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SHIPPING IMPACTS ON CLIMATE:

A SOURCE WITH SOLUTIONS

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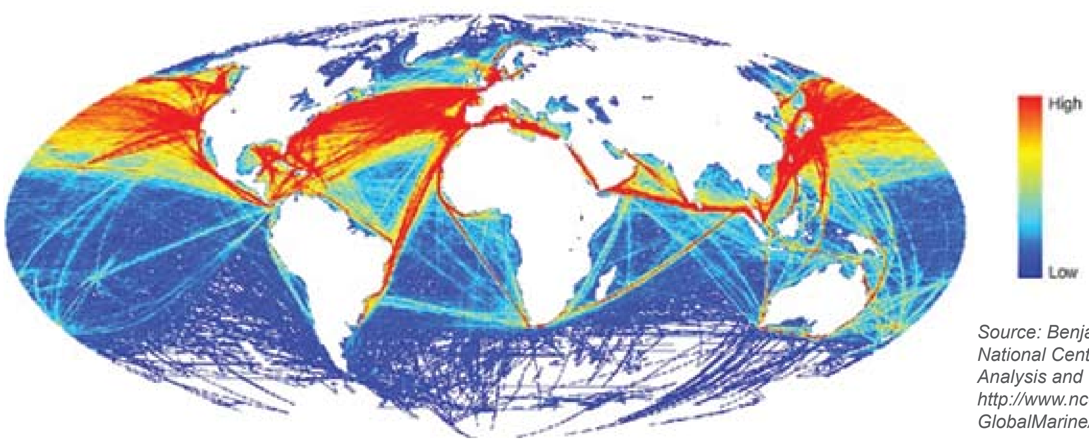
INTRODUCTION

Although shipping may be a more efficient mode of transport than planes or trucks, it is indisputably a major source of carbon dioxide and other greenhouse gases.

Over 90 percent of world trade is carried across the world's oceans by some 90,000 marine vessels.[1,2] Like all modes of transportation that use fossil fuels, ships produce carbon dioxide emissions that significantly contribute to global climate change and ocean acidification. Besides carbon dioxide, ships also release a handful of other pollutants that also contribute to the problem. To make matters worse, these ships also burn the dirtiest fuel on the market, a fuel that is so unrefined that it can be solid enough to be walked across at room temperature.[3,4] In addition to exacerbating climate change, shipping emissions have been blamed for posing a significant threat to human health. The particulate matter emissions alone from shipping can account for approximately 60,000 cardiopulmonary and lung cancer deaths each year.[5]

GLOBAL SHIPPING ACTIVITY

Lines represent the shipping routes of 11 percent of the merchant fleet at sea in 2005.



Source: Benjamin S. Halpern, National Center for Ecological Analysis and Synthesis http://www.nceas.ucsb.edu/GlobalMarine/impacts

The shipping industry is responsible for a significant proportion of the global climate change problem. More than three percent of global carbon dioxide emissions can be attributed to ocean-going ships.[6] This is an amount comparable to major carbon-emitting countries—and the industry continues to grow rapidly. In fact, if global shipping were a country it would be the sixth largest producer of greenhouse gas emissions. Only the United States, China, Russia, India, and Japan emit more carbon dioxide than the world's shipping fleet.[7] Nevertheless, carbon dioxide emissions from ocean-going vessels are currently unregulated.

RANKING	COUNTRY	EMISSIONS (BILLION TONS CO_2)
1	USA	6.05
2	China	5.01†
3	Russia	1.52
4	India	1.34
5	Japan	1.25
6	**Global Fleet**	**1.12***
7	Germany	0.8

† Recent data suggests that China has overtaken the USA as the largest CO_2 emitter.

** Oceana estimates suggest that 2004 shipping emissions (~0.97 billion tons of CO_2) exceeded Germany's emissions, making shipping the sixth largest CO_2 emitter even without considering 2007 levels.*

Sources: See endnote six for shipping data and endnote seven for country data.

