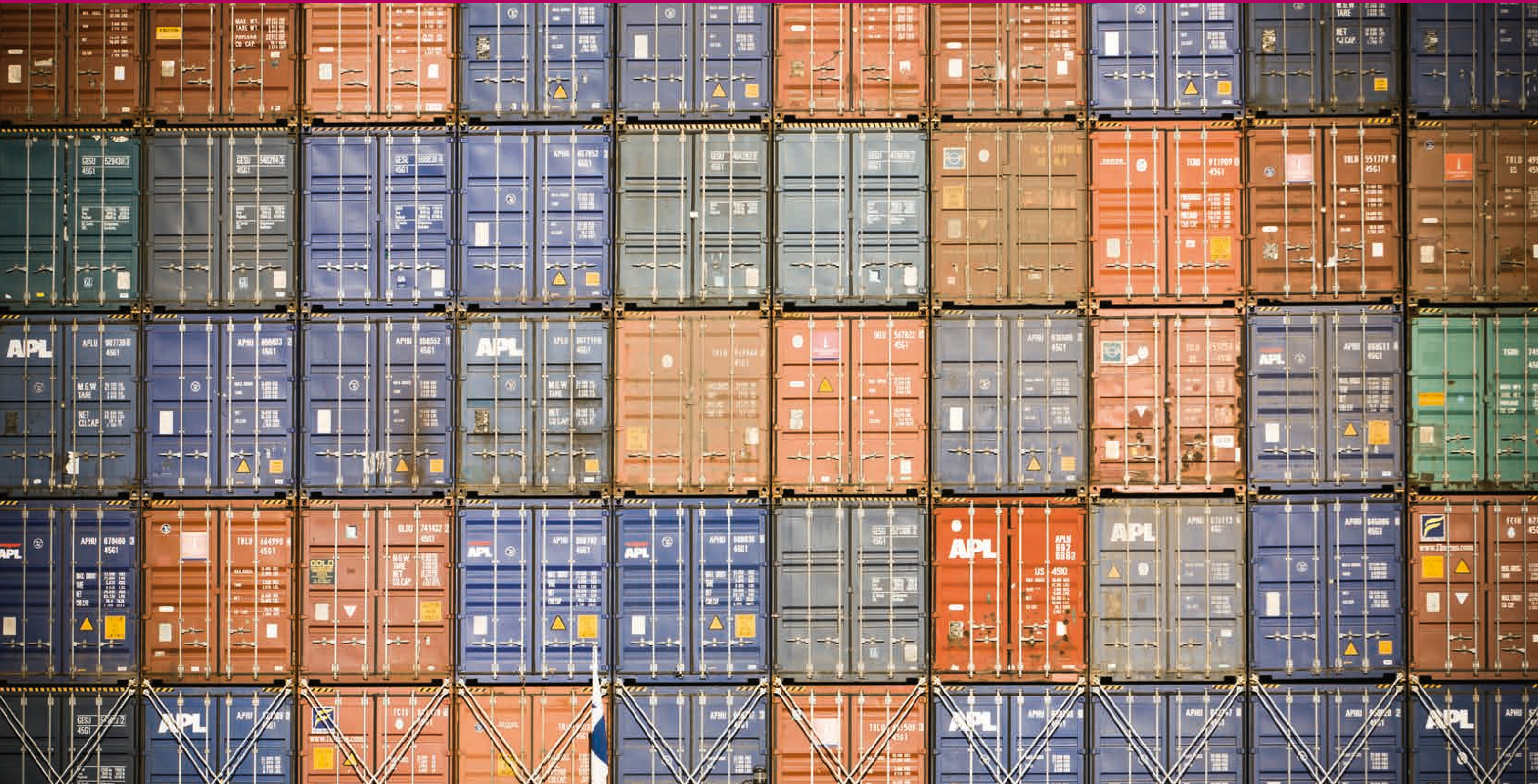
4 Transport over the seas

> In recent decades shipping has become the backbone of international trade. More and more goods are being transported from one continent to another by ship. But this growth also has a downside. Exhaust emissions from ships pollute the air and accelerate climate change, while noise, sewage, garbage and invasive species put pressure on marine ecosystems. New, environmentally sound solutions are needed as quickly as possible.



Shipping at a turning point

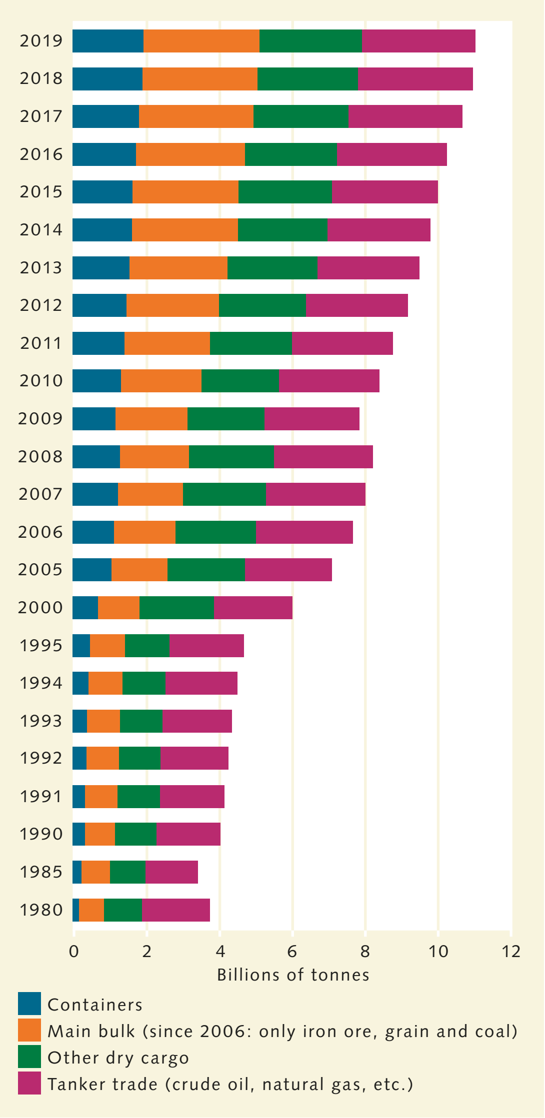
> The international merchant shipping fleet now numbers almost 100,000 vessels conveying bulk resources and other goods around the globe. Competition is fierce and environmental concerns scarcely featured in the past. However, it has become clear in the meantime that the sector must reduce its carbon footprint and improve its environmental performance. This calls for new propulsion systems, strict and globally applicable environmental standards and major financial input to upgrade a partially ageing fleet.

The backbone of global trade

Without shipping across the seas and oceans there would be no fresh bananas or mangoes for purchase in European stores, nor would there be any products made from raw materials such as petroleum, iron ore or phosphorite. These are, for the most part, produced, farmed or mined on other continents, and ultimately transported to Europe by bulk carriers, container ships or tankers for sale or further processing. Over 80 per cent of all goods and raw materials traded worldwide are carried to their destinations by ships. Transport by ship is especially important for developing countries, where transportation over land or by air is impractical because of inadequate roads and airports. In these regions, ships are often the only means of moving large quantities of goods from place to place over rivers, lakes and coastal waters.

The motivation for transport over the seas is always the same, and it can be expressed in very simple terms: Ships transport goods and products from a region where they are relatively inexpensive to produce to places where they can be sold at a much higher price. In terms of the total value of goods traded worldwide, shipping is estimated to account for only around 60 to 70 per cent. This is because relatively high-priced goods and products are often sent as air freight, especially when they are expected to reach the recipient as fast as possible.

For statistical purposes, ship transport can be divided into three different categories. The first includes the transport of crude oil, natural gas and petroleum products such as diesel, kerosene, propane gas, bitumen and asphalt in tankers. The second category comprises bulk cargoes, especially iron ore, grain and coal, which are transported in bulk carriers. The third category encompasses all container goods traded worldwide, as well as special non-liquid goods including piece goods, automobiles and animals.



4.1 > The quantity of goods transported by ship has been increasing for years. More than two thirds of all freight consists of bulk goods, other dry cargo and container goods. The remainder is tanker cargo.

