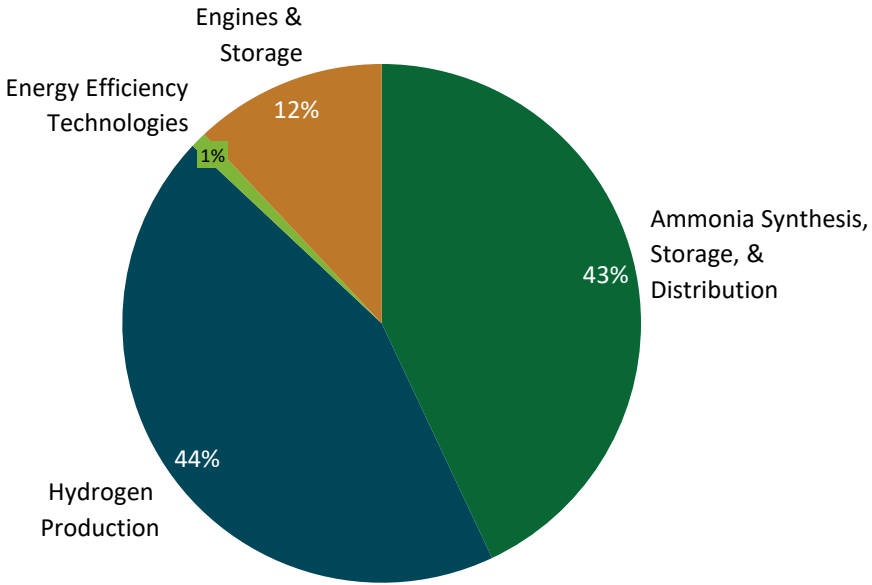
Measure	Description	Challenge
Slow steaming	Operating transoceanic cargo ships at a reduced speed can increase fuel efficiency	Slow steaming can introduce operational challenges for shipping and increase the cost of transporting cargo
Wind-assisted propulsion	Sails or other wind capture devices can help increase fuel efficiency	For the wind-assisted propulsion to be significant, capital investment is needed to retrofit ships
Efficient ship design	Modern materials can make ships lighter and more fuel efficient, decreasing overall fuel usage	Slow ship turnover can limit the rollout of efficient ships into global trade routes
Electric ports	Forcing ships to plug into electric power in ports can reduce the emissions of harmful pollutants into nearby communities	Infrastructure is needed to install the electrification systems at both ports and on ships

In the longer term, there are several ZEV technologies emerging

ZEVs can be either electric or operated with a green fuel such as green hydrogen, ammonia, or biofuels. Fuel-based ZEVs can use either an internal combustion engine or fuel cell technology. There are no commercially viable ZEV cargo ships yet, though getting ZEVs on the water by 2030 is an essential step toward meeting the IMO GHG targets.

		**Electric** A few ferry-sized vessels are on the water, but the technology is limited for longer distances because of battery size constraints
		**Hydrogen/Ammonia** Significant infrastructure investments are needed before hydrogen or ammonia ships can be deployed and scaled
		**Biofuel** Sustainable biofuels are not scalable to meet all shipping demands

Approximately $1-1.4 trillion USD investments are needed by 2050 to achieve the IMO 50% GHG reduction target



Investment breakdown across vessels and land-based infrastructure

$1-1.4 trillion USD of investment is needed by 2050 to meet the IMOs 50% GHG reduction target.