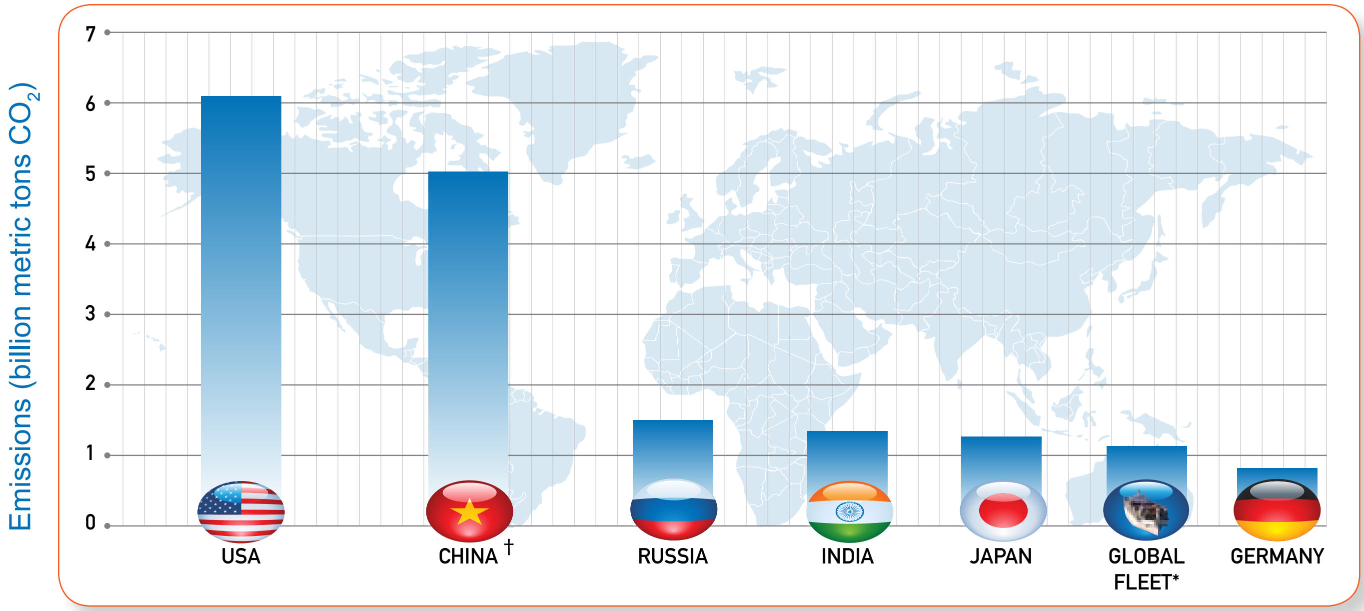
SHIPS ARE MAJOR CARBON DIOXIDE EMITTERS

Shipping companies have many methods at their disposal for reducing emissions of global warming pollutants. These include slowing down, which not only reduces emissions but saves fuel and therefore money for ship operators; switching to cleaner fuels; and implementing technical and operational measures that can improve fuel efficiency. Some of these solutions, such as speed reductions and weather routing, can be employed quickly, easily and in some cases with financial benefits to shippers. In fact many shipping lines, including BP[8,9], Germanischer Lloyd[10], Hapag-Lloyd[11], Nippon Yusen Kaisha (NYK)[12], and Maersk[13], have already implemented slower steaming protocols to both save money and cut their emissions. Given the magnitude of the climate crisis, it is critical that the shipping industry embraces these solutions and incorporates them into regular business operations as soon as possible.

Addressing the climate change crisis requires a concerted effort from all industries, including shipping, in addition to actions by individuals. Although shipping may be a more efficient mode of transport than planes or trucks, it is indisputably a major source of carbon dioxide and other greenhouse gases. Some approaches to climate change have excluded shipping emissions; however, just as all nations of the world need to reduce their emissions, so do all sectors of the global economy. The shipping industry must be included in that process.

If global shipping were a country it would be the 6th largest producer of greenhouse gas emissions.

GLOBAL SHIPPING ACTIVITY - AMONG THE LARGEST CARBON DIOXIDE EMITTERS



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** Oceana estimates suggest that 2004 shipping emissions (~0.97 billion tons of CO_2) exceeded Germany's emissions, making shipping the sixth largest CO_2 emitter even without considering 2007 levels.*

Sources: See endnote six for shipping data and endnote seven for country data.

GLOBAL SHIPPING IS A MAJOR THREAT TO THE OCEANS

Ships emit various global warming pollutants, including carbon dioxide (CO_2), black carbon (BC), nitrogen oxides (NOx) and nitrous oxide (N_2O). These pollutants all contribute to global climate change either directly, by acting as agents that trap heat in the atmosphere, or indirectly by aiding in the creation of additional greenhouse gases.

Greenhouse gases are important in the natural temperature regulation of the planet. Energy from the sun passes through the atmosphere, hitting and warming the Earth. The warmed surface of the Earth radiates heat, some of which is absorbed by the greenhouse gases in the atmosphere. These greenhouse gases re-emit this energy, returning it to Earth where it further warms the planet. Earth is habitable in part because of greenhouse gases; without them the planet would be 33°C (59°F) colder on average.[14]

However, the climate to which humans and nature have adapted relies on just the right amount of greenhouse gases existing in the atmosphere. Since the Industrial Revolution humans have been emitting increasing amounts of greenhouse gases, predominantly carbon dioxide, which are building up in the atmosphere. These human-produced greenhouse gases are enhancing the natural greenhouse effect, causing the planet to warm. The more carbon dioxide we release, the warmer the planet will become.

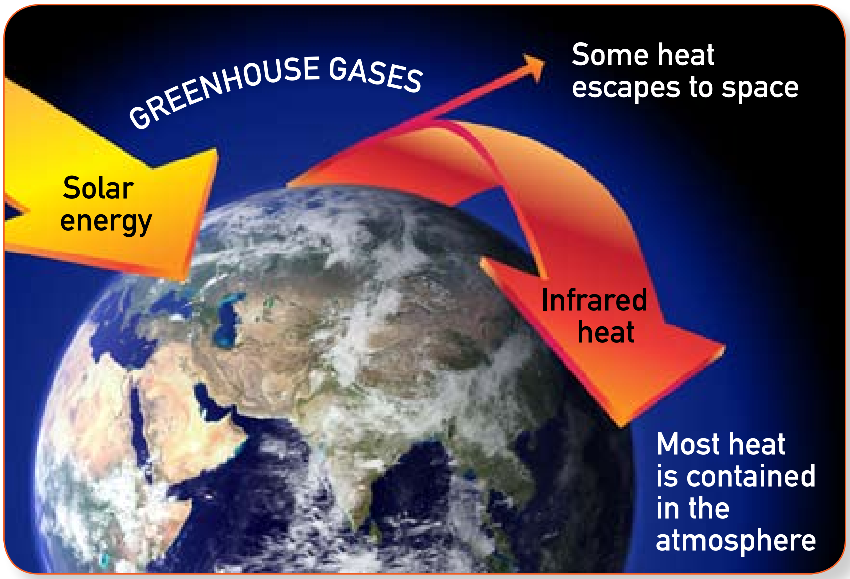
The increase in global temperatures will almost certainly result in a series of catastrophic changes across the globe, including worse droughts, stronger storms, flooding of low-lying areas by rising sea levels, extinction of many species and a major disruption in the global production of food.[15]