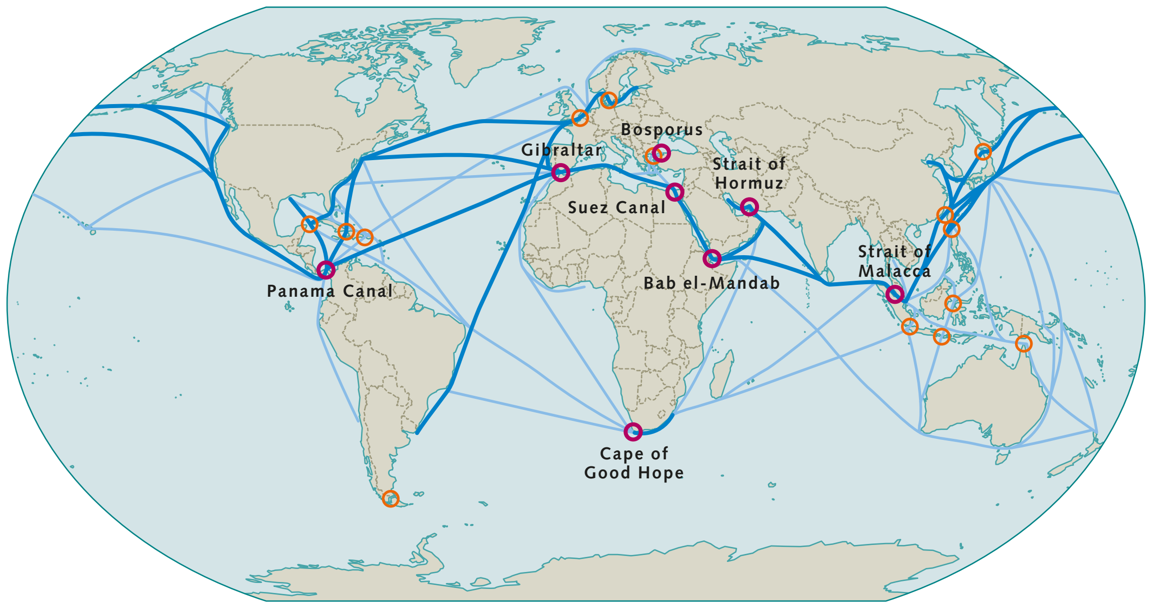
Significant differences can be seen between the freight statistics from the year 1970 and those of today. For one, the total quantity of goods transported by ship has more than quadrupled within this period of 50 years. It increased from 2.6 billion tonnes in 1970 to around eleven billion tonnes in 2019. For another, the overall proportion of oil and natural gas transport has decreased considerably. While these made up 55 per cent of all transported goods and products in 1970, they were only around 28 per cent in 2019, whereby the total amount of petroleum has not decreased at all. On the contrary, more than twice as much oil was shipped in 2019 than in 1970. But transport in the third category described above has increased even more. In terms of value, 60 per cent of the goods traded are now shipped in containers. This large proportion is due to the fact that goods loaded into containers such as entertainment systems, computers, clothing, sporting goods and foodstuffs, are generally far more expensive per tonne than bulk goods such as oil, iron ore or coal.

The direction of the flow of goods has also changed. Until about two decades ago the same transport and trade patterns were being followed as in colonial times, by which the so-called developing nations exported large quantities of resources and raw materials by ship and imported relatively smaller amounts of consumer goods. But the trends have been changing since the beginning of the new millennium. Many of these countries now also import raw materials and actively participate in the trade of intermediate and end products as both buyers and sellers. This means that goods and products not only leave these lands, but they are also imported on a large scale. According to the United Nations Conference on Trade and Development (UNCTAD), the significant increases in these shipping trends can be mainly attributed to increased trade among developing nations.

This development has been enhanced by the globalization of production processes and the increasing division of labour, in the course of which companies have transferred many of the individual steps of product manufacturing to different countries and continents. It is primarily ships that have the task of transporting the various intermediate products from one location to another where they then undergo further processing. According to UNCTAD, more than half of the products made by companies with their headquarters in industrialized countries are now produced and sold abroad. At the same time, these companies import raw materials and intermediate products from other countries in similar quantities. These two developments have created a situation where many markets have become strongly international and have thus also resulted in the establishment of many corresponding dependencies. For instance, when the 400-metre-long giant container ship *Ever Given* became wedged in the Suez Canal in March 2021, clogging this bottleneck of global trade for six days, the disruptions to freight transport worldwide were severe. Hundreds of freighters were caught in the backlog, closely time-phased supply chains tore and the economic impacts were felt for long.

The high degree of globalization of economies worldwide also explains why political tensions among large industrial powers can have direct effects on international merchant shipping. The trade dispute between China and the USA in 2019, for example, not only slowed the growth

4.2 > The mega-freighter *HMM Hamburg* is 400 metres long and can carry 23,964 containers. This capacity makes the ship, which sails a regular route between Europe and East Asia, one of the largest container ships in the world.



4.3 > Most shipping travels along established routes that connect the industrial centres with each other. Specialists distinguish between core routes and secondary routes, and are also familiar with the shipping lanes where caution is advised due to the high volume of ship traffic.

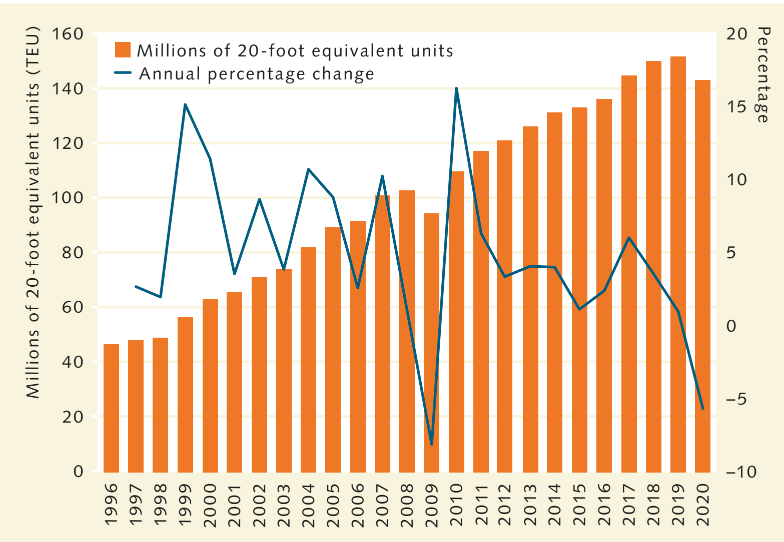
of the entire industry, it also caused many US producers to look for alternative markets and to redirect their flow of goods. As an example, raw materials and goods that had been exported to China prior to the beginning of the dispute subsequently began to go primarily to South East Asia.

The rise of the containers

Increasing globalization of production and markets since the 1970s has presented an enormous challenge for marine shipping. For example, to save on storage costs, producers began to order their goods and commodities in smaller batches and to expect delivery at a specified time ("just in time"). In order to meet these demands, the shipping companies could no longer treat the goods as bulk cargo, but were forced to load them in smaller units that could be quickly loaded onto trains or trucks at the destination ports and sent on from there to their final destinations. Thus began the rise of container shipping, which continues to grow today. This development is reflected, among other things, by the growing size of the individual container ships. While the first generation of ships (built in the early 1970s) had a load capacity of 600 to 900 containers, the newest generation of container ships can now transport 24,000 containers to destinations around the world.

The giant container ships are mainly used on the regular routes between Europe and Asia, or those across the Atlantic and Pacific. This is because competition between shipping companies is greatest on the major international shipping routes, and the pressure on prices there is particularly high. The more containers a ship can transport in this situation, the lower the prices a shipping company can offer and thus remain more competitive. Based on this logic, a large number of container ships have been built in recent years, and the overall prices for ship transport have continued to fall accordingly. The lower prices, in turn, have increased the motivation for merchants to order their goods for delivery on short notice rather than pay extended storage fees. For this reason, international production and delivery chains are now so dependent on container-ship transportation that the UNCTAD experts employ the trends in this transport branch as a direct indicator of overall economic development.

4.4 > A liquid-gas tanker docked at the Port of Malta. Because the global trade of liquified natural gas is steadily increasing (11.9 per cent growth in 2019), the number of these special ships is also mounting.



4.5 > The increasing container transport in numbers. The moderate decline in 2020 is due, among other things, to the global economic consequences of the corona pandemic.

