



SHIPPING SOLUTIONS:

TECHNOLOGICAL AND OPERATIONAL METHODS AVAILABLE TO REDUCE CO₂

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EXECUTIVE SUMMARY

Global shipping is a major contributor of carbon dioxide to the atmosphere.

Operational and technical measures that can drastically reduce emissions are available to the existing fleet, and need to be used. In 2007 shipping was responsible for approximately 3.3 percent of global carbon dioxide (CO₂) emissions (over 1 billion tonnes).¹ If the global shipping fleet were a nation it would be the sixth largest emitter of carbon dioxide, only emitting less than China, the United States, Russia, India and Japan.² In the absence of emission reduction policies, emission scenarios predict a doubling to tripling of 2007 emission levels by 2050.³

The growth in shipping due to an expansion of global trade is projected to be responsible for a substantial increase in future emissions. Although technological advances will allow newbuilds to be more efficient than ships of today, a sizable portion of the current fleet is relatively young and will potentially be in service for many years to come. These ships could continue to be on the water for decades. Consequently, reductions in emissions that could be achieved by phasing in more efficient vessels will be slow.⁴

The International Maritime Organization (IMO) has recognized that an Energy Efficiency Design Index (EEDI) can be a cost-effective measure to reduce emissions from new ships. The EEDI, however, does not address the current fleet and overlooks the large potential to reduce emissions from these ships. On the other hand, incentivizing both technical and operational measures for existing ships could be done through an Energy Efficiency Operational Index (EEOI).⁵ Maintenance, operational changes and retrofits can all result in substantial increases in the efficient running of a vessel. Policies must be put in place to ensure that these large emission reduction potentials are not squandered.

Shipping is one of the most efficient modes of transportation currently available. However, the industry has been allowed to rely on this fact for too long, while it continues to ignore huge inefficiencies in its operations. Whether or not it is more efficient than other modes of transportation, the fleet must be held accountable for its large contribution to global carbon dioxide emissions.

The growth in shipping due to the expansion of global trade is expected to cause a substantial increase in future emissions.



Key Findings

- » Operational measures can have an almost immediate effect on emission reductions. These near-term mitigation measures can help reduce current emissions and prevent the projected extreme growth in emissions.
- » The International Chamber of Shipping recognizes that reductions of 15 to 20 percent of the carbon dioxide emitted per tonne of cargo transported are possible from 2007 to 2020, primarily through the use of operational and technological measures.⁶ Similarly, Det Norske Veritas (DNV) also finds that a 15 percent reduction of carbon dioxide from across the existing fleet can be achieved in a cost effective way.⁷
- » Aggressive action to increase vessel efficiency could reduce absolute emissions to 10 percent below 2007 levels by 2020 and to almost 18 percent below 2007 levels by 2050.⁸

Examples of Currently Available Emission Reduction Measures

MEASURE	REDUCTION IN CO ₂ EMISSIONS
Operations	10 – 50%
Slow Steaming	30% below BAU by 2013
Weather Routing	2 – 4%
Just-in-Time Arrival	1 – 5%
Optimization of Trim & Ballast	1%
Propeller Polishing & Maintenance	3%
Engine Tuning	1 – 2%
Technology	10 – 50%
Hull Coatings	10%
Propellers	5 – 10%
Vanes, Vane Wheels, Swirl Devices, Fins, Ducts, Rudders	5 – 10%
Waste Heat Recovery	10%
Alternate Fuels & Propulsion	
Marine Diesel Oil	5%
Kites	10 – 35%

- » By 2030 a reduction of 33 percent below the business-as-usual baseline could be attained at no cost. However, for a relatively small abatement cost of \$70 per tonne, emissions could be reduced by 45 percent, taking absolute emissions down to almost 6 percent below 2007 levels. Similarly, a cost of \$205 per tonne of carbon dioxide could result in an emission reduction of 56 percent, taking emissions down to almost 23 percent below 2007 levels.⁹
- » There is a large potential for short-term emission reductions through speed reductions even when putting extra ships to work. By 2013, a combination of speed reductions and utilization of previously out-of-work vessels could result in an approximately 30 percent reduction in carbon dioxide emissions below business-as-usual levels across the fleet. If put into immediate effect, this reduction in emissions would result in the elimination of 465 to 507 million tonnes of carbon dioxide in the period of 2011 to 2012 alone,¹⁰ which is the equivalent of shutting down 11 to 12 percent of the coal based emissions in the United States for the same period.¹¹
- » More than 225 shipping companies are engaging in slow steaming.¹² In 2009 alone Maersk saved \$300 million in fuel costs and has been able to reduce the carbon dioxide emission per container moved by 7 percent.¹³
- » Technical measures, especially those like hull coatings that are widely applicable, can be an important way to reduce carbon dioxide emissions from the fleet. Such measures can increase efficiency and reduce per tonne emissions across the fleet 10 to 50 percent below 2007 levels by 2050.¹⁴

INTRODUCTION

In 2007 over 100,000 ships plied the seas, emitting over one billion tonnes of carbon dioxide.

The continued burning of fossil fuels produces billions of tonnes of carbon dioxide each year. This carbon dioxide is the main driver of climate change and ocean acidification, the impacts of which could be catastrophic in the near future. Warming global temperatures are changing weather patterns, altering food production capabilities, and contributing to melting glaciers, rising sea levels, shifting animal populations and bleaching corals. Increasing ocean acidity caused by the absorption of carbon dioxide into ocean waters is making it more difficult for marine calcifiers to create their shells and skeletons, as well as disrupting many other important functions and processes throughout the ocean. This could result in a mass extinction of coral reefs beginning only about forty years from now.