The oceans have not been spared from the pressures of climate change. As more carbon dioxide and heat are added to the climate system, considerable amounts of each are absorbed by the oceans, causing significant changes—changes that will be devastating for many of the species, including humans, that depend upon the oceans.[16]

The increasing amounts of carbon dioxide being absorbed by the oceans is changing their very chemistry, causing them to become more acidic and jeopardizing the future of coral reefs and other organisms that produce calcium carbonate shells and skeletons, which could result in the breakdown of many important marine food webs, including those upon which humans depend.[17] The oceans are also warming, which is causing sea ice to melt and sea levels to rise, all of which disrupts marine ecosystems and ocean circulation.[18] Humans too will be directly affected by these changes as huge swaths of coastline will be lost, weather patterns will change and food production methods will be altered.[19]

The future of the oceans as we know them is in jeopardy and in order to give them the best possible chance of surviving we must reduce the pressures of climate change and ocean acidification by cutting global carbon dioxide emissions. Reducing emissions from a major contributor such as shipping is an important step in protecting the oceans' future.

THE GREENHOUSE EFFECT



Source: Modified graphic from U.S. National Park Service.

GLOBAL WARMING POLLUTION FROM SHIPPING IS SIGNIFICANT AND VIRTUALLY UNREGULATED

Ships are an important source of carbon dioxide, the main driver of climate change and ocean acidification. Humans create carbon dioxide primarily by burning carbon-based fuels, such as wood, oil, and coal. Carbon dioxide is a greenhouse gas and is found naturally in the Earth's atmosphere, where it plays a role in regulating the Earth's temperature.[20] However, human-caused carbon dioxide emissions are a form of pollution, recognized as the primary driver of climate change[21] regardless of where on Earth they occur.[22]

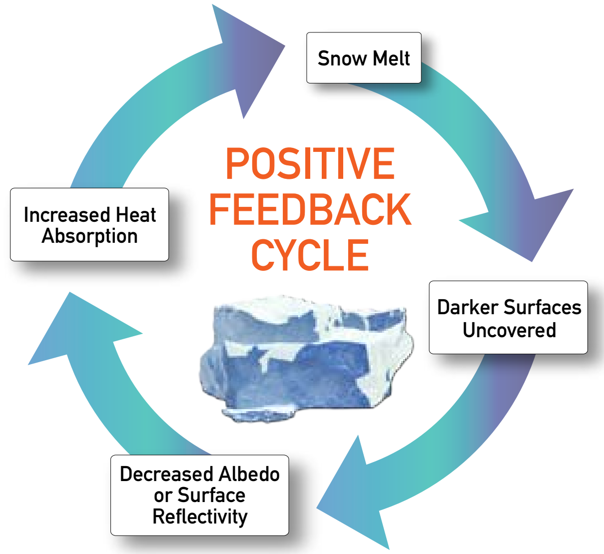
The world's leading scientific body assessing climate change, the Intergovernmental Panel on Climate Change (IPCC), is a non-partisan, international body composed of thousands of world-renowned experts in many fields. In its 2007 report the IPCC concluded that there is unequivocal warming taking place and that carbon dioxide and other global warming pollutants are almost without a doubt the cause.[23] According to the IPCC, "carbon dioxide is the most important anthropogenic greenhouse gas."[24] Over the last 650,000 years carbon dioxide levels in the atmosphere have generally ranged from 180-300 parts per million (ppm).[25] However, since the Industrial Revolution humans have far surpassed this natural range, with carbon dioxide levels nearing 385 ppm[26] and growing at a rate of more than 2 ppm per year.[27] In 2007 alone, humans added an additional 19 billion metric tons of carbon dioxide to the atmosphere.[28]

Ships contribute a significant amount of carbon dioxide to the atmosphere. The International Maritime Organization (IMO) calculated that ocean-going vessels released 1.12 billion metric tons of carbon dioxide in 2007.[29] This is equivalent to the annual greenhouse gas emissions from over 205 million cars, [30] or more cars than were registered in the entire United States in 2006 (135 million).[31] Shipping is responsible for over three percent of global anthropogenic carbon dioxide emissions, and is growing.[32] Over the last three decades, the shipping industry has grown by an average of five percent per year.[33] The IMO predicts that without introducing measures to reduce emissions from shipping, carbon dioxide emissions from the industry could rise to 1.48 billion metric tons by 2020,[34] equivalent to putting 65 million new cars on the road.[35]

[The more carbon dioxide we release, the warmer the planet will become.]

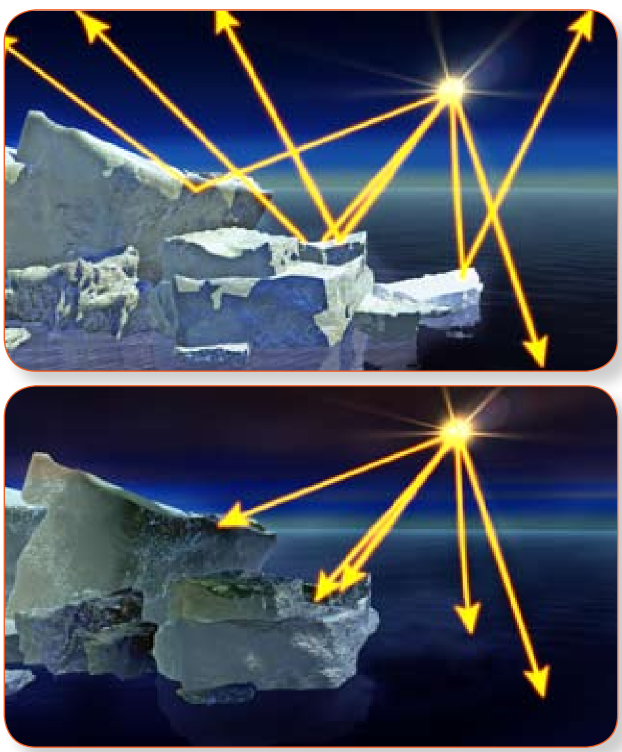
[The future of the oceans as we know them is in jeopardy and in order to give them the best possible chance of surviving we must reduce the pressures of climate change and ocean acidification by cutting global carbon dioxide emissions.]