The stakeholders in bulk freight transport have also embraced the motto, “the bigger, the cheaper”. Until about 20 years ago, most of the bulk carriers used could typically load around 200,000 tonnes of cargo. Then, in 2011, the first ship of the Valemax, or Chinamax Class was put into service, with a length of more than 350 metres and a carrying capacity of 400,000 tonnes. It transports iron ore from Brazil to China and other Asian ports. Worldwide there are now 61 of these ships in use, which is a significant factor in the 25 per cent decrease in transport prices for iron ore on the Brazil–China route.

The merchant fleet in numbers

Outflagging
Outflagging is when a ship is not registered in the home state of the shipping company, but in another country, yet the ownership of the ship does not change. The reasons often involve cost savings as well as the ability to hire foreign personnel.

However, the ships are not only getting larger, their numbers are also growing. In early 2020, UNCTAD experts reported a total of 98,140 cargo, container, tanker, ferry and passenger ships operating worldwide. Their total freight volume was 2.06 billion tonnes. Bulk carriers, which continue to be the largest business segment, accounted for 43 per cent of this. Oil tankers, with a freight-volume share of 29 per cent, made up the second largest division. This means that the available freight volume of the merchant fleet has more than doubled within the two decades since 2000, when the freight volume was 800 million tonnes.

The quantity of goods transported, however, has not increased by an equivalent amount. This has resulted in an excess in total capacity, causing freight prices to go down and the profits of shipping companies to shrink, especially in the container sector. This trend, which has been ongoing for years, has led to the buyout of smaller container shipping companies, and to larger companies entering into alliances with their market competitors. Three large groups now control more than 80 per cent of the global container business. It is important to note here that the shipping companies are no longer concerned only with the transportation of goods from one port to another. In order to profitably fill the large container ships in particular, the companies attempt to take control of the transport chain as early as possible, before the goods even arrive at the port of departure, and to retain control for as long as possible, ideally until their delivery directly to the recipient.

As a result, the shipping companies have evolved into multimodal logistics enterprises. They not only organize the ship transport; in many places they also operate the container port terminals. They also undertake the subsequent transport of the containers to inland locations and operate container depots there as well. This trend is especially significant for countries and regions that are not on the large trade routes. The trade infrastructures in these places are not as well developed, and this often means they have to pay higher freight costs than countries along the established routes.

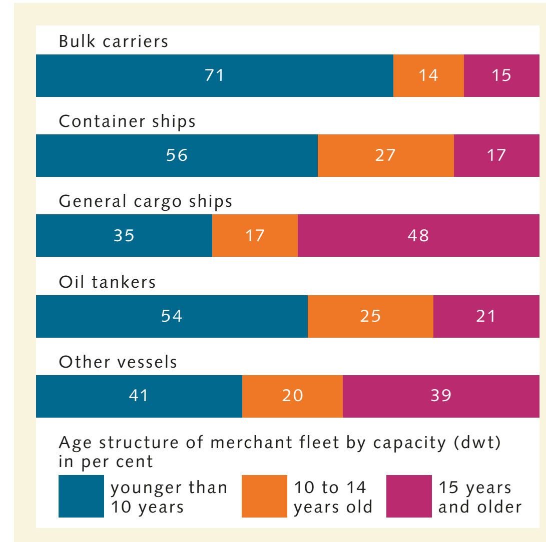
The huge investments in large container ships and bulk cargo freighters by shipping companies are also reflected in the age structure of the international merchant fleet. The average age of a ship at the beginning of 2020 was around 21.3 years. Sorting by age categories, however, revealed that the bulk carriers, container ships and oil tankers were mostly only ten years old or younger. The fleet of general cargo ships and ships of other types (ferries, etc.), on the other hand, were far from modernized. In 2019 these kinds of ships were generally more than ten years old.

In recent years, as a result of investments by Asian shipping companies, China, Singapore and Hong Kong have risen into the ranks of the top five ship-owning nations. Together with Greece (first place) and Japan (second place), the owners from these countries possess so many ships that they transport more than half of the worldwide available freight volume.

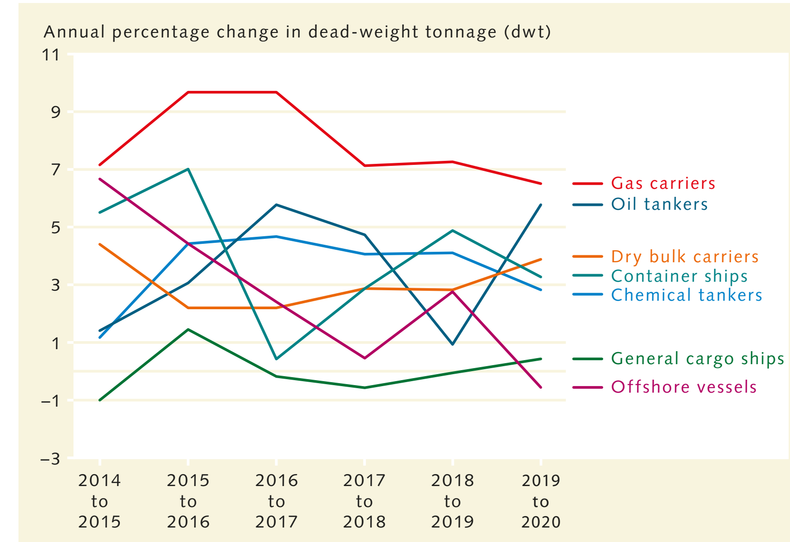
But the great majority of ships in the merchant fleet (70 per cent of the freight capacity) are registered under foreign flags, because of the many financial and regulatory advantages associated with this practice. Open registries, for example, have made it easier in the past for shipping companies to hire foreign crews and save on taxes. Today, however, ship owners make the decision to register under foreign flags for other reasons. For example, if a ship is registered in a country with a good reputation worldwide, the inspections in port take less time and the shipping company saves money each time. However, the question of modern security precautions (cyber security) and certified processes is also becoming increasingly important. Both of these are needed to guarantee the smooth operation of the shipments as well as long-term acceptance by the customers. The ship owners therefore always select a registry or flag whose services best fit their own business profile and are ultimately the least expensive. Ships today that still sail under their own national flags generally do it because they belong to state-owned companies or institutions, they receive state subsidies, or they provide transport services in another country that has limited the access to its domestic market by providers from certain nations.

The leading flag states are Panama, Liberia and the Marshall Islands, followed by Hong Kong (China) and Singapore. These and the many other flag states are increasingly obligated to effectively enforce applicable shipping regulations as well as to uphold safety, environmental, labour and social standards.

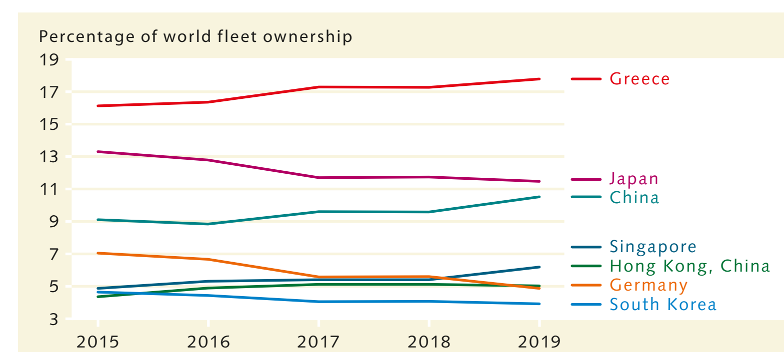
Whether the flag states and ship registries are fulfilling this role is being monitored in Europe’s ports, for



4.6 > In recent years shipping companies have concentrated new construction investment on bulk carriers and container ships. There are therefore many newer ships of these types.



4.7 > The situation in the commercial market dictates which types of ships are needed. The growth from 2019 to 2020 was primarily seen in the fleet of gas and oil tankers.



4.8 > Almost 40 per cent of all merchant ships belong to people or companies based in Greece, Japan or China. The shares of all other nations lie in the single-digit range.