The shipping industry contributes substantially to global carbon dioxide emissions. In 2007 over 100,000 ships above 100 gross tonnes plied the seas,¹⁵ emitting over one billion tonnes of carbon dioxide.¹⁶ Emissions are expected to grow considerably over the coming decades if emission reduction requirements are not put in place. Huge inefficiencies exist across the fleet; in fact a substantial amount of power produced by each ship is lost using current practices and does not contribute to propulsion.¹⁷ These inefficiencies result in large amounts of unnecessary emissions that can, in many cases, be easily mitigated through the implementation of improved operational and technical measures. A sizable proportion of the current fleet will remain in operation for many years to come; it is therefore vitally important to focus on emission reduction that can be gained from the current fleet instead of simply relying on the production of more efficient ships in the future.

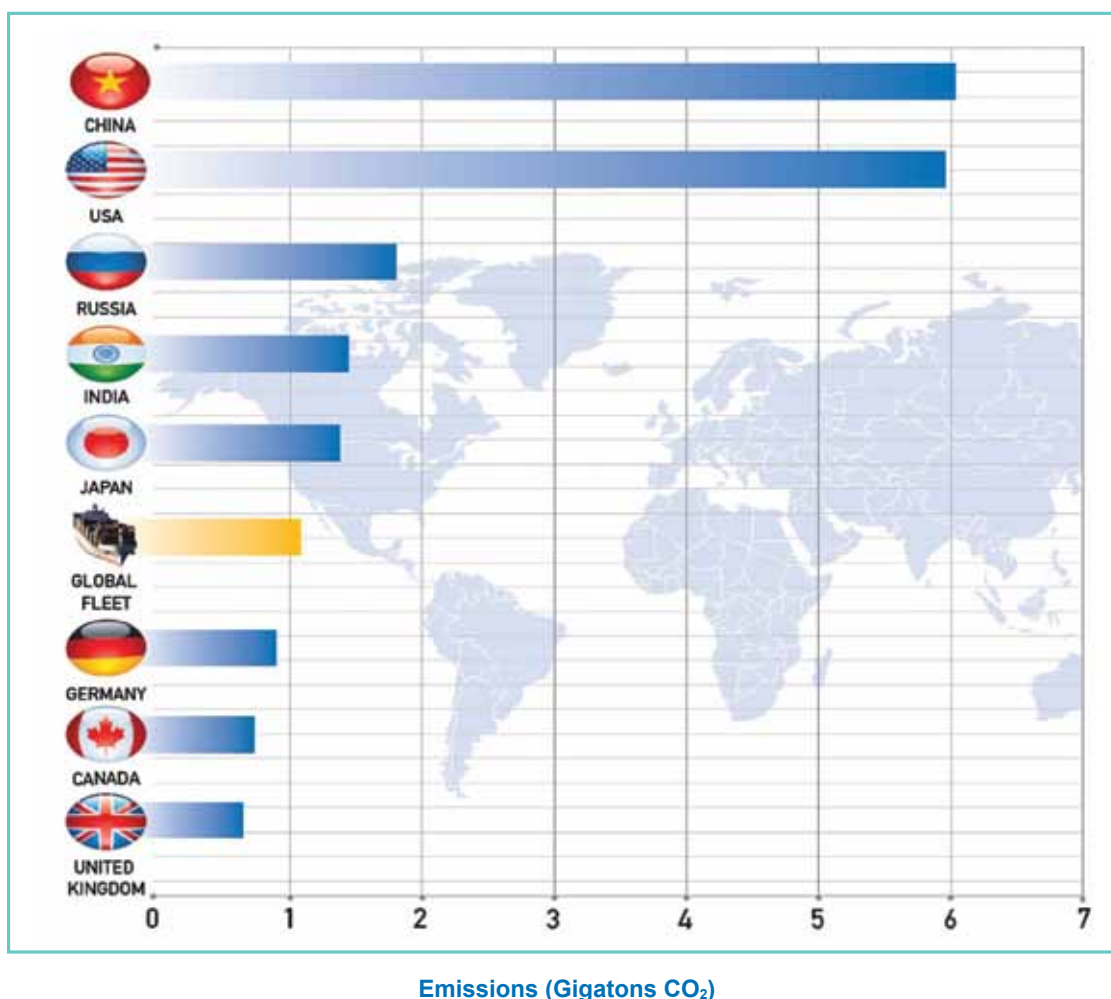
The IMO has focused much of its attention on development of an Energy Efficiency Design Index (EEDI) which could be a cost-effective measure to reduce emissions from new ships. The EEDI however, does not address the current fleet and will not reduce emissions from existing ships. Incentivizing both technical and operational measures can be done using an Energy Efficiency Operational Index (EEOI).¹⁸ Establishing an EEOI should be high on the agenda of the IMO as it could result in substantial emission reductions from across the existing fleet.



Shipping is one of the most efficient modes of transportation currently available. However, the industry has been allowed to rely on this fact for too long, while it continues to ignore huge inefficiencies in its operations. Whether or not it is more efficient than other modes of transportation, the fleet must be held accountable for its large contribution to global carbon dioxide emissions. Operational and technical measures are available to the existing fleet that can drastically reduce emissions. Many of these measures can be easily implemented and often at a cost saving. Climate change and ocean acidification threaten our planet and way of life, the shipping industry has the opportunity to play a large role in preventing, rather than causing, catastrophe.

**If shipping were
a nation it would
be the sixth
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carbon dioxide.**

Global Shipping Is Among the Largest Carbon Dioxide Emitters



Source: 2006 Country data from www.eia.doe.gov/pub/international/iealf/table1co2.xls and 2007 Shipping data from Buhaug, Ø, et al. (2009) Second IMO (International Maritime Organization) GHG Study 2009; International Maritime Organization London, UK

MANY METHODS ARE PROVEN EFFECTIVE

There has been some skepticism among the industry about earlier Oceana suggestions that slow steaming and other operational and technological advancements are not only cost effective but also safe. However, with rising fuel prices and increased awareness of shipping's impact, the industry itself has demonstrated that many of these changes are not only good for the environment, but also good for business.