Reducing black carbon from ships could slow warming, buying time for further steps to reduce carbon dioxide emissions. Black carbon, more commonly known as soot, is made up of fine particles created by the incomplete combustion of a carbon fuel source, such as oil or coal.[36] Aging engines and poor engine maintenance can also contribute to incomplete combustion.[37]



Black carbon is known to be a potent warmer both in the atmosphere and when deposited on snow and ice. Black carbon contributes to warming in two ways – through direct absorption of heat in the top of the atmosphere, and by lowering the Earth's albedo, or reflectivity.[38] Unlike greenhouse gases, black carbon is a solid and not a gas, and it warms by absorbing sunlight, rather than absorbing infrared or terrestrial radiation.[39] Black carbon warms the atmosphere by absorbing light, which dries the surrounding air by evaporating the water in the air and on other nearby particles. This reduction of water content decreases the reflectivity of the other particles, thereby allowing them to absorb more sunlight and create an even larger warming effect in the atmosphere. Additionally, the evaporated water from the particles remains in the air as water vapor, another highly potent greenhouse gas.[40]

BLACK CARBON REDUCES REFLECTIVITY AND INCREASES HEAT ABSORBTION



Polar ice reflects light from the sun. As this ice begins to melt, less sunlight gets reflected into space. It is instead absorbed into the oceans and land, raising the overall temperature, and fueling further melting. Darker, soot-covered ice reflects less light as well, instead absorbing it and increasing the rate at which the ice melts. Credit: NASA (modified)

Alongside the warming effect black carbon has in the atmosphere, once deposited on snow or ice the darker particles can reduce the albedo, or reflectivity, of the lighter surfaces.[41] Reduced albedo means less solar radiation is reflected back into space and will instead be absorbed, thereby heating the Earth's surface.[42] Since more light is reflected from the Earth's surface in the polar regions it is likely that the impacts of black carbon will be more acutely felt in these areas.[43]

Black carbon is an excellent example of the complexities of climate-related pollutants, and also of the disturbing ability for these pollutants to create positive feedback loops, where one warming effect can actually stimulate yet another. Deposition of black carbon and its absorption of sunlight accelerate the melting of the snow or ice upon which the black carbon is deposited.[44] As the ice melts, black carbon particles can become more concentrated on the surface, further reducing the surface albedo and prompting more snow or ice melt.[45] In addition, the melting of snow and ice can uncover darker surfaces, such as water, vegetation or ground, resulting in more heat being absorbed leading to further warming and melting.[46]

As a result of all these warming contributions and triggering of positive feedback loops, black carbon may be second only to carbon dioxide in terms of direct contribution to global warming,[47,48] with a warming effect as much as 55 percent of that of carbon dioxide.[49] In fact, 0.3-0.4°C of current global warming may be directly attributed to black carbon.[50]

Black carbon is not emitted uniformly around the globe, and since it is short-lived in the atmosphere, its impacts on the climate can vary spatially.[51] Unfortunately, one quarter of all black carbon occurs in environmentally sensitive regions like the Arctic[52] where it has a unique ability to exacerbate warming. On snow and ice – even at very low concentrations – black carbon triggers melting, and is likely responsible for at least 30 percent of Arctic warming.[53] This is particularly important since the Arctic is currently warming at twice the rate of the rest of the world.[54] Arctic warming could trigger another series of positive feedback loops that could actually make climate change far worse, such as melting of the Arctic permafrost, which may release more carbon in the form of methane into the atmosphere than has been released since the Industrial Revolution.[55]

International shipping contributes about 133 thousand metric tons of black carbon to the atmosphere each year,[56] approximately 1.7 percent of global anthropogenic emissions of black carbon.[57] While black carbon from shipping is mainly emitted over the oceans, plumes can travel great distances and deposit on areas far from the initial emission source.[58] For example, plumes of black carbon from Asia are believed to deposit on snow in the Arctic.[59] In some regions, including the Gulf of Alaska, shipping can contribute an additional 40 percent to atmospheric concentrations of black carbon.[60] The Alaska region is particularly vulnerable to black carbon pollution from shipping as the routes between North America and Asia significantly increase the amount of black carbon found in this region.[61] The impact of black carbon emitted by shipping into environmentally sensitive areas, such as the Arctic, may have critical impacts on warming and may induce serious feedback loops as described above.[62] Dr. Charlie Zender, a climate physicist at the University of California, Irvine, who studies the impacts of black carbon on snow, has suggested that the opening up of Arctic shipping routes to ships emitting black carbon could spell the end of summer sea ice.[63]

Immediate reductions in black carbon emissions could play a particularly important role in slowing climate change, because reductions will result in almost immediate cooling benefits.[64] While preventing dangerous climate change requires global carbon dioxide emissions to start declining within the next 10 years, the removal of black carbon can contribute to a significant reduction in warming and may act as a stopgap measure in the very immediate future until carbon dioxide emissions can be brought under control. One study suggests that the elimination of all black carbon generated by fossil fuel use would reduce total global warming by 8-18 percent within 3-5 years.[65] The U.S. Climate Change Technology Program has also suggested that activities reducing black carbon "will have large public health and local air quality benefits, in addition to their role in mitigating climate change."[66] The ability to realize immediate cooling benefits from the reduction of black carbon emissions is a critical first step and an opportunity in our efforts to solve the climate crisis; however, it should not be seen as an excuse to delay other important actions, most significantly the reduction of carbon dioxide emissions, which are equally critical.