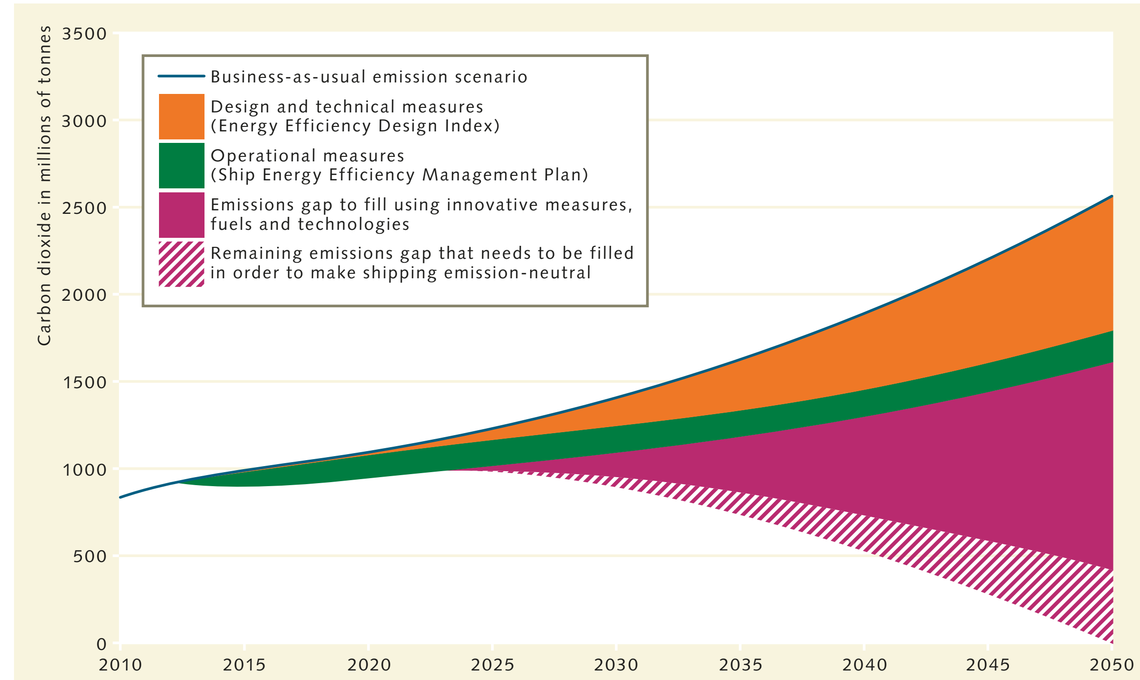
example, through ship inspections according to the community standards set down in the Paris Memorandum of Understanding on Port State Control (Paris MoU). This has now been ratified by 27 European states.

Every member state reports the results of its ship inspections to the Committee of the Paris MoU, which publishes an annually updated rating list for flag states and ship registries. Participants with comparatively few violations earn a position in the "white" category on this list. States and registries in the "grey" category have only moderately fulfilled their supervisory obligations, and assignment to the "black" category indicates serious shortcomings.

In 2019, member states of the Paris MoU carried out almost 18,000 ship inspections. More than half of these revealed substantive issues. Ships were detained in port 526 times, and prevented from continuing their voyage under the existing conditions. Ships were barred from entering ports 27 times. The reasons included sailing despite being detained, failure to have repairs carried out, or being detained as a result of inspections three times within three years. In its current rating list, the committee has 41 flag states in the "white" category, 16 in the "grey" category, and 13 on the "black" list. The high-risk nations include the Comoros, Albania and Togo, followed by Moldova, Tanzania and Ukraine.

Although flag states are increasingly called upon to enforce regulations and rules, with regard to the actual shipments themselves, it is becoming less and less important where the participants come from. Merchant shipping is a thoroughly internationalized area of business. The operation of a ship can involve people and machines from more than a dozen countries. For example, when a ship that was built in Korea and belongs to Greek owners is chartered by a Danish shipping company, it may then hire a Filipino crew through an agent on Cyprus. Meanwhile, the same vessel could be registered in Panama, insured in the United Kingdom and transporting goods manufactured in Germany on a scheduled route from a port in the Netherlands to Argentina, with terminals in the two ports operated by companies based in Hong Kong and Dubai. The software and IT services necessary for terminal operation, in turn, may be provided by a company in India. This globalization is only able to function because critical aspects of merchant shipping such as container size, information and data systems, as well as quality and safety requirements are standardized worldwide, and the same standards apply in many places.

4.9 > Soot, sulphur oxides, particulate matter: Ships have been poisoning the air for decades. The seagoing vessels using heavy fuel oil as a fuel were especially problematic. Since January 2020, however, a new regulation is in effect that requires fuels to be lower in sulphur.



4.10 > To cut the carbon dioxide emissions of merchant shipping in half by 2050, the International Maritime Organization is relying on a number of technical innovations. By their calculations, simply operating the ships in an energy-efficient and fuel-saving way is not enough by far.

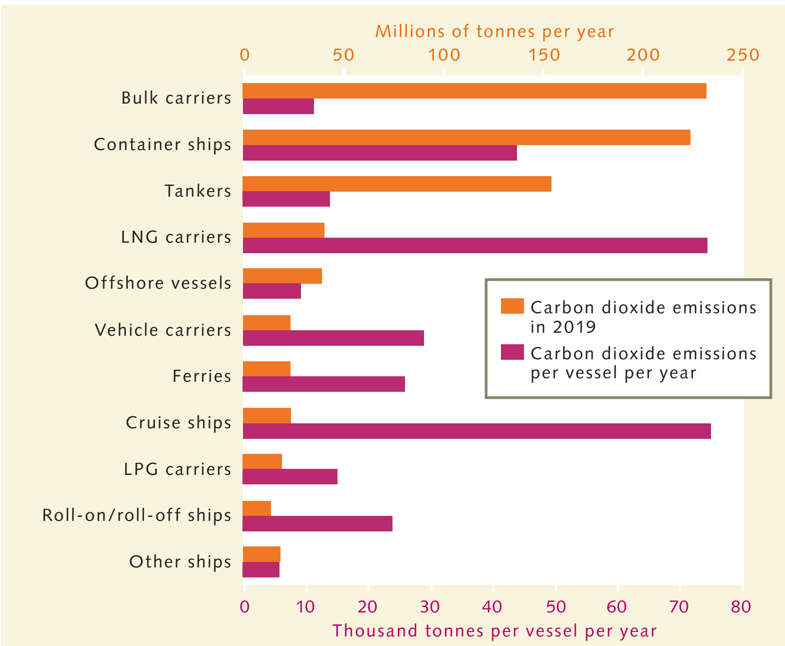
Pathways to emission-free shipping

Today, the most energy-efficient means for transporting goods and commodities internationally is still by ship over the ocean. However, engine-powered shipping has been generating increasingly more greenhouse gases over the past ten years, as diesel engines have been used almost exclusively. For these, the ocean vessels consume either heavy fuel oil or marine diesel oil as fuel. According to the International Energy Agency (IEA), the following fuels were used in international shipping in 2019: heavy fuel oil, amounting to 180 million tonnes of oil equivalent; distillate fuels, such as marine diesel, amounting to 45 million tonnes of oil equivalent; and natural gas, mainly in the form of liquefied natural gas, amounting to 0.1 million tonnes of oil equivalent.

When these fuels are combusted they produce substantial quantities of greenhouse gas emissions. According to the International Maritime Organization (IMO), international shipping (combined fisheries and merchant shipping in both national and international waters) generated greenhouse gas emissions amounting to 1076 million tonnes of carbon dioxide equivalent (CO_2e) in 2018, an increase by 9.6 per cent compared to 2012, when the value was 977 million tonnes. This means that shipping now contributes 2.89 per cent of the total amount of global greenhouse gases released by humankind. If growth in the shipping sector continues through the middle of the century at its present rate, experts predict a further increase of ship-generated carbon dioxide emissions by 50 to 250 per cent.

This trend would surely result in a failure to limit global warming to less than two degrees Celsius by 2100,

Carbon dioxide equivalent (CO_2e)
CO_2 equivalent (CO_2e) is a unit of measure used for amounts of greenhouse gas emissions that, besides carbon dioxide, also includes other greenhouse gases like methane and nitrous oxide. Their impact on environmental warming of the Earth's atmosphere is thus recalculated to an equivalent amount of carbon dioxide (CO_2), so that the warming effect of a mixture of greenhouse gases can be expressed by a single number.



4.11 > The UNCTAD experts keep accurate records of how much carbon dioxide is emitted by which types of ships and fleets. Their tally for the year 2019 shows that bulk carriers had the highest total fleet emissions because there is such a large number of them. Cruise ships were at the top of the individual ship rating.

the goal prescribed by the Paris Climate Agreement of 2015. Shipping, like all other key sectors, will therefore have to drastically reduce its greenhouse gas emissions. Initial plans are already being made toward this end. In April 2018 the IMO resolved to reduce the amount of all greenhouse gas emissions by 2050 to half of the amount released in 2008. This includes a reduction in the amount of carbon dioxide emissions by 70 per cent by this date. The long-term goal, however, is to completely eliminate emissions.