More than 225 shipping companies are currently engaging in slow steaming.¹⁹ According to a recent Dynamar study, half of the currently active container fleet is slow steaming.²⁰ In fact, some of the largest lines including Maersk, Hapag-Lloyd, NYK Group and COSCO have employed this method. In 2009 alone Maersk saved \$300 million in fuel costs and has been able to reduce its carbon dioxide emissions per container moved by 7 percent.²¹ The company hopes to reduce its carbon emissions by 25 percent by 2020 and believes slow steaming will be a part of its strategy to do so.²² Clearly, if the rest of the industry followed this example, great progress could be made, with the shipping sector leading many others in adapting to changing environmental needs.

Companies' efforts to reduce costs and emissions are not limited to slow steaming. There are many examples of companies using technological and operational measures to reduce their emissions as well. Alongside slow steaming, APL is using a suite of methods, including trim optimization, cold-ironing, propeller fins and hull coatings.²³ Silicon paint hull coatings reduce fuel consumption, and therefore emissions, by 6 to 7 percent, while propeller fins are increasing the efficiency of APL's ships and reducing emissions an additional 2 to 4 percent.²⁴ With the use of a hull monitoring system,

The industry itself has demonstrated that many of these changes are not only good for the environment, but also good for business.

Horizon Lines determined that propeller polishing every four months could reduce the emissions from one of its vessels by 1.12 percent, saving one tonne of fuel from being used every day. Horizon is expanding the use of this system to its other vessels.²⁵

The fact that companies are voluntarily changing their operations to reduce carbon dioxide emissions is evidence that these options are effective and safe. However, these changes are not enough to solve a problem that is large and growing larger. Policies that institute these changes are needed to ensure that they are adapted industry-wide and maintained into the future.





NOAA

EXISTING FLEET IS A MAJOR EMITTER

In 2007 shipping was responsible for approximately 3.3 percent of global carbon dioxide emissions (1 billion tonnes).²⁶ If shipping were a nation that amount would make it the sixth largest emitter of carbon dioxide, surpassed only by China, the United States, Russia, India and Japan.²⁷ International shipping, excluding domestic shipping and fishing vessels, emitted 2.7 percent of global emissions (870 millions tonnes) that same year.^{28,29} The majority comes from cargo vessels, which account for 89 percent of total gross tonnage of the global fleet.³¹ Ship emissions are not only limited to carbon dioxide—other pollutants included SO_x, NO_x, PM, VOCs and CO. While some of these pollutants are greenhouse gases, actions to mitigate them do not offer the same potential for reducing global warming and ocean acidification as reducing carbon dioxide emissions.³² Like carbon dioxide, many of these pollutants will be reduced as the energy efficiency of ships is improved.³³

On average global shipping has grown by 3 percent annually over the last three decades³⁴ and emissions are projected to grow by more than 20 percent by 2020 and 50 percent by 2030, above 2007 levels.³⁵ In the absence of emission reduction policies, emission scenarios predict a doubling to tripling of 2007 emission levels by 2050.³⁶ Assuming reductions are achieved by other sources as is necessary to limit climate change to two degrees Celsius, unregulated shipping emissions could come to account for 12 to 18 percent of global carbon dioxide emissions in 2050.³⁷

While growth in shipping due to an expansion of global trade could cause a substantial increase in future emissions, there are already many available technologies and design practices that can be employed to build more efficient vessels. Technological advances will allow newly built ships to be more efficient than ships existing today. However, a sizable portion of the current fleet is relatively young and will potentially be in service for many years to come. Approximately half of the world fleet is 20 years old or younger; however by gross tonnage about half the fleet is 10 years old or younger.³⁸ Since the average life of a ship is 30 to 40 years,³⁹ these ships will foreseeably be on the water for decades to come. Consequently, reductions in emissions that result from phasing in of more efficient vessels will be very slow.

Ships may be the most efficient mode of goods transport currently available; however, there are still many inefficiencies across the fleet that can and should be corrected. Propulsion thrust is only generated by a small fraction of the fuel energy going into a ship's main engine; the rest is lost as heat or in the exhaust. In fact, over 90 percent of the energy provided by fuel can be lost.⁴⁰ Inefficient engines, propellers, and fouled hulls can all contribute to the reduction in a vessel's power. Maintenance, operational changes and retrofits can all result in substantial increases in the efficient running of a vessel. Policies must be put in place to ensure that these large emission reduction potentials are achieved.

EMISSION REDUCTION OPTIONS ARE AVAILABLE TO THE CURRENT FLEET



Large emission reductions are attainable across the existing fleet. Emissions can be reduced by increasing efficiency, using less carbon-intensive fuels or power sources, including renewables and using emission reduction technologies, such as chemical conversion.

Improving efficiency means decreasing fuel consumption per tonne-mile, or that the same amount of work is done using less energy. The original design of the ship in part dictates the efficiency.⁴¹ This is why good design is imperative in the future to lower emissions. However, there are technological options that are available to the existing fleet that can considerably reduce emissions. These can include novel hull coatings, retrofitted propellers and rudders, engine upgrades, waste heat recovery systems and the use of wind power.⁴²

The speed and capability of a ship is also closely linked to its operations,⁴³ and therefore operations are an important part of the emissions reduction potential of the fleet. Operational measures can include enhanced weather routing, energy management, hull and propeller cleaning, engine maintenance and tuning and optimized ballasting.⁴⁴

Operational measures can have an almost immediate effect on emissions. These near-term mitigation measures can help reduce current emissions and prevent the projected extreme growth in emissions. Operational measures should not be the only tool utilized to reduce shipping emissions, but they are the low hanging fruit that can take immediate effect and reduce emission from the current fleet that will continue to be in operation for the coming decades.