Reductions in nitrogen oxides could significantly reduce warming in the Arctic. Nitrogen oxides are a group of compounds made up of a nitrogen atom combined with varying numbers of oxygen atoms. Examples of compounds in this group include nitric oxide (NO) and nitrogen dioxide (NO_2).[67] Because nitrogen and oxygen, two of the most common elements present in air, combine when they are heated, nitrogen oxides are created whenever something is burned.[68] The longer and hotter a combustion process, the greater the amount of nitrogen oxides formed.[69]

Nitrogen Oxides Create Ozone and Hydroxyl Radicals

While nitrogen oxides themselves are not greenhouse gases, they play a major role in influencing the climate by creating ozone (O_3) and hydroxyl radicals (OH^-) in the troposphere (lower atmosphere).[70,71] The IPCC considers ozone to be the third most damaging greenhouse gas.[72] In the lower atmosphere, ozone has been estimated to have a warming effect of about a quarter of that of carbon dioxide.[73] Some of the warming due to the creation of ozone may be offset by the creation of hydroxyl radicals, which help to destroy methane (CH_4) another important greenhouse gas. However, since this effect is not as large as the warming created by ozone, NOx emissions have an overall net warming effect on the atmosphere.[74]

According to the International Maritime Organization (IMO), ocean-going ships released 25.8 million metric tons of nitrogen oxides in 2007. These emissions already equate to approximately 30 percent of global NOx emissions[75] and are projected to increase to 34.2 million metric tons by 2050.[76]

NOx emissions from ships are responsible for the creation of low level ozone. Low level ozone is transported to the Arctic with high efficiency and therefore has a significant impact on Arctic warming.[77] It is likely that tropospheric ozone is responsible for 0.3°C of the annual average Arctic warming, or more than 20 percent of the warming that has taken place over the 20th century.[78,79]

Ozone emissions from shipping are likely to become even more damaging to the Arctic climate if shipping through the Arctic is increased, which could cause Arctic ozone levels to increase by a factor of two or three compared to present day levels.[80] Reducing the nitrogen oxide emissions from ships, especially those moving close to or through the Arctic could significantly reduce the rapid rate of Arctic warming.[81]

Nitrogen oxide reduction technologies could reduce NOx emissions by as much as 85 percent by 2050, despite the expected growth of the shipping fleet.[82, 83]

Nitrous Oxide

Nitrous oxide (N_2O) is sometimes considered one of the nitrogen oxides, however, unlike NOx gases, nitrous oxide is a highly potent, long-lived greenhouse gas.[84] Nitrous oxide has a global warming effect approximately 300 times that of carbon dioxide over 100 years.[85] Because it is found in much lower concentrations in the atmosphere, however, human caused nitrous oxide emissions have approximately 10 percent of the impact of carbon dioxide on the climate.[86] Like carbon dioxide and other greenhouse gases, nitrous oxide directly traps heat in the atmosphere and remains in existence for many decades once emitted.[87] Human activity is responsible for emissions of between four and 24 million metric tons of nitrous oxide every year.[88]

Nitrogen oxide reduction technologies could reduce NOx emissions by as much as 85 percent by 2050, despite the expected growth of the shipping fleet.

Nitrogen Oxides Contribute to Ocean Acidification

Nitrogen oxides are also known to react with other substances in the air to form acids which fall to earth as rain, fog, snow or dry particles.[89] Acid rain is known to corrode buildings and have harmful impacts on plants and animals.[90] Acid rain also contributes to ocean acidification.[91] Approximately one-third of all nitrogen oxide emissions end up in the oceans.[92] The impact of these emissions on acidification is intensely felt in specific, vulnerable areas. In some areas the acidifying effect of nitrogen oxides can be as high as 10 to 50 percent of the impact of carbon dioxide.[93] The hardest hit areas are likely to be those directly around emissions sources, which are in close proximity to coastal waters.[94]

SOLUTIONS

Global warming pollution from shipping is currently unregulated. This pollution is largely unnecessary, as technological and operational improvements can result in major reductions.[95] While such measures can be employed relatively quickly and easily to generate immediate emissions reductions, the shipping industry has remained essentially unregulated with respect to climate change pollutants. In addition to those solutions that offer near-term reductions, longer-term solutions will also need to be implemented to ensure continued pollution reductions by the fleet.

[Slowing down, even by a small amount, can result in significant fuel savings and emissions reductions.]

SPEED REDUCTIONS YIELD IMMEDIATE, SIZABLE REDUCTIONS IN EMISSIONS AND FUEL COSTS

Emissions, especially those of carbon dioxide, are directly proportional to fuel consumption. Greater speeds require increased fuel consumption. Consequently, slowing down, even by a small amount, can result in significant fuel savings and emissions reductions.[96] The IMO calculated that a speed reduction of just 10 percent across the global fleet by 2010 would result in a 23.3 percent reduction in emissions.[97] Hapag-Lloyd found that slowing some of their ships by just five knots, or 20 percent, resulted in savings of around 50 percent on fuel costs.[98] Restrictions on vessel speed would reduce emissions of carbon dioxide, black carbon, nitrogen oxides, and nitrous oxide.[99]

[A speed reduction of just 10 percent across the global fleet by 2010 would result in a 23.3 percent reduction in emissions.]