The shift to emission-free shipping will require a radical transformation within the sector. Experts from the International Energy Agency and UNCTAD have concluded that operational measures to reduce emissions by shipping, such as slower cruising or improved utilization of capacity on ships, will be far from sufficient to effectively reduce the greenhouse gas emissions. Instead, alternative forms of propulsion, as well as new fuels whose combustion releases minor amounts or no greenhouse gases at all will have to be developed.

But time is pressing. In the view of the Getting to Zero Coalition, a private-sector initiative, ships with emission-free propulsion will have to be deployed at the latest by 2030 in order for the goal of emission-free shipping to be achieved over the long run. But it is precisely on this point that the sector now finds itself in a dilemma that the operators themselves refer to as a system blockade. The problem is summarized as follows:

International maritime shipping is a capital-intensive sector of industry involving large investments, such as for the construction of new ships, that can only pay off over many years. For this reason, investors have a strong interest in keeping a ship in operation for as long as possible. Competition is great and the profit margins are comparatively small. Furthermore, the wellbeing of the entire sector depends on the global availability of sufficient fuel.

The development of alternative fuels, however, has not yet advanced sufficiently to alleviate uncertainty among potential investors. Moreover, it is anticipated that the possible alternative fuels will initially be more expensive than petroleum-based fuels. This expectation, in turn, raises questions about the competitive potential of ships with new technologies assuming that market conditions do not change. To address this problem it may be conceivable, for example, to promote the changeover to new fuels with lower or zero emissions by imposing an international CO_2 tax.

Many stakeholders within the shipping industry itself would approve of such a step if it could be applied across the board and equally for all competing parties. Most of them have long been aware that marine fuels have been traded far too cheaply, and that the industry has not yet contributed in any way for the long-term damage caused by ship emissions. Experts with the International Monetary Fund are likewise in favour of a carbon tax. According to their calculations, a tax of USD 75 for every tonne of carbon dioxide released could reduce the emissions caused by shipping by 25 per cent by 2040 and generate an income of USD 150 billion, which could then be invested for research and development.

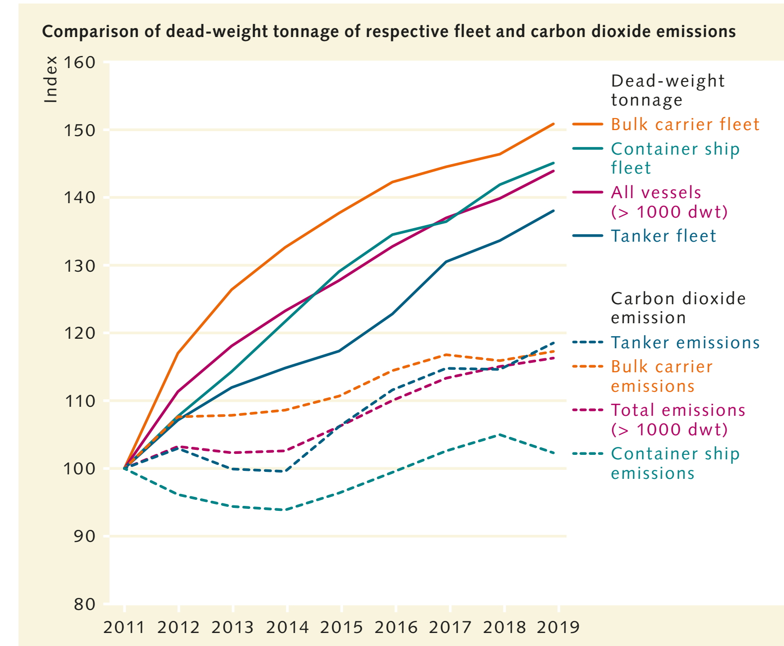
This approach is also supported by the International Chamber of Shipping (ICS) and other industry organizations. They suggest a joint IMO funding programme for research and development of emission-free propulsion systems and fuels. It would be financed by ship charterers, who would pay a set fee for each tonne of fuel they purchase. This would generate about USD five billion, money that is urgently needed for research.

The key idea behind this approach is: The higher the charges on carbon dioxide emissions and the cheaper the new technologies become, the more likely ship owners will be to replace their conventional fleets with ships with low-emission propulsion systems. The IMO has been collecting data on the fuel consumption of the international merchant fleet since January 2019. Ships with a gross tonnage of 5000 and greater (standard size specification for ships) must report once a year the amount of fuel they have consumed broken down by voyages. The purpose for collecting this information is to improve estimates of energy consumption and the volume of emissions in shipping.

However, in order to achieve decarbonization, what is needed most of all is money. According to a study by the Global Maritime Forum, the shipping industry will have to invest around USD 1.0 to 1.4 trillion during the period from 2030 to 2050 in order to cut the emissions in half by 2050. USD 1.4 to 1.9 trillion would be required for a complete decarbonization of the industry. Just for comparison, in the year 2018 alone governments and the private sector invested USD 1.85 trillion in the energy sector. This shows that such sums are not totally inconceivable.

However, a significant obstacle to increasing investments in the shipping industry has been the fact that it is not the investor or ship owner who would benefit from the technical innovations, but the companies that charter the ships for transport. As a general principle in international shipping, the charterer pays for the fuel and, where applicable, also for the tax on greenhouse gas emissions. So, although the ship owners would have to pay for the conversion, others would reap its benefits.

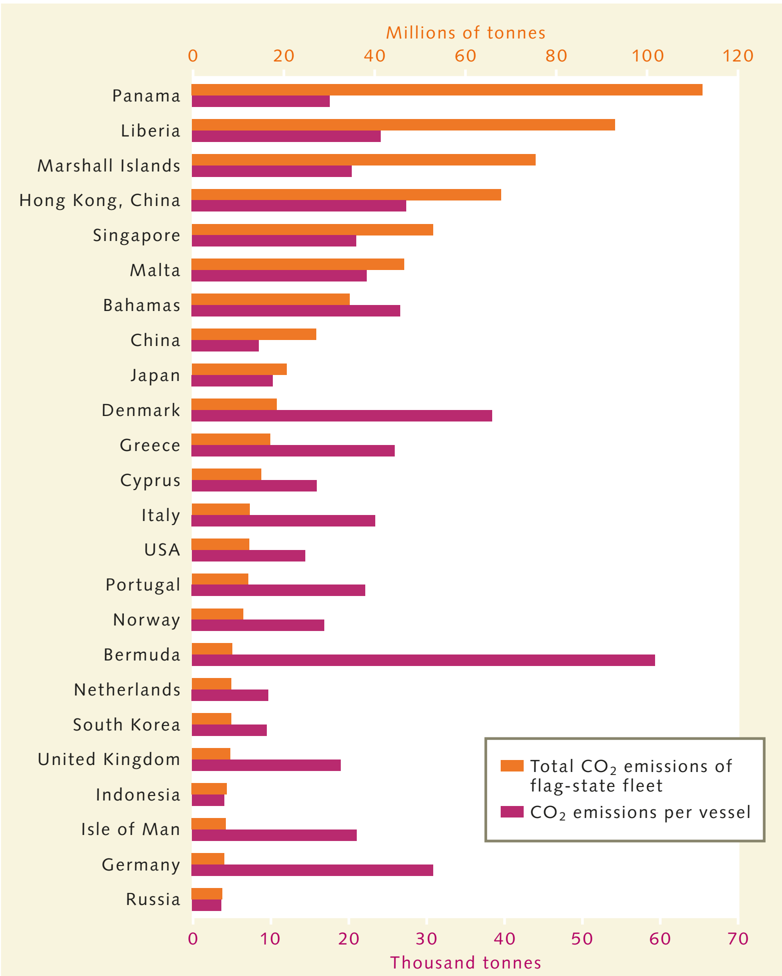
Ship owners and investors, moreover, have a strong interest in keeping their vessels in service for as long as possible in order to achieve the maximum profits. The specialists at UNCTAD have therefore made a relevant calculation. If ships remain in operation for as long in the future as they have in the past, almost 30 per cent of the present-day fleet of offshore supply ships will probably still be in service in 2051. More than 20 per cent of all ferries and



passenger ships, and significantly more than ten per cent of all freighters would still be operating. The UNCTAD authors conclude that low-emission technology must therefore come onto the market as soon as possible so that as few of the new-construction ships as possible are fitted with conventional motors. A report by a large producer of ship fuels makes the point even more vividly. It refers to 2030 as "tomorrow", and to 2050 as merely the life of a ship away.