Port operations, though not the focus of this report, can also play an important role in reducing emissions. These can include improving logistics to reduce congestion and turn around time and implementing a system of slot time allocation.⁴⁵

While many of these emission reduction techniques may seem piecemeal, they will contribute to reducing fuel consumption and hence carbon dioxide emissions from individual ships. Incremental decreases in emissions from individual ships can result in large reductions across the entire fleet.⁴⁶ In fact, the 2009 IMO study suggests that the fleet can become 25 to 75 percent more efficient than it is currently through both operational and technological measures (retrofits and newbuilds) by 2050. This same study finds that operational measures alone can reduce emissions by 10 to 50 percent.⁴⁷

The International Chamber of Shipping recognizes that reductions of 15 to 20 percent of the carbon dioxide emitted per tonne of cargo transported are possible from 2007 to 2020 through mainly operational and technological measures.⁴⁸ Similarly, Det Norske Veritas (DNV) confirms that a 15 percent reduction of carbon dioxide from across the existing fleet can be achieved cost effectively.⁴⁹

While many technical improvements are only applicable to newbuilds, operational measures are applicable to all ships and have the potential to reduce emissions by 621–854 million tonnes in 2050 under conditions of moderate support from market-based drivers or 835–1137 million tonnes when driven by substantial policy and market mechanisms and very high fuel prices.⁵⁰ In this more aggressive scenario vessel efficiency is increased by around 70 percent of 2007 levels, resulting in 70 percent less carbon dioxide emitted by the fleet.

Future emissions will depend not only on how much emissions can be reduced per tonne-mile but also on how the fleet grows in the future. Only if the percentage growth of the fleet is smaller than the percentage reduction in per tonne-mile emissions will the absolute emissions from the fleet fall below current levels. An annual growth rate of between 2 and 3 percent, which represents a range of growth patterns without including the extremes, coupled with aggressive emission reductions will result in emissions remaining close to the 2007 level until 2050 (Table 1). However, the emissions avoided in this scenario could be as much as 2.7 billion tonnes of carbon dioxide,⁵¹ which is the equivalent of shutting down all the coal plants that are projected to be in operation in the United States in 2035.⁵²

YEAR	POTENTIAL CO ₂ EMISSION REDUCTIONS PER MILE (%)
2020	10 – 25
2030	33 – 45
2050	25 – 75

Table 1: Per-mile emission reductions possible from a combination of technical and operational measures from across the fleet.

There are technological options that are available to the existing fleet that can considerably reduce emissions.

Operational and Technical Measures Can Reduce Emissions

	USE OF MEASURES	EMISSIONS (MT CO ₂)	EMISSION REDUCTIONS (%)	MITIGATED EMISSIONS (MT CO ₂)	PERCENTAGE OF 2007 LEVEL (%)
2020	None	1333 – 1467	0	0	131 – 145
	Low	1260 – 1384	6	73 – 82	124 – 136
	Medium	1040 – 1139	22	294 – 327	102 – 112
	High	910 – 996	32	424 – 471	90 – 98
2050	None	2820 – 3883	0	0	278 – 383
	Low	2338 – 3211	17	428 – 671	230 – 216
	Medium	1303 – 1782	54	1517 – 2101	128 – 176
	High	835 – 1137	70	1986 – 2746	82 – 112

Table 2: Possible 2020 and 2050 CO₂ emission levels due to either no, low, moderate or high implementation of operational and technical measures and use of alternative fuels compared to 2007 assuming growth scenarios that represent a range of growth patterns without representing extremes.⁵³

* EIA coal plant emission projections stop at 2035.

Large Emission Reductions Are Possible

Increasing the per tonne-mile efficiency of the fleet is one approach that can be used to reduce absolute emissions, and as is evident large gains can be made. If the industry grows at a rate of between 2 and 3 percent in the future, as discussed above, approximately neutral growth in emissions is a realistic target with aggressive implementation of operational and technical measures and alternative fuels (see high emission reduction scenarios in Figure 1).⁵⁵ Aggressive action to increase

vessel efficiency could reduce absolute emissions 2 to 10 percent below 2007 by 2020 and 12 percent above to almost 18 percent below 2007 levels by 2050 (Table 2).⁵⁶ However, reducing absolute emissions will require additional measures over and above increasing efficiency.⁵⁷ A high price on carbon could drive the implementation of a wider range of measures that could yield larger emission reductions, even below current levels.