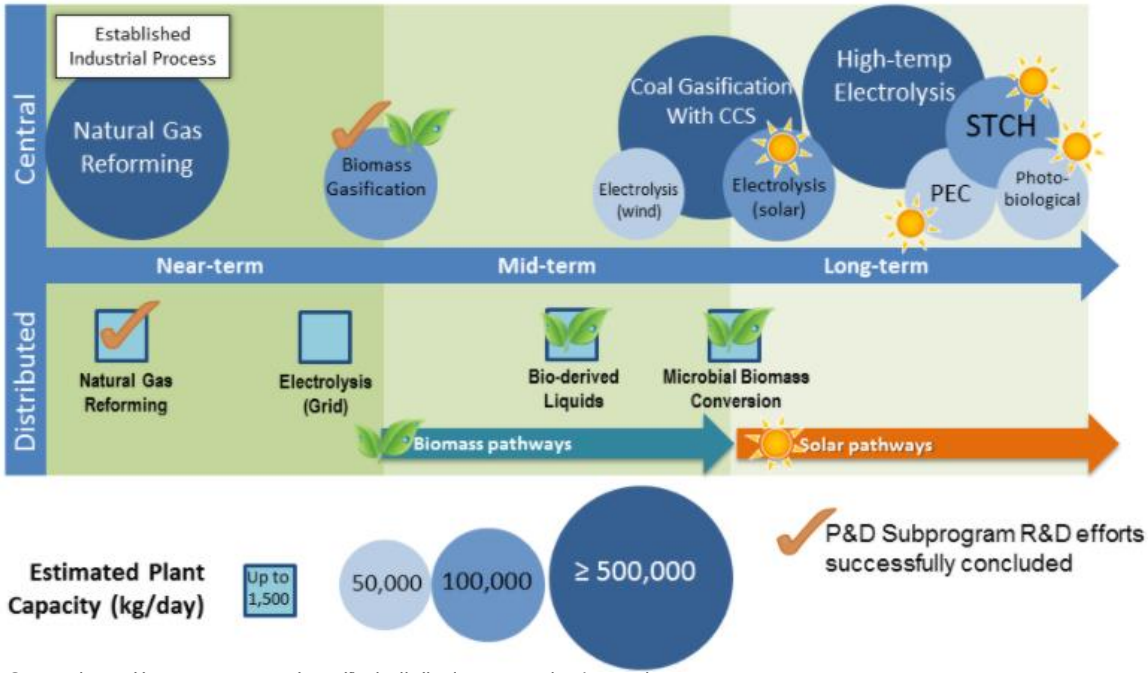
If shipping was to fully decarbonize by 2050, an additional $400 billion USD of investment would be needed. Due to the slow turnover of ships, ZEVs need to be rolling out by 2030 to meet the IMO GHG target, meaning construction must begin by around 2027.

87% of investment is needed for land-based infrastructure (i.e., hydrogen/ammonia production and distribution)

Sources: Krantz, Søgaard, and Smith 2020, "The scale of investment needed to decarbonize international shipping"

Hydrogen and ammonia fuel production will need to be powered by renewable energy resources to deliver climate benefits

US Department of Energy's stylized timeline of the development of H_2 production pathways

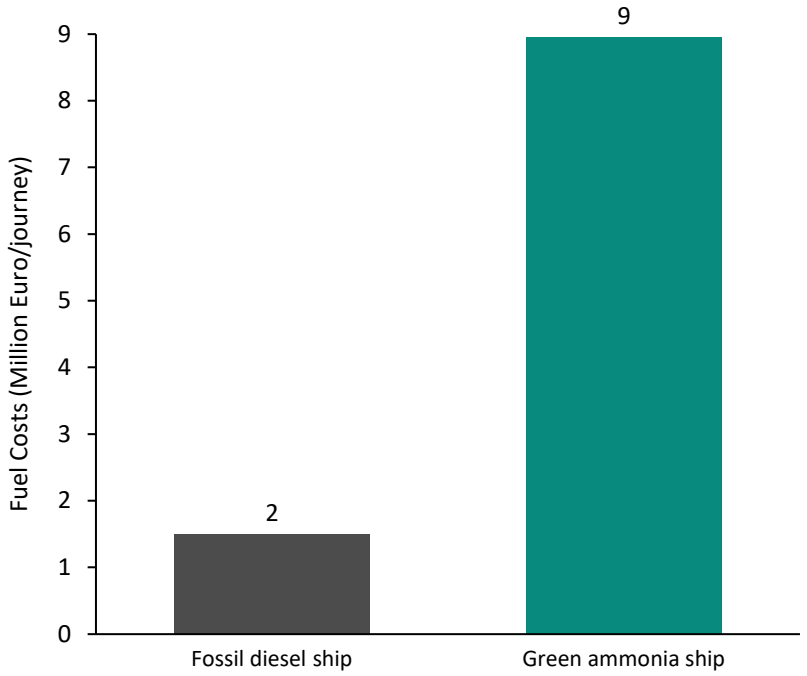


Source: https://www.energy.gov/eere/fuelcells/hydrogen-production-pathways

The standard process for hydrogen production is through natural gas reforming, which creates significant emissions. **To deliver climate benefits for the shipping industry, hydrogen will need to be produced with renewable energy.** Likewise, standard ammonia production is through steam reforming and the Haber-Bosch process which is greenhouse gas intensive and will require a transition to green production pathways.

Other challenges to ZEVs include fuel energy density, fuel price, safety standards, and risk for industry

- The relatively low energy density of green fuels like hydrogen and ammonia require more onboard storage, increasing capital cost and reducing cargo space and revenue.
- The higher cost of producing green fuels is currently a significant disincentive to moving toward ZEVs.
- Hydrogen and ammonia fuels pose a safety risk in their production and usage, but do not necessarily pose any larger threat than the risks posed by continued fossil fuel usage (spills, combustion, etc.).
- Industry is generally risk averse; they are unlikely to pursue a technology that poses additional risk or carries up-front capital investment with out additional incentives.