Recently, as the price of fuel has been increasing, shipping lines have been voluntarily reducing their speeds to realize financial gains through fuel savings. A senior official with the French line CMA CGM stated that in order to minimize fuel consumption most lines will begin steaming at “economic speeds.”[100]

Compared to other forms of transport, ships traveling at slow speeds have been found to be far more efficient and less polluting - roughly ten times more efficient than trucks and at least a hundred times more efficient than air transport.[101] As ship speeds increase, much of this efficiency is lost. In fact, ships traveling at very high speeds have been found to have similar energy demands to those of airplanes.[102]

Some lines have even found that they have been able to add additional slow steaming ships to their fleet, to ensure they meet delivery times, while still achieving cuts in fuel use and pollution.[103] Since the fuel consumption of a ship does not depend primarily on its size, but rather on its speed, the same amount of transport work can be achieved by more, slower ships, as by fewer, faster ships.[104]

[Speed reductions are a quick, easy and very effective way to achieve emissions reductions from ocean-going vessels.]

One case study compared the fuel consumption of two fleets, each providing the same transport capacity. The first fleet was made up of ten ships of 16 knot design speed, while the second was comprised of 14 ships of 10.5 knots design speed. The faster fleet consumed 140,000 metric tons of fuel in comparison to the slower fleet that consumed 60,000 metric tons of fuel (a decrease of 57 percent in fuel consumption and therefore emissions).[105]

The Ports of Los Angeles and Long Beach have already implemented a speed reduction program, which provides financial incentives and recognition for ships that remain below a speed of 12 knots within 20 nautical miles of the ports.[106] In 2006, the program met with an over 80 percent compliance rate.[107] The ports are, however, aiming for 100 percent compliance, which would result in significant reductions in ship emissions. At 100 percent compliance, the Port of Los Angeles would see reductions of 49 percent of particulate matter (of which black carbon is a component) and 37 percent of nitrogen oxide emissions.[108]

Overall, speed reductions are a quick, easy and effective way to achieve emissions reductions from ocean-going vessels. Given the recent increases in oil prices, speed reduction makes sense not only environmentally, but also economically.

SWITCHING TO CLEANER FUELS CAN REDUCE EMISSIONS ACROSS THE BOARD

Residual oil used by most ocean-going ships is of low quality. It is used because of its low cost, around $550 per metric ton.[109] Even so, its use presents challenges for ship operators. For example, residual fuels must be heated to about 140°C before being used. A proportion of the fuel, the sludge which cannot be put though the engine, must be removed, and is regularly burned on board for disposal.[110] The sulfur content of residual fuels varies according to the crude stock, but globally averages about 2.5 percent.[111] In contrast, cleaner fuels such as marine diesel oil contain 0.5 percent sulfur, while marine gas oil contains only 0.1 percent sulfur.[112]

Switching to low-sulfur fuels would reduce emissions of fine particles, including black carbon, as well as carbon dioxide, nitrogen oxides and nitrous oxide, and enable the use of other emissions control equipment that the sulfur levels in residual fuel would otherwise impede.[113] Use of marine diesel oil and marine gas oil causes a reduction in particulate matter and nitrogen oxide releases compared to the use of heavy fuel oil.[114] The IMO projects a switch from heavy fuel oil to marine diesel oil would result in a four to five percent reduction in carbon dioxide emitted per metric ton of fuel consumed.[115] Such a switch could also reduce nitrous oxide by more than 91 percent, particulate matter by 63 percent and nitrogen oxides as a group by nearly five percent.[116]

The switch to clean fuels would also eliminate the need for purifiers, heating of fuel tanks and sludge burning, which will reduce costs for vessel owners and operators. Loss of fuel due to sludge removal would be avoided and the energy used to refine residual oil on board could be put towards powering the ship. As mentioned above, such a switch also would allow for the use of end-of-the-pipe emission controls, enabling considerable additional reductions of greenhouse gases and other air pollutants otherwise not likely to be achieved.

POLLUTANT	PERCENTAGE REDUCTION FROM FUEL SWITCH
Carbon Dioxide	4-5
Nitrous Oxide	91
Particulate Matter	63
Nitrogen Oxides	5

Sources: IMO (2000) and Winebrake, J. and Corbett, J. (2007).

Experience shows that fuel-switching makes sense. The Danish ship owner Maersk Line voluntarily implemented a fuel switching program for all its ships calling at California ports.[118] More than 60 of the company's ships are participating in the program. The ships switch to distillate fuel in their main engines 24 nautical miles from port. A Maersk spokesperson explained that "The fuel switch can be implemented very quickly, without the need for capital investment or additional equipment."[119] According to reports this program has already reduced overall emissions by approximately 400 metric tons per year, including an 80 percent reduction in particulate matter and a 17 percent reduction in nitrogen oxides.[120]

Some have argued that the switch to low sulfur fuels could incur slight lifecycle increases (approximately two to five percent) in carbon dioxide emissions, incurred primarily at the refineries[121] and that since sulfur emissions from ships have an overall cooling effect on the atmosphere, moving to cleaner fuel is not an effective response to global climate change. However, these arguments fail to consider the many benefits of fuel switching. First among these is the fact that emissions are more easily addressed at a stationary location rather than on board a vessel.[122] Furthermore, refineries can in fact refine residual oils and extract the sulfur and use it for other purposes, for example as a source of gypsum which could be an additional benefit of such a switch.[123] Moreover, fuel switching could result in a reduction of overall emissions per metric ton kilometer. Any additional emissions generated at the refinery would likely be offset by other emission reduction mechanisms such end-of-the-pipe pollution control technologies that become available due to the absence of sulfur in the fuel. Sulfur reductions allow for the use of technological controls that can achieve much larger reductions in nitrogen oxides.[124] These end-of-the-pipe technologies can effectively reduce emissions from ship engines, however many of these technologies require the use of low or ultra-low sulfur fuels in order to work effectively.