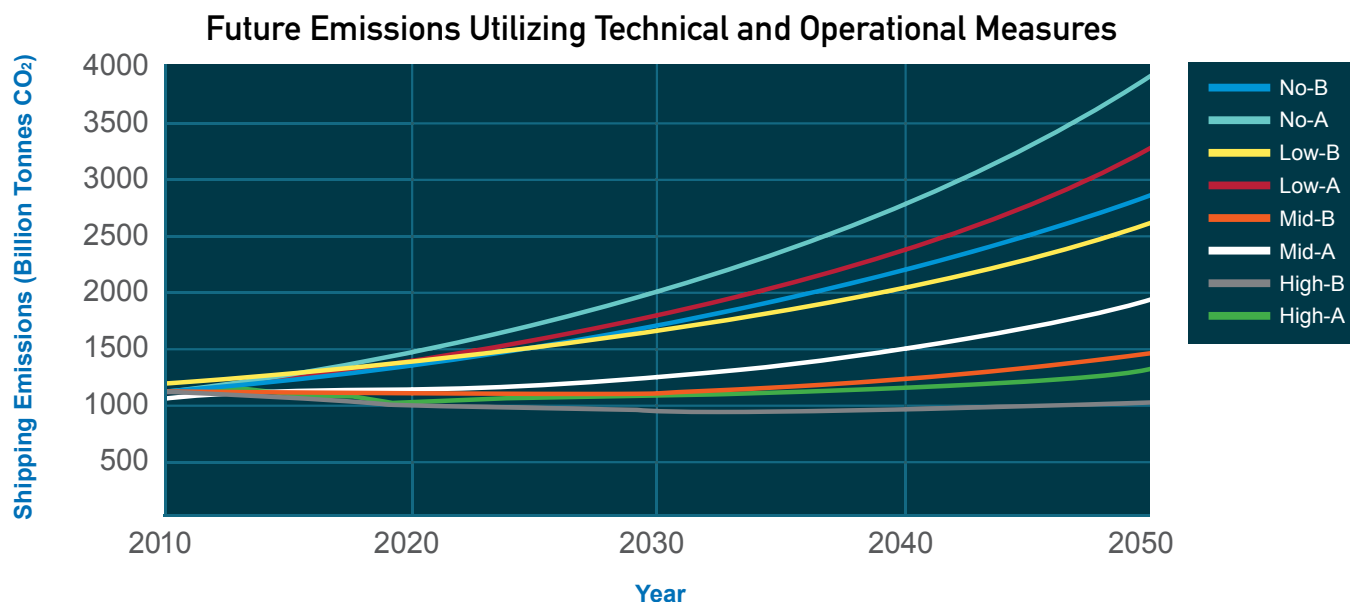


Figure 1: Future emission levels under no, low, medium and high emission reduction scenarios.⁵⁴ Each of the growth futures is broken into A and B scenarios, which correspond, respectively, to the global development A1B and B1 scenarios examined in the 2009 Second IMO GHG Study.



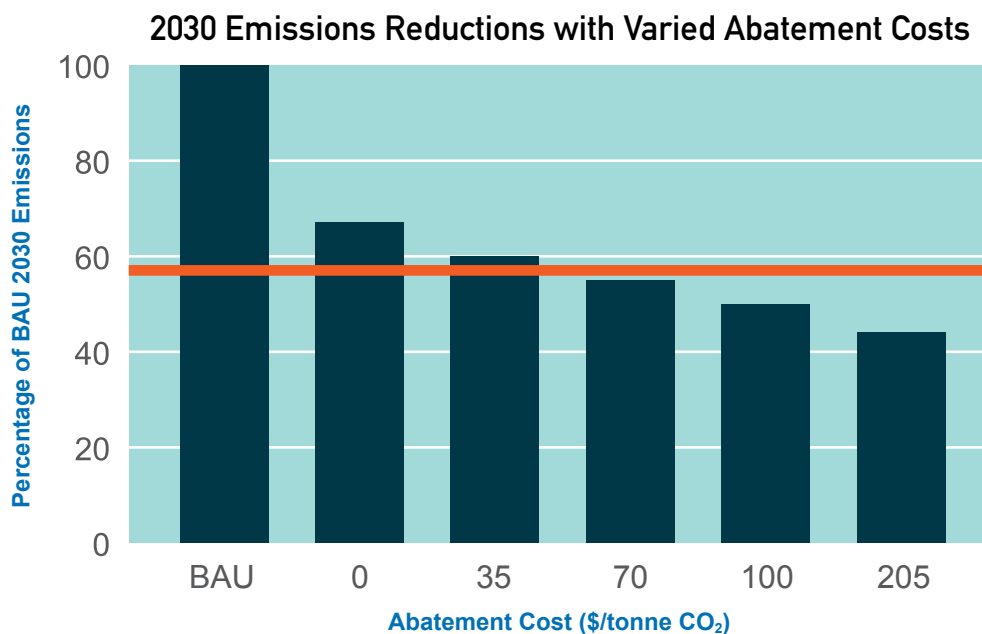


Figure 2: An abatement cost of \$205/t CO₂ will result in an emission level 23 percent below 2007 levels. The orange line represents the 2007 emission level.⁶¹

Fuel costs have increased substantially over recent years and continue to account for an increasingly larger portion of a vessel's operations costs.⁵⁸ Finding ways to increase efficiency and reduce fuel consumption will be of benefit to the fleet as a whole. By 2020 the fleet could reduce emissions, at no cost, by 25 percent below the business-as-usual baseline.⁵⁹ By 2030 a reduction of 33 percent (18 percent above 2007 emissions) could

also be attained at no cost; however, for a relatively small abatement cost (cost to avert one tonne of CO₂—\$/tonne CO₂) of \$70, emissions could be reduced by 45 percent, taking absolute emissions down to almost 6 percent below 2007 levels. Similarly a cost of \$205 could result in a reduction of 56 percent, taking emissions down to almost 23 percent below 2007 levels (Figure 2).⁶⁰ This would allow accelerated emission reductions.



Operational Measures to Increase Ship Efficiency and Reduce Emissions

Much of the emissions savings that can be realized across the existing fleet comes from improvements in operations. These measures can be implemented by all ships, many almost immediately, and some have the potential to reduce emissions by as much as 50 percent by 2050.⁶² Operational measures include vessel maintenance and operation, and improvements in speed, route, port logistics, and fleet management.

Many of these changes can be made without retrofits and therefore can result in instant savings due to decreased fuel consumption. Investments in training the crew may be required to effectively implement new operational measures.⁶³ However, these investments should pay off quickly. The most beneficial option for reducing fuel consumption, and hence emissions, via operational measures is slow steaming.⁶⁴

Slow Steaming

Slow steaming (traveling at 20 knots or below rather than 24 or 25 knots) is an operational measure that can be easily implemented without retrofits and can reap immediate rewards,⁶⁵ often at a cost saving. It has been suggested that slow steaming alone can reduce carbon dioxide emissions in some instances by as much as 70 percent when speed is halved.⁶⁶ A conservative assessment of emission reduction potential suggests that just a 10 percent speed reduction across the fleet could reduce total emissions by 7.9 percent below business-as-usual in 2020 (98.7 million tonnes of carbon dioxide).⁶⁷ This is the equivalent of preventing 4.5 percent of projected emissions from coal fired power plants in the United States in that same year.⁶⁸

Slow steaming does result in a decrease in capacity, however there are methods that can make up for this, including more efficient ports and adding extra vessels.⁶⁹ While adding additional vessels reduces the potential for emissions savings, savings can still be realized—even if additional ships are put into service, slowing down makes sense.