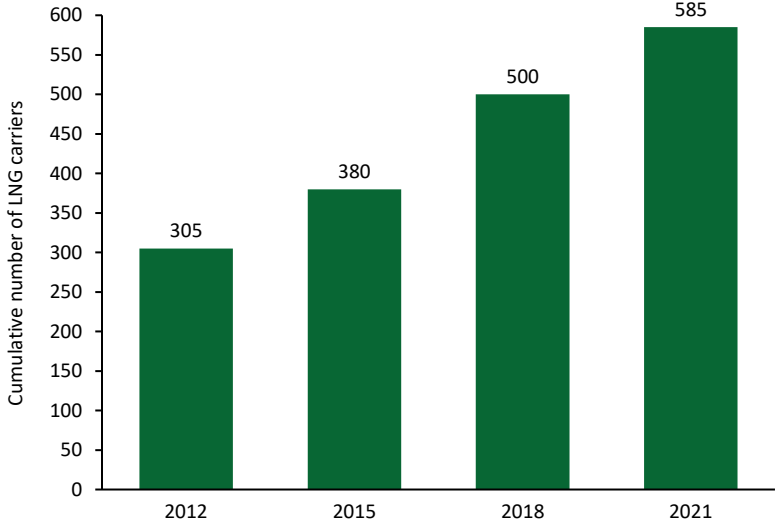
Comparison of costs of a green ammonia and fossil diesel ship

Source: Adapted from Transport & Environment

Source: Transport & Environment

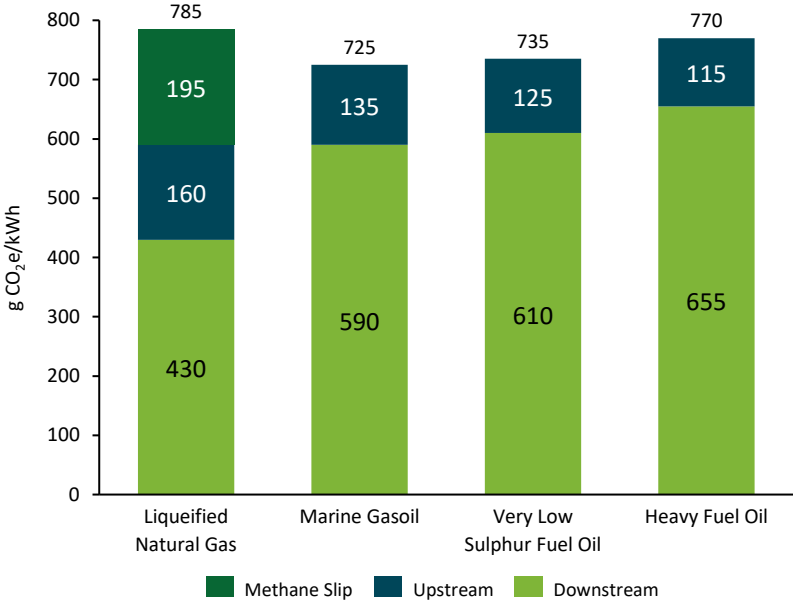
Parts of the maritime industry are turning to LNG as an alternative fuel, but this provides little to no climate benefit

LNG fueled ships are growing in number but offer little greenhouse gas savings from a life-cycle perspective – they may even have higher emissions than oil-fueled ships.



Cumulative LNG carriers built or on order as of mid-2018 (i.e., not annual production)

Source: IHS (2019). Note: LNG carriers represent more than 70% of LNG fueled ships



Life-cycle GHG emissions by engine and fuel type, 100-year GWP

Source: ICCT (2020). Note: Upstream is the emissions from production and transport. Methane slip is the leakage of uncombusted methane

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Current Interventions

Several strategies are being deployed by advocates to advance shipping decarbonization (1/2)