Sulfur emissions also have another very significant downside – sulfur, along with nitrogen oxide emissions also contribute directly to ocean acidification.[125] As the oceans absorb more carbon dioxide, sulfur and nitrogen oxides from the atmosphere, they become more acidic, having severe consequences for organisms that form shells or structures from calcium carbonate, such as corals and oysters.[126] Thus, since there are ways of addressing carbon dioxide pollution and its effects that also reduce harmful sulfur emissions, the optimal solution is to confront both problems at once.

MORE TECHNOLOGICAL AND OPERATIONAL MEASURES ARE AVAILABLE TO REDUCE SHIPPING EMISSIONS

Operational measures could be employed relatively easily and cost-effectively to further reduce emissions. These could include weather routing, improved efficiency of logistics and voyage planning, fuel-economy standards for ships, and optimal ship and engine operations. Other technologies and methods can also be used to reduce fuel consumption. For example:

- **The use of "cold ironing" at ports, where ships shut off their diesel engines and are connected to shore-based power for their electrical needs reduces direct emissions in port areas and allow energy needs to be met by low-emission sources, such as wind or solar energy.**[127]
- **Improved hull design can achieve reductions in emissions through reduced fuel consumption.**[128]
- **A bulbous bow can increase a ship's fuel efficiency by reducing its wave-making resistance.**[129]
- **A stern flap, a small plate that extends behind a ship's transom, lengthening the bottom surface of the hull, can reduce a ship's resistance and thus increase fuel efficiency by a few to several percent.**[130]
- **Special coatings applied to propellers may reduce fuel use by four to five percent, while simultaneously reducing maintenance requirements. This practice could likely pay for itself within a year.**[131]
- **Sail or kite-assisted propulsion can provide zero-emissions wind power, and plans are already underway to employ such technologies on some new and existing cargo vessels.**[132]
- **DK Group has developed an Air Cavity System (ACS), which it says can reduce the shipping industry's emissions by up to 15 percent per year.**[133]