The amount of carbon dioxide emitted by a ship is proportional to the fuel consumed by that vessel. Fuel use and speed are generally related by a third power function, hence a 10 percent reduction in speed equates to an approximate 27 percent reduction in fuel consumption and emissions per unit of time.* However, since reduction in speed results in an increase in trip time (a 10 percent reduction in speed increases trip time approximately 11 percent) the relationship between speed and fuel consumption is better reflected by a quadratic relationship. Hence, a 10 percent reduction in speed results in a 19 percent reduction in emissions.⁷⁰ In reality a 10 percent reduction will reduce emissions somewhat more than 19 percent since vessels only travel at their optimal speed for a small portion of their trip.⁷¹ While it is difficult to generalize the emission reductions possible for each vessel, it may be possible



**10% reduction in speed, therefore the vessel is operating at 90% of its original speed ($0.93 = 0.73$). Therefore, operating at 90% produces 73% of the emissions if operating at full speed, hence an emission reduction of 27%.*

to reduce the engine load on large ships without any retrofits by as much as 40 percent,⁷² which would equate to an approximate 16 percent reduction in speed and a 29 percent reduction in fuel use and emissions when additional capacity is included.

The reduction in capacity due to slower speeds can be addressed by increasing the cargo carried by each ship, increasing the number of ships working or improving port efficiency. Increasing the work load or number of ships will increase the fuel use and carbon emissions, however fleet-wide fuel consumption and emissions can still be lower than a smaller fleet travelling at faster speeds.⁷³ Therefore, the need to add additional vessels should not be seen as an excuse not to reduce speeds across the fleet. In fact, the global fleet currently faces an oversupply of ships, and these ships can be put to work to make up the capacity lost due to ships traveling at slow speeds. In 2009 approximately 10 percent of the container fleet capacity was not used.⁷⁴ It has been reported that extra slow steaming has put to work almost 100 ships.⁷⁵ This could be increased as more lines choose to slow their ships in the future.

The short term potential for emission reductions by reducing speed is large even when putting extra ships to work. By 2030 reducing speeds to utilize all laid-up vessels, and without any retrofits would allow tankers to reduce their emissions from 12 to 20 percent, bulkers by 17 to 29 percent and container ships by 4 to 16 percent. Combined, this could total an approximate 30 percent reduction in carbon dioxide emissions below business-as-usual across the fleet. This reduction in emissions would result in the mitigation of 465 to 507 million tonnes of carbon dioxide in the period of 2011 to 2012 alone,⁷⁶ or the equivalent of shutting down 11 to 12 percent of the coal plant emissions in the United States for the same period.⁷⁷ Some of these reductions may have already been realized by the fleet; however there is still room for larger reductions in the very near term. Slow steaming can cause concerns due to vessels operating off-design. Concerns include loss of efficiency from the heat recovery systems, propeller and turbo charger; increased hull and propeller fouling; increased maintenance of auxiliary systems; increased consumption of lubricant; and increased level of vibrations.^{78,79} Most of these concerns can be

By 2033, reducing speeds to utilize all laid-up vessels could total an approximate 30 percent reduction in carbon dioxide emissions.

overcome with minor retrofits, or do not risk of causing permanent damage to the vessel.⁸⁰ Maersk has reportedly found that slow steaming does not cause long term detrimental effects to the life of a vessel's engine.⁸¹ Large vessels with 2-stroke engines can operate at minimum engine load of about 40 percent without damage and vessels can even operate below this with engine de-rating or slow steaming upgrade kits.⁸² Vessels that are to be operated at slow speeds on a permanent basis can have their engines de-rated protecting the engine at lower speeds and enabling it to run in a more effective, fuel efficient manner. This has been shown to be very effective, especially for older engines.⁸³

It is unmistakable that considerable emission reductions are possible through slow steaming. In fact, many lines have implemented slow steaming over the past years as a way to reduce fuel consumption in the face of high fuel costs.⁸⁴ Sustainable Shipping recently reported that more than 225 vessels are slow or super slow steaming.⁸⁵ This is evidence that slow steaming works to reduce fuel and emissions and is not a danger to the life of an engine. Shipping companies such as Maersk describe slow steaming "as the most innovative development in container shipping in recent history."⁸⁶ Hapag-Lloyd has reported that by reducing the ship speed by just five knots, equating to a 20% reduction in vessel speed, the company would save approximately 50% on fuel costs.⁸⁷

While it is likely that slow steaming will remain in favor while fuel prices are high, if fuel prices drop again in the future lines may shift back to full steaming. It is therefore important that policies are implemented to institutionalize the practice of slow steaming so that reductions in emissions, not just costs, are seen long into the future.

Improved voyage planning

The efficiency of a voyage can be improved through weather routing, shaft, trim and ballast optimization and just-in-time arrival.⁸⁸ Weather routing, includes selecting optimal routes based on weather conditions and currents to reduce energy consumption.⁸⁹ Weather routing is possible for all types of ships and has the potential to achieve emission reductions as high as 2 to 4 percent.⁹⁰

Just-in-time arrival takes into account tides, congestion and arrival windows to avoid long wait times at the port.⁹¹ Vessels will often travel quickly to a port and then spend large amounts of time waiting to berth. This increases emissions during the voyage and while ships are idling at the port. This can be avoided with just-in-time arrivals. Studies estimate that just-in-time arrivals offer the potential to reduce emissions by 1 to 5 percent.⁹²

Optimization of ballast and trim attempts to find the best operating trim and avoids carrying unnecessary ballast.⁹³ The resistance of a vessel through the water is heavily influenced by the trim and ballast conditions.⁹⁴ Optimizing trim and ballast can reduce this resistance and therefore the emissions produced by the vessel. Optimizing ballast and trim has been estimated to reduce fuel consumption by up to 1 percent.⁹⁵ Computer software can be run while a vessel is at sea to find the optimal trim, and these approaches have reportedly achieved fuel, and therefore emissions savings, of up to 5 percent.⁹⁶

Studies estimate that just-in-time arrivals offer the potential to reduce emissions by as much as 5%.