Because of this situation of complex interests and the steadily rising urgency for reduced emissions, specialists in the transport industry are demanding clear guidelines from politicians and shipping organizations. What is needed is a globally binding set of rules and a secure, level playing field where green technologies should not be reserved only for the most economically successful companies. Instead, there must be international investment incentives that compensate for initial competitive disadvantages (alternative fuels are more expensive than marine diesel oil or heavy fuel oils). For example, tax relief might be considered for investments in sustainable ship technology. In a survey to find possible solutions conducted in the summer of 2020, leading stakeholders in

4.12 > Since 2011 the load capacity of the merchant fleet has grown at a significantly greater rate than its total emissions. This means that transporting goods with a fully loaded mega-freighter produces a smaller amount of greenhouse gases than the same quantity of goods sent with two ships.



4.13 > The greenhouse gas emissions of a ship are assigned to the carbon footprint of its flag state. Although the total emissions of ships registered in Germany make up a relatively small quantity, the amount calculated per ship is relatively high. That is because they are mostly container ships.

international merchant shipping identified the following five high-priority action areas:

1. Increase demand for low-emission ship transport

The demand for low-emission shipping must be stepped up in order to provide more security for investors and shipping companies. Charter companies and customers must agree to long-term contracts and make ecological delivery commitments. State-owned companies and large corporations with ambitious emission goals could help to get this started.

2. Uniform rules and deadlines

To guarantee equality in competition and opportunity, the shipping industry needs uniform global rules and deadlines for the implementation of emission-reducing measures. Towards this purpose, it is also important to coordinate the new guidelines of the International Maritime Organization (IMO), expected to be released in 2023, with leading national and regional shipping authorities.

3. Cross-sectoral research and development

For the development of low-emission ship technology, the industry has to think beyond its own sector boundaries and engage in cooperative research projects with other parties that are working on similar problems outside the shipping industry. These partners could be from the energy or automobile industries, for example. In addition, much more capital and expertise will be needed in order to advance the technology, and at the same time provide the necessary infrastructures for its production and operation.

4. Expansion of pilot projects

Significant progress can be achieved by testing green pilot projects under normal competitive conditions on selected transport routes, and including all stakeholders such as customers, charter companies, shipping companies, ship owners and port agents. Container ships sailing on shorter scheduled lines would be particularly suited to such practical tests.

5. Coordinated voluntary commitment by the entire shipping industry

In order to increase the effectiveness of the existing climate initiatives, the goals and measures of the various efforts must be unified and strengthened. A jointly created steering committee could take on this challenge with the primary task of transforming ideas into action and freeing the industry from its present developmental stagnation.

What will power the ships of tomorrow?

One of the hurdles along the path to low-emission shipping is the lack of progress thus far in developing emis-

Main international regulatory policies covering air pollution and greenhouse gas emissions in maritime shipping

Name	Geographic coverage	Year introduced	Description	Regulatory actor
IMO Initial Strategy	Global	Adopted in 2018	Reduce absolute greenhouse gas emissions from shipping at least 50 % by 2050 relative to 2008; reduce CO_2 emissions per transport work at least by 40 % by 2030, pursue efforts towards 70 % by 2050	IMO
Data collection system (DCS) for fuel oil consumption	Global	2019	All ships over 5000 tonnes engaged in international voyage must collect consumption and other data for each type of fuel oil consumed. Flag states must collect and aggregate the data and submit to the IMO	IMO
Submission of CO_2 emissions reports (MRV)	Ships calling at EU ports	2018	Companies must submit a CO_2 emissions report for all voyages in the European Union for all vessels under their responsibility	European Commission
EU Emissions Trading System (ETS)	Ships calling at EU ports	2022 (expected)	Proposal to include shipping in the ETS as part of the Green Deal	European Commission
Energy Efficiency Design Index (EEDI)	Global	Enforced in 2013	Requires minimum energy efficiency per tonne-km for new large vessels and mandates improvement steps depending on vessel type: 10 % in 2015, 20 % in 2020 and 30 % in 2030 compared with average performance of vessels built in 2000 to 2010	IMO
Ship Energy Efficiency Management Plan (SEEMP)	Global	Adopted in 2016	Monitors ship efficiency performance, mandates collection and submission of relevant data and establishes mechanisms to improve efficiency of existing ship operations	IMO
Global sulphur cap	Global	January 2020	Limits the sulphur content of maritime fuel used on board vessels trading outside of sulphur ECAs to a maximum of 0.5 %. Ships without exhaust gas scrubbers are not permitted to carry fuel for use with a sulphur content exceeding 0.5 %	IMO
Emission Control Areas (ECAs)	Baltic Sea, North Sea, Caribbean Sea and North American Sea	Enforced respectively in 2005, 2006, 2012 and 2014	To operate in these areas, ship engines must comply with stricter standards for SO_X and NO_X than in global waters. In particular, there is a limit of 0.1 % sulphur for fuel used by ships operating in SO_X ECAs and NO_X TIER III standards apply to ships operating in NO_X ECAs	IMO

Notes: IMO = International Maritime Organization; MRV = monitoring, reporting and verification; EU = European Union; SO_X = sulphur oxides; NO_X = nitrogen oxides

4.14 > Over the past two decades the IMO and the EU Commission have undertaken a number of steps to reduce the emissions of merchant shipping. Their most important initiatives are listed here.

sion-free fuels and propulsion systems. For transportation through inland waters or for short distances in coastal waters, battery-driven electric motors are a viable option. There are presently around 250 ships with electric or hybrid propulsion in operation worldwide or now being built. Norway, for example, plans to have about 80 electric-powered ferries in regular operation by 2022. But electric propulsion systems are also being installed on tugboats as well as on aquaculture and fishing vessels. The first cruise-line companies have announced that they will equip new ships with large battery systems to make hybrid propulsion possible. Furthermore, electric current from onshore sources will become more readily available to serve cruise ships and other vessels during port layovers. This measure alone would reduce up to eleven per cent of the greenhouse gas emissions caused by international shipping.

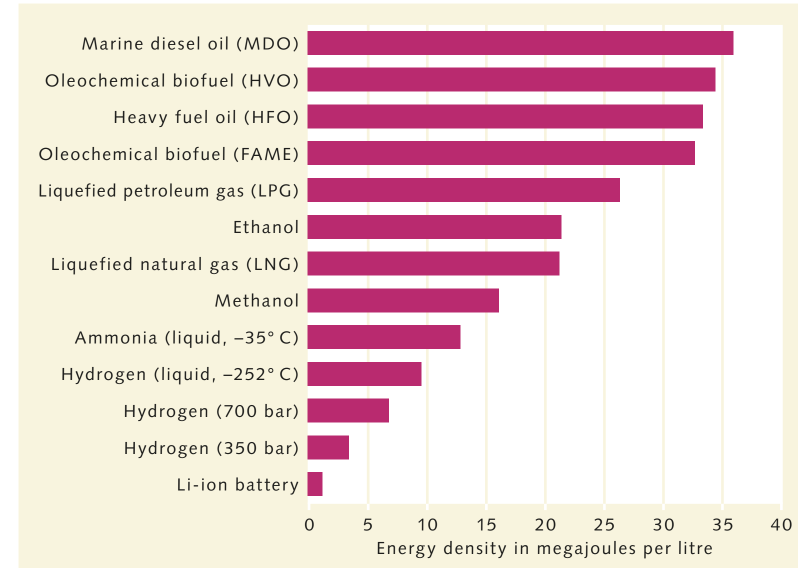
But for maritime shipping, which accounts for 85 per cent of the greenhouse gas emissions in shipping, and which is greatly dependent on fuels with a high energy density, there is as yet no alternative fuel known that could conceivably cut emissions in half by 2050. For the transition, shipping firms like the French company CMA CGM are turning to liquefied natural gas (LNG). This is natural gas that is cooled down to minus 161 degrees Celsius. At this temperature it changes to a liquid and shrinks to one-six-hundredth of its original volume, so that 600 litres of natural gas become one litre of liquid gas. In this state, a significant amount of space can be saved in its transportation and storage. It is transformed to the gaseous phase again to be burned in the ship's motor. But first, undesirable components like carbon dioxide, nitrogen and water are removed, leaving a composition of almost 100 per cent methane. This cleaning step is one of the reasons that ships fuelled by LNG, such as CMA CGM's giant freighter *Jacques Saadé*, emit up to 20 per cent less carbon dioxide, 99 per cent less particulates, and 85 per cent less nitrogene dioxide than comparable freighters powered by heavy fuel oil. The change to LNG thus significantly reduces the emission of pollutants.