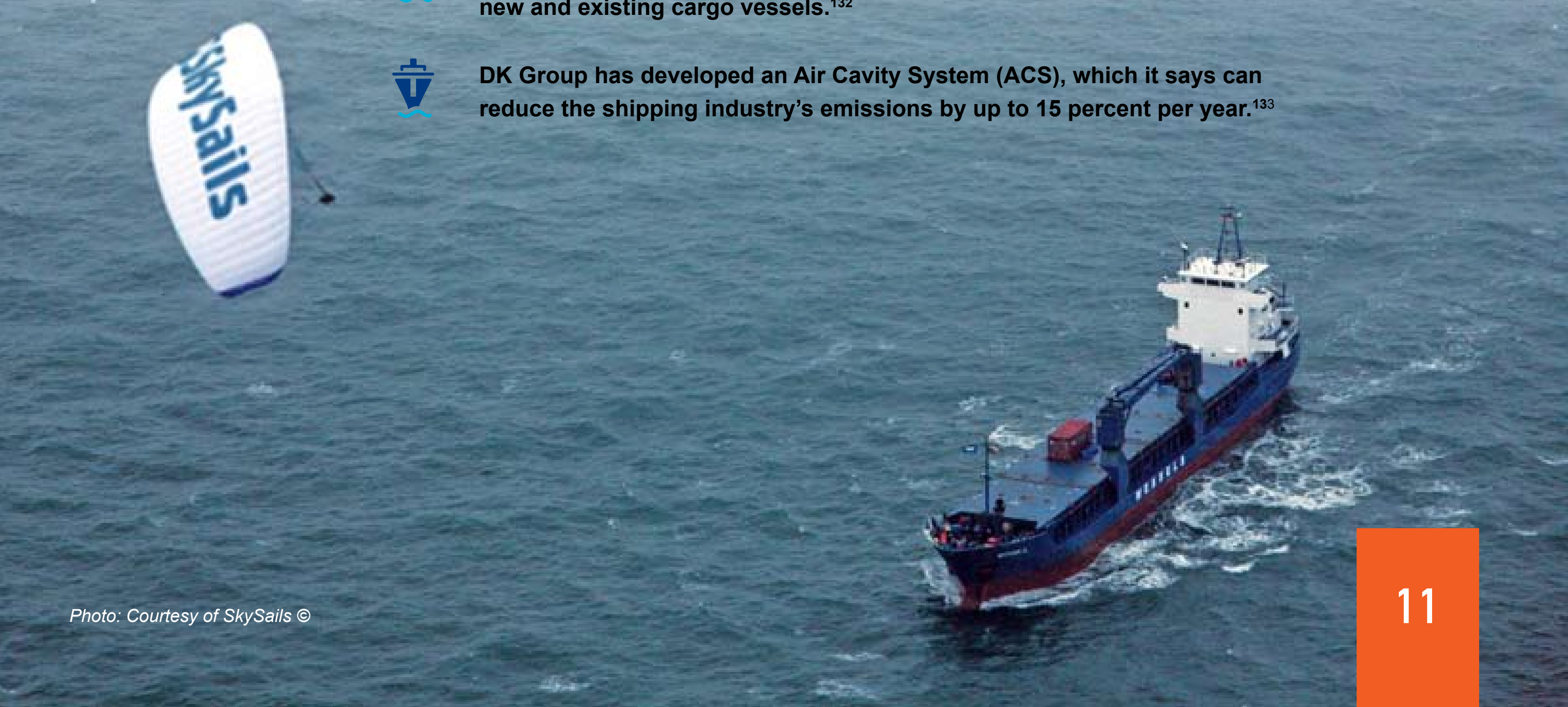


Photo: Courtesy of SkySails ©

RECOMMENDATIONS

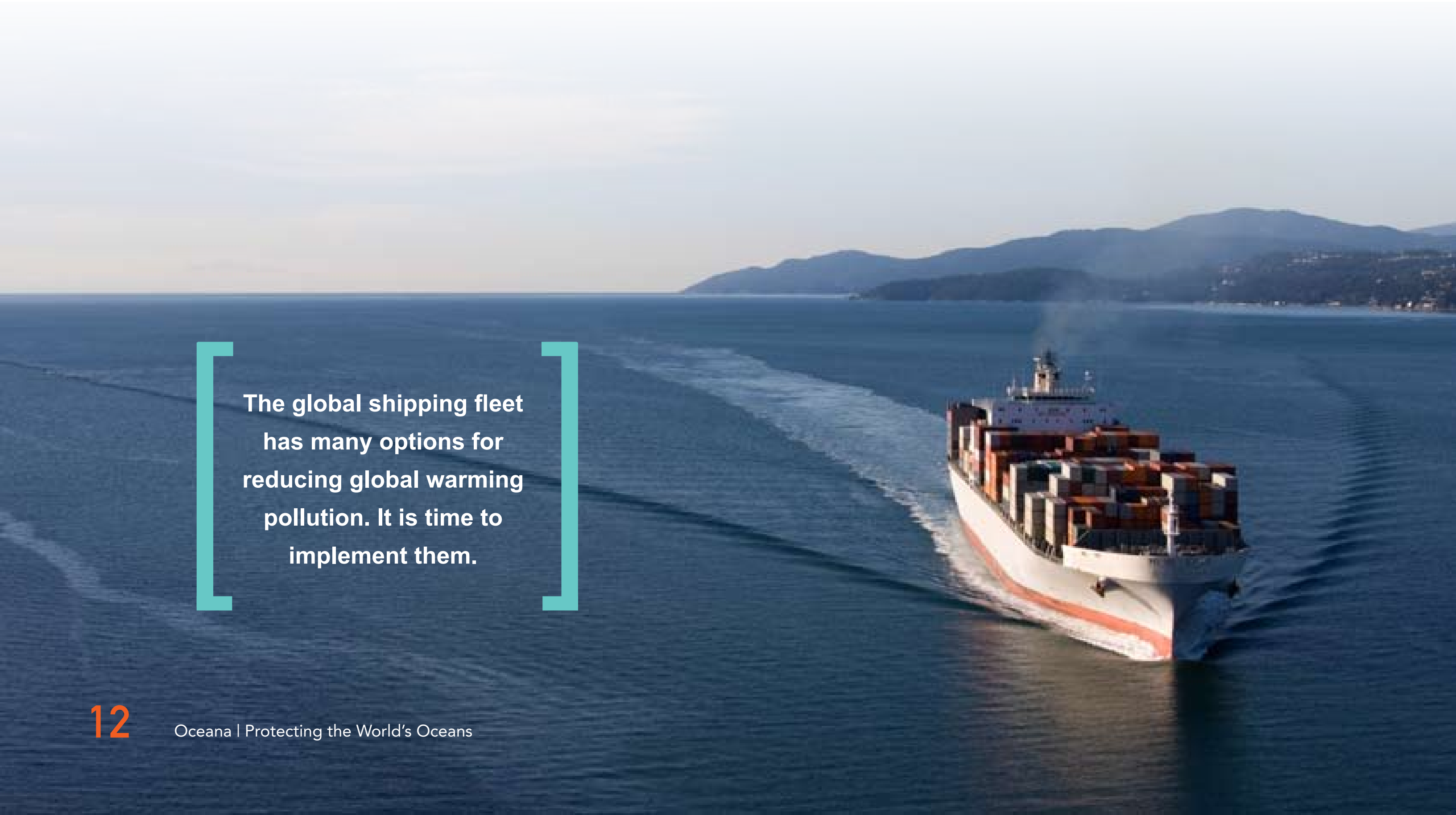
- *Shipping fleets should implement technical and operational measures to reduce global warming pollution immediately. Such measures include speed reductions, weather routing, fuel switching and specialized hull coatings.*

- *Fleets should begin to implement longer-term measures to reduce global warming pollution, such as fuel efficient design of new ships and engines created specifically for slow steaming.*

- *The U.S. EPA should find that the carbon dioxide, black carbon, nitrogen oxides and nitrous oxide emissions from ships significantly contribute to climate change and ocean acidification and therefore pose a threat to public health and welfare.*

- *The U.S. EPA should regulate global warming pollutants from ships operating within the U.S. Exclusive Economic Zone. This can be done by setting emission standards and by requiring specific operational procedures, such as speed restrictions.*

- *The IMO should set international emission standards to reduce global warming pollutants from the shipping industry.*



The global shipping fleet has many options for reducing global warming pollution. It is time to implement them.

ENDNOTES

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