Propeller, Hull and Propulsion System Maintenance

While the selection of the optimal propeller should occur during construction, it is possible to upgrade a propeller (see section on technical measures). Beyond upgrades proper propeller maintenance can increase ship efficiency. Polishing a roughened propeller and correct maintenance can decrease fuel consumption by up to 3 percent.⁹⁷ Hull resistance can be increased substantially due to hull fouling and roughness. Hull cleaning can drastically reduce resistance. Maintenance of the engines is important to ensure they are operating most effectively and therefore efficiently. Main engine tuning has been observed to reduce fuel consumption by 1 to 2 percent.⁹⁸

Technological Measures to Increase Ship Efficiency and Reduce Emissions

Technological changes have the potential to reduce per tonne-mile emissions by as much as 50 percent. These changes can include propeller and engine upgrades, low resistance hull coatings, and waste heat recovery systems.

One of the most effective and widely applicable technical measures to reduce carbon dioxide emissions is the application of hull coatings that can reduce resistance to 20 to 50 percent of the vessel as it travels through water.⁹⁹

Paints and Hull Coatings

During the operation of a vessel's organic growth, damage and cracking can increase the roughness of the hull. Fuel consumption can be increased by as much as 40% due to hull fouling according to the U.S. Navy.¹⁰⁰ Maintaining a clean, smooth hull is very important for optimal fuel efficiency and hull coating and maintenance can reduce fuel use by 5 percent.¹⁰¹

Self-polishing coatings can be used to prevent organic fouling. While some of these coatings release toxic substances, others are silicone based and are 'slippery' so they do not allow growth to take hold. These are commonly known as foul release coatings. The effectiveness of hull coatings declines over time and will

periodically need to be cleaned and then replaced.¹⁰² Hull fouling and roughness may increase resistance through the water between 6 and 80 percent. The average for a hull that has not been well maintained is 30 percent.¹⁰³ This 30 percent increase in resistance equates to an average 20 percent increase in fuel consumption.¹⁰⁴ Approximately a third of the global fleet has hulls in good condition with resistance below 20 percent. About a half of the fleet have hulls in reasonable condition (20 to 40 percent resistance) that could see improvements in fuel efficiency relatively easily. The remainder of the fleet, some 10,000 dwt, has added resistance over 50 percent.¹⁰⁵ Sending a ship into dry-dock can reduce the added resistance to as little as 0 to 4 percent, even a partial treatment in dry-dock can reduce resistance to 50 to 20 percent.¹⁰⁶

Increasing fuel prices in the 1990s saw many owners investing in foul release coatings, despite their costs being as much as four times what they had traditionally paid for hull coatings.¹⁰⁸ Four to six percent savings were realized with these coatings and payback on these investments was seen in less than 1 year.¹⁰⁹ Newer coatings have been reported to achieve 10 percent fuel savings,¹¹⁰ with the payback still occurring in less than a year.¹¹¹ Coatings currently under trials may result in even larger fuel savings of 17 percent or more.¹¹²





It is possible to retrofit a vessel with a more efficient propeller and reduce fuel consumption by as much as 15%.

Propellers

Large rotating propellers that turn at a low revolution produce high propulsive efficiency.¹¹³ It is possible to retrofit a vessel with a more efficient propeller. This could increase fuel consumption by as much as 15 percent, with a range of 5 to 10 percent likely.¹¹⁴

The loss of propeller energy can also be recovered by measures such as vanes, free rotating vane wheels, pre and post-swirl devices, fins, ducts and high-efficiency rudders. These measures can reduce a vessel's propulsion power by 5 to 10 percent.¹¹⁵

Automatic Controls

Upgrading the automatic systems, such as temperature control, lights, and speed control, can also improve the efficiency of a vessel. These improvements can reduce the need for auxiliary power by about 10 percent.¹¹⁶



Waste heat and engine energy recovery

Waste heat recovery systems use waste heat from the exhaust to either generate electricity or help propel the vessel. These systems can not be retrofit on every vessel but they are commercially available for many.¹¹⁷ Waste heat recovery can reduce fuel use by about 10 percent.¹¹⁸

Engine energy recovery systems can increase engine power and therefore reduce fuel use and emissions. These systems can increase engine power by 9 to 11 percent.¹¹⁹

Alternative Fuels and Propulsion

Alternative fuels present options to lower the lifecycle carbon dioxide emissions of fuels currently used. Heavy fuel oils can be replaced with marine diesel oil (MDO) which is less carbon intensive and allows for more effective fuel combustion, resulting in better efficiency and lower levels of emitted particulate matter.¹²⁰ Switching over to MDO can reduce carbon dioxide emissions from vessels by as much as 5 percent.¹²¹ Vessels are already switching to low sulfur fuels (LSFO) in emission control areas, and this transition will occur more widely as the MARPOL Annex IV rules come into force, reducing carbon dioxide emitted from the vessels.¹²² The use of LSFO can also result in more energy generation for auxiliary systems as waste heat recovery systems can work with lower exhaust temperatures.¹²³ Alternative fuels will become a more attractive option in the future as more fuels are developed.