4.15 > No more black clouds of soot: The container ship *Jacques Saadé*, operated by the French shipping company CMA CGM, is powered by liquified gas and is presently the largest freighter with this kind of alternative propulsion system.

The emission reductions, however, fall far short of what is necessary to achieve the IMO target or the goals of the Paris Agreement. LNG is thus largely considered to be only an interim technology, although even this view is now being disputed. Conservationists and climate activists argue that although the burning of natural gas releases less carbon dioxide than burning heavy fuel oil, such large quantities of the greenhouse gas methane escape during the production, storage and transport of LNG that the overall global warming impact of using LNG is at least equal to if not greater than burning oil for propulsion. Experts are therefore calling for improved greenhouse gas determinations for all marine fuels, including biofuels, that will take into account emissions during production as well as those from combustion.

Ship designers worldwide are currently testing several potential new fuels, including hydrogen, ammonia, methanol and biofuels. But with all of the alternatives they are still being deterred by the economic limitations. The new fuels are still more expensive than heavy fuel oil. In addition, they are less efficient, which means that larger quantities are necessary, in turn making their storage more expensive and subject to strict safety regulations. Moreover, many ports currently lack the infrastructure needed to provide sufficient quantities of alternative fuels.

What is required, therefore, are new energy-efficient propulsion systems combined with tank facilities large enough to store the necessary amounts of fuel. The international merchant fleet presently requires an annual energy supply on the order of 3.3 petawatt hours. This would be enough to supply the greater New York City area with electricity and heat for more than 60 years. According to calculations by the International Energy Agency (IEA), more than 80 per cent of the fuel required by merchant shipping could be provided by sustainably produced biodiesel, ammonia and hydrogen by 2070. However, this progress assumes that around 13 per cent of the hydrogen produced worldwide will be used in shipping by that time, as well as a continued increase in the energy efficiency of transportation. Specialists at the Global Maritime Forum, on the other hand, speculate that sustainably produced ammonia will be the primary fuel for ships in the future because it is more economical to produce and store than hydrogen.



4.16 > High-energy-density fuels are required to power ships' motors. This chart illustrates that low-emission alternatives like hydrogen have less than half the power of marine diesel oil.

Initial tests for improving the energy efficiency of ship propulsion are already underway. In August 2018, for example, the Mærsk shipping company installed two Flettner rotors on their tanker *Mærsk Pelican* for trial purposes. These are large cylinders installed vertically on the ship's deck like sailing masts. When the wind flows past these turning cylinders, a power of up to three megawatts is generated that propels the ship at right angles to the wind. In the first year they were used, the rotors helped the tanker to save 8.2 per cent in fuel and 1400 tonnes in carbon dioxide emissions. These savings are far short of the IMO target, but the company has decided to keep the rotors and continue to let the wind augment the propulsion of the tanker.

There are already propulsion systems working in submarines that most experts hope will become the future for merchant shipping. The underwater vehicles use fuel-cell technology and are powered by hydrogen stored in metal hydride storage systems. In commercial shipping, fuel cells have been tested as a source for on-board energy and have proven to be more efficient than comparable diesel units. However, the fuel cells have not been

4.17 > All emission reductions are important. For this reason, a number of operational measures as well as various kinds of new or advanced technology are being considered in the shipping industry. This summary shows the energy savings and resulting fuel savings associated with each of these.

Energy efficiency solution		Energy and greenhouse gas emission savings
Design and technology options		
Design modifications and structural optimisation	Increase in ship carrying capacity	10 % (for larger ships) to 25 % (for smaller ships)
	Increasing the length/beam ratio	3 % to 5 %
	Higher strength steel, material substitution	0 % to 1 %
Reduction of drag/skin friction	Hull surface texturing	2.5 % to 7.5 %
	Air lubrication	0 % to 13 %
	Wake equalising and flow separation reduction	1 % to 3 %
Increasing propulsion efficiency	Pre-swirl devices	2 % to 6 %
	Post-swirl devices	2 % to 6 %
	High-efficiency propellers	3 % to 10 %
Renewable energy integration	Sails	Up to 30 % in best cases, where applicable
	Flettner rotors	8 % on average, and up to 20 % in best case, broader applicability than sails
	Solar electricity	0 % to 1 %
Machinery improvements (main and auxiliary engines)	Main engine performance measurement and control	1 % to 2 %
	Waste heat recovery	5 % to 11 % (requires large engine power)
	Engine hybridisation and optimisation of engine size, power and loads (includes de-rating)	0 % (steady engine load) to 24 % (dynamic load)
Operational improvements		
Speed reduction		27 % hourly fuel consumption reduction at 10 % reduction in speed
Weather routing		2 % to 5 %
Trim/draft optimisation		1 % to 2 %
Hull and propeller condition management and maintenance		3 % to 12 %
Ship system management – includes reducing on-board energy use, fuel consumption measurement and reporting		Enabler of energy saving technology developments
Overall energy efficiency management – includes the application of the IMO Ship Energy Efficiency Management Plan (SEEMP)		Enabler of energy saving technology developments

powered by hydrogen but by other fuels like methanol, natural gas or diesel fuels. These fuels are more accessible and are often easier to store.

The use of hydrogen-powered fuel cells for ship propulsion, on the other hand, is still in the early test stages, with applications so far limited to smaller passenger ships, ferries or sport boats. Fuel cells big enough to power large merchant ships do not yet exist. One reason for this may be that the associated propulsion technology as well as the hydrogen fuel itself are still significantly more expensive than a diesel motor powered by heavy fuel oil.

Seaports and climate change

The severe impacts of climate change are already being felt by the international shipping industry, especially in ports, the hubs of international transport chains, whose exposed locations in low-lying coastal areas or estuaries make them particularly vulnerable. When ports are forced to interrupt their operations due to extreme weather events, the transportation of goods comes to a complete standstill – with radical consequences. In August of 2005 in the USA, as a consequence of Hurricane Katrina, three ports through which 45 per cent of all agricultural products were normally imported and exported had to be closed, causing a nationwide increase in food prices of three per cent. Reports indicate that Hurricane Harvey had a similar impact on fuel prices in 2017.

A survey by the magazine *The Economist* revealed that more than half of the goods traded globally pass through ports that are exposed to high risk due to climate change, whereby the ports situated in estuaries or river courses are often subjected to different climate impacts than those directly on the coasts. Scientists, however, see an increasing risk of damage for all 136 mega-port cities in the world. The most severe impacts of climate change on ports include the following:

Flooding as a result of rising sea level and increasing frequency of storm surge events

The consequences of rising water levels are not limited to the suspension of loading operations for the duration of the flooding, but also include long-term damage to loading facilities, containers, warehouses and railways in the entire port area. According to a study in 2018, a one-metre rise in sea level by 2100 will likely result in the flooding of more than 60 per cent of all European seaports, with extremely high waters of up to three metres above mean sea level included in the calculation. Many seaports in Greece, Great Britain and Denmark could face the danger of flooding as early as 2080.

Heavy rainfall resulting in high water levels or flash floods

Extreme rainfall can lead to rising water levels and flash floods, as well as flooding and erosion of riverbanks. Not only are important streets, bridges and rail connections in the ports damaged, but also the port facilities themselves. Poor visibility, wet soils and strong currents in river ports also increase the danger of accidents when ships are loading and unloading. Another problem is sediment displacement, which can alter the shape of river beds and affect shipping traffic.

Rising temperatures, heatwaves and severe drought

Not only do rising air temperatures and heatwaves endanger the health of passengers, ship crews and port personnel, extreme heat also affects railways, streets and other paved surfaces, which are abundant in the ports. Moreover, the water levels of rivers decline during extended periods of drought, which makes it difficult to operate port facilities located on rivers. In the Arctic region, warming is thawing the permafrost and causing harbour structures to lose their foundational stability. At the same time, the riverbanks and sea coasts are eroding, which is strongly affecting port operations in many areas.