	IMO Advocacy	Member State Advocacy	Corporate engagement
Approach	**Accelerate action at the IMO** to eliminate dirty fuels from the shipping sector and improve shipping efficiency	**Cultivate decarbonization leadership** at the regional and national level	**Build industry support** for a clean shipping future
Illustrative Priorities	1. Negotiating short- and long-term GHG measures 2. Raising ambition of the GHG strategy 3. Securing ambitious financial mechanisms to drive decarbonization 4. Advocacy for policies that indirectly drive decarbonization (e.g., HFO bans, open loop scrubber bans, monitoring and reporting requirements, etc.)	1. EU advocacy with a focus on shaping rules of shipping in the ETS 2. Building NGO infrastructure for long-term dialogue with China on shipping decarbonization 3. Supporting emissions control area (ECA) development in the Mediterranean and China 4. Support local NGOs to build awareness of shipping pollution and mobilize pressure on governments	1. Engage with the “Getting to Zero Coalition” which includes 120 major shipping companies and finance companies. 2. Support major goods owners (e.g., Amazon, Walmart) to make commitments to zero carbon shipping and drive initial ZEV deployments through guaranteed contracts with shippers. 3. Hard hitting campaigns on high profile companies (e.g., Carnival)
Selected actors	TRANSPORT & ENVIRONMENT SEAS AT RISK icct	TRANSPORT & ENVIRONMENT NABU	THE ASPEN INSTITUTE GLOBAL MARITIME FORUM STAND.earth

Several strategies are being deployed by advocates to advance shipping decarbonization (2/2)

	Influence finance	Port advocacy
Approach	**Influence financiers** to integrate climate considerations into their lending decisions for the shipping sector	**Build decarbonization leadership** at ports and reduce localized air pollution for the most marginalized communities
Illustrative Priorities	1. Influence finance for the sector through initiatives like the Poseidon Principles, a framework for assessing and disclosing the climate alignment of shipping portfolios.	1. Advocate for ports to adopt climate-friendly measures (e.g., electrical hook up requirements, slow steaming incentives, ZEV bunkering infrastructure). 2. Support environmental justice organizations to apply pressure on ports. 3. Build a roadmap for a ZEV shipping route (e.g., LA to Shanghai)
Selected actors	UCL	Ocean Conservancy, icct

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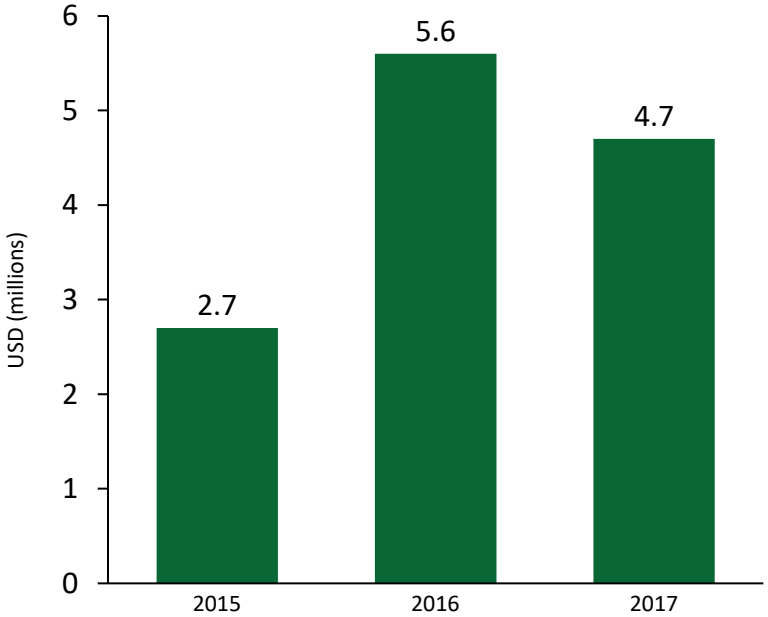
Funding Landscape

Historically, grantmaking for shipping decarbonization has been about $5M USD per year



Annual grants to shipping decarbonization from climate funders

Source: ClimateWorks Funding Data

Historically, only about $5M USD in annual grantmaking is directed to shipping decarbonization. This is supplemented by grantmaking from marine funders working on more traditional marine conservation shipping issues (e.g., marine mammal strikes, spill risk).

ClimateWorks, Pisces, Heising-Simons, and High Tide have been key funders of shipping sector work and their funding has been relatively stable for the last few years.

More funding is entering the sector highlighted by increased funding from the Bezos Earth Fund for ClimateWorks and Oceankind's entrance to the field, but more funding is needed to address the challenge.

Pisces Foundation

climateworks FOUNDATION

BEZOS EARTH FUND

HIGH TIDE FOUNDATION

oceankind

HEISING-SIMONS FOUNDATION

NGO landscape

Note: Illustrative examples of NGOs, not comprehensive

Reflections on shipping decarbonization from philanthropic funders

"The other thing that helped drive our decision [to invest in shipping], is that what they have done, they are doing it on a small amount of money."

"I would say every place in this sector, everything is underfunded."

"It is a small enough community that there is a lot of value in philanthropic investment. It is an 18th/19th century industry. Just the small things that you can do can have a major, major impact."

"I actually think, relatively speaking, it [IMO] is an international body that you can actually get something done."