Renewable energy, wind, solar and wave power can be used on board to either contribute directly to propulsion or to power auxiliary systems. Solar and wave power technologies are not yet widely available, however wind technology in the form of sails, kites, solid wings and rotors can be added to current vessels with large reductions in fuel consumption. Wind technology could create fuel savings of about 5 percent for vessels travelling at 15 knots and about 20 percent for vessels traveling at 10 knots.¹²⁴ Kites have been reported to gain a 10 to 35 percent saving in fuel for a single voyage.¹²⁵ Kites take up only a small area on the deck and can be relatively easily retrofit.¹²⁶

**Alternative fuels
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THE REGULATORY OPTIONS

The International Maritime Organization

The IMO could play a vital role in determining how the global fleet will reduce emissions. Various IMO studies have concluded that there is large potential for reducing emissions through operational and technical measures.¹²⁷

However, the IMO was charged with addressing the issue of greenhouse gases from ships thirteen years ago. In that time, no requirements have been set to address global warming pollution. This is due, in part, to opposition from some countries, such as China, who seem to oppose any action, indeed, oppose even the discussion of emissions reductions for greenhouse gases. Similarly, flag-states, or countries that many ships are flagged by, have also frustrated such actions. While the IMO is not required to have full consensus in decision-making, it does appear to prefer such an approach and as a result, little has been accomplished in the past thirteen years. In fact, the IMO has failed to set a target for emission reductions, a baseline that emission reductions will be measured against and even a method of how emissions will be reduced.¹²⁸

In the last thirteen years the IMO has conducted a series of studies, all pointing to large carbon dioxide emissions from ships, and demonstrating the many

options that exist to reduce emissions. However, the organization has done little more than develop an efficiency measure for newly built ships—one that has not even been made mandatory.

While the IMO has recognized that an Energy Efficiency Design Index (EEDI) for new ships can be a cost-effective measure to reduce emissions it has not at all addressed the emissions from the current fleet. A similar emissions index that has been considered but not adopted focuses on the operations of existing ships, from which a much greater contribution to carbon dioxide reductions could be achieved. Putting in place an Energy Efficiency Operational Index (EEOI) would promote both technical and operational measures.¹²⁹

In 2000, IMO found that speed reductions and other measures could reduce emissions 40% by 2010.

IMO by the Numbers

1997

Kyoto Protocol delegates responsibility of shipping emissions to the IMO.

2000

IMO *Study of Greenhouse Gas Emissions from Ships* finds shipping emissions account for 1.8% of global CO₂ emissions; however, significant potential exists to reduce emissions via operational and technical measures. Speed reductions, the single most effective means to reducing CO₂, combined with other operational and technical measures could reduce emissions by over 40% by 2010.



National and Regional Action

Oceana and its partner organizations, EarthJustice, Center for Biological Diversity and Friends of the Earth petitioned the United States Environmental Protection Agency (EPA) to require emissions standards that employ the available technologies. The EPA has the authority to do this under the Clean Air Act, which provides the authority to set emissions standards for new nonroad engines and vehicles.¹³⁰ Many tens of thousands of ships enter United States waters each year. By regulating their emissions the United States would be taking a huge step forward in reducing carbon dioxide emissions from shipping.

The European Union has signaled that it is unhappy with the IMO dragging its feet on regulating carbon dioxide emissions and has suggested that it may integrate shipping emissions into its own emission trading scheme. While the EU has stated it prefers global action, it is prepared to act unilaterally if there is no action by 2011.

Global action is obviously the preferred course of action; however, if global regulations are not agreed upon national and regional action may be the best way to move forward to reduce carbon dioxide emissions from ships. It is simply unacceptable to wait years, and possibly decades for the much needed and economically achievable changes to be made.

2007

Global shipping emits over 1 billion tonnes of carbon dioxide.

2009

The *Second IMO GHG Study* finds shipping emissions have grown to account for 3.3% of global CO₂ emissions. Technical and operational measures are estimated to be able to reduce emissions by up to 75%.




2010

No policies regulating carbon dioxide emissions from ships have been implemented despite the huge reductions available from operational and technical measures.

CONCLUSION

- >> Operational measures are a very important tool in reducing emissions from across the fleet. These measures are broadly applicable and can be quickly and easily implemented. Since these measures aim to increase vessel efficiency and cost little to implement they can also result in large cost savings across the fleet. However, to reach the emissions reductions required from the shipping industry more than just cost-saving operational measures will be required. Many technical measures that are available to the current fleet can also increase efficiency and can therefore also result in cost-savings.
- >> Technical measures, especially those like hull coatings that are widely applicable, can be an important way to reduce carbon dioxide emissions from the fleet. Such measures may be able to increase efficiency and reduce per tonne emissions across the fleet from 10 to 50 percent below 2007 levels by 2050.¹³¹
- >> Operational and technical measures will need to be implemented fleet wide to see substantial reductions in emissions. While, these are the most readily applicable methods to reduce emissions alternative fuels and methods of propulsion will become more important in the future.
- >> Policies should be implemented to make sure that they are used to their full advantage as it is evident that many emission reduction options are available to the fleet. But even before these policies are implemented studies have shown that many of these measures are in fact cost effective and can in fact save ship owners money as they act to reduce fuel consumption.

Recommendations

-  Shipping fleets should implement technical and operational measures to reduce carbon dioxide emissions immediately. Such measures include speed reductions, weather routing, improved maintenance and specialized hull coatings.
-  The U.S. EPA should regulate carbon dioxide emissions from ships. This can be done by setting emission standards and by requiring specific operational procedures, such as speed limits.
-  The IMO should implement a mandatory EEOI that will drive the use of operational and technical measures to reduce carbon dioxide emissions. Policies should be applied to all ships regardless of flag state. Such policies should not be subject to consensus approval and voting should be utilized to speed this outcome.



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Oceana campaigns to protect and restore the world's oceans. Our team of marine scientists, economists, lawyers and advocates win specific and concrete policy changes to reduce pollution and to prevent the irreversible collapse of fish populations, marine mammals and other sea life. Global in scope and dedicated to conservation, Oceana has campaigners based in North America, Europe, and South America. More than 300,000 members and e-activists in over 150 countries have already joined Oceana. For more information, please visit www.Oceana.org.