Extreme winds and waves

Storms and high waves have catastrophic impacts. They exacerbate coastal erosion, wash over or undercut port facilities, and cause damage to cranes, vehicles and other exposed equipment. Furthermore, loading operations are interrupted during heavy storms, increasing the costs and financial losses for the port operators. Ports in the paths of

Metal hydride storage
Hydrogen can be stored by bringing it into contact with certain metal alloys. These react with the hydrogen to a metal hydride, which binds the hydrogen chemically in its metal lattice. To release the hydrogen, only heat needs to be applied. In this manner more than ten times as much hydrogen can be stored than in a pure pressurized tank.

The Port of Rotterdam – flooding as a calculated risk

The Port of Rotterdam in the Netherlands, Europe's largest commercial port, has been pursuing an ambitious programme to adapt to the consequences of climate change since 2008. It focuses on flood protection, which the port operator is addressing in close cooperation with the city administration, the Dutch government, and companies located in the port area.

4.18 > The arc-shaped gates of the Maeslant Barrier close when the Rotterdam metropolitan area is threatened by a storm surge. It protects the city and the port from high water levels.

Based on calculations that assume a rise in sea level of 35 to 85 centimetres during the period from 1990 to 2100, the project partners studied the flood risk for all sectors of the port and established a detailed plan of measures. For example, electric power lines threatened by flooding were waterproofed or elevated, and buildings at risk were augmented with flood-protection technology. Furthermore, there is now a Disaster Management Plan that assures that in the case of flooding all work can be stopped according to an orderly procedure and then be resumed as soon as possible. For all new structures, the risk of regularly occurring flooding in the future must be taken into account from the outset, and appropriate protective measures included in their design.

Port authorities have also set a target for reducing greenhouse gas emissions by port and industrial operations by 95 per cent by 2050. After all, the emissions by businesses in the port area account for one-fifth of the total emissions of the Netherlands. Methods to achieve this ambitious goal include:

- electrification of many processes, which can then be powered by current from renewable sources;
- capture and subsequent processing or storage of carbon dioxide produced during the refining of fossil resources;
- use of biomass fuels in industrial processes where fossil resources were previously used;
- extensive use of alternative, low-emission fuels such as green hydrogen;
- establishment of a circular economy.

Through the digitalization of many information streams, the approximately 30,000 ships that call at the Port of Rotterdam each year can be processed more efficiently. This includes the timely sending of accurate arrival times to the ships.

Scientific studies in the Port of Rotterdam have shown that if all of the container ships arriving in 2018 had known twelve hours in advance when they were expected in the port (known as "just in time arrivals"), the ships' commanders could have reduced the speed of their ships accordingly, allowing reductions in fuel use and emission levels of four per cent.

Another field trial in December 2020 found savings of as much as eight or nine per cent when the captains received precise instructions up to 24 hours before port entry, and were able to adjust their ship's speed accordingly.

tropical storms are particularly hard-hit. In 2017, for example, Hurricanes Irma and Maria caused combined damages of USD 252 million in the ports, airports and streets of the British Virgin Islands alone. For one week, Hurricane Sandy paralysed operations in one of the largest container ports in the USA, resulting in economic damages and subsequent costs of up to USD 50 billion.

The protective and adaptive measures that port operators can take depends on the hazard level. Extreme events like storms or intense heat require different solutions than climate threats that progress gradually, such as the deterioration of Arctic permafrost coasts or permanent flooding due to sea-level rise.

Extreme events require protective measures that immediately reduce the risk. But as a rule, these are very expensive, particularly because the infrastructures in many ports are comparatively old and were not designed to cope with the present and imminent climate conditions.

Gradual processes, on the other hand, require long-term strategies that are in part dependent on political action. In many cases, in fact, the basic question has to be considered of whether the port has any future at all in the face of rising sea level. The possible courses of action are protection, raising, or moving, and each of these has its particular disadvantages. The construction of large protective walls leads to further coastal erosion, destroys near-coastal reefs and other habitats, and is also very expensive. Physically raising port terminals only makes sense when all of the other port facilities can also be raised with them. Efficient operation would otherwise be impossible. The decision to relocate a seaport, on the other hand, depends on the availability of an alternative site, with harbour approaches deep enough for the giant container ships and sufficient space to adapt to the continuing rise in water levels. The costs and environmental consequences of the new construction would likewise have to be assessed.

Ports as geopolitical outposts

Without a doubt, ports have a key function in the intermeshed flow of global commodities. Whoever controls them not only controls the import and export of goods in particular regions, thereby influencing their markets and economic development. Ports can also play a strategic role, for example, when they serve as ports of call and supply points for foreign naval forces. Until the 1980s, the world's ports were mostly in public hands. Their operations were organized either by the individual municipalities or directly by the state. With the introduction of container shipping, however, criticism of the public administrations became more and more frequent. The work of the ports was alleged to be inefficient, and they were accused of reacting much too slowly to the current needs of the transport industry. The World Bank recommended that coastal states and port cities privatize their ports by awarding concessions to operating companies that had sufficient expertise and capital to modernize the facilities and port operations at a pace matching the changes in the shipping industry itself and the growth of the global flow of goods.

Many stakeholders followed this advice and placed control of their ports or individual loading terminals into the hands of operating companies. Smaller companies like this had existed previously, but the privatization of many ports around the world allowed many of them to rise to the status of global players. These included the A. P. Møller-Mærsk group of companies, which includes not only the large terminal operator APM Terminals, but also Mærsk, the world's largest shipping company. A. P. Møller-Mærsk now operates container terminals around the world, enabling it to dovetail its shipping and terminal businesses in a highly cost-efficient manner.

The modernization of ports is showing results. Container ships in scheduled traffic now spend less than 24 hours in a port. In the most modern ports, the loading and unloading of container ships can be completed in as little as 14 to 15 hours. The ships are thus able to quickly continue their journeys, saving time and money. However, the privatization of terminals and ports also has its darker aspects. For example, western security experts criticize the fact that China, through its investments in European, African and South East Asian trading ports, is gaining control over these locations, and is establishing outposts where it had no influence previously. The People's Repu-

4.19 > Since the China Ocean Shipping Company (COSCO) took charge of the Port of Piraeus, more container ships loaded with goods from Asia have been calling at the Greek Mediterranean port.

blic denies such geopolitical ambitions. On the other hand, it has been expanding its influence for years.

The China Ocean Shipping Company (COSCO), although actually a large shipping company, is now the largest terminal operator in the world with regard to the total number of containers loaded. The company is active in 61 port terminals around the world and controls, among others, the Greek Mediterranean port of Piraeus, where, according to reports, COSCO has invested USD five billion in expansion and infrastructure. Container turnover in Piraeus has grown by more than 700 per cent since the takeover by COSCO, mainly because giant Chinese container ships that enter the Mediterranean via the Suez Canal are unloaded here and the goods are then distributed throughout the Mediterranean by smaller ships. This strategy is known as transhipment. COSCO is also investing in railway lines that can transport goods from Greece to the Balkans and Eastern Europe. This distribution directly from Piraeus saves time and is less expensive than having the giant container ships travel all the way to Rotterdam or Hamburg and then sending the goods from there to their ultimate destinations. Specialists therefore believe that Piraeus will soon become the busiest port in the Mediterranean region.

Another large Chinese port operator is China Merchants Group. By its own account, the Hong Kong based, state-owned company operates 41 ports in 25 countries and regions, including the port in Colombo, the capital of Sri Lanka and one of the busiest and most profitable container ports in the world. China Merchants Group also manages operations in the Port of Djibouti, one of the main supply ports for US and other international naval forces deployed to fight piracy in the Horn of Africa. This situation is a thorn in the side for many western security experts.

Direct collateral effects of shipping

While the greenhouse gas emissions from international shipping alter the sea in indirect ways by driving global warming, the transport of goods across the oceans

Retreating sea ice in the Arctic allows more frequent open passage

Climate change is transforming shipping, particularly in the Arctic region where the marked retreat of sea ice is opening up new shipping lanes. This is true for both the Russian marginal seas and the waters of Alaska. In places where the sea ice is receding, fishing boats are able to venture into previously unexploited fishing grounds. Drilling ships or platforms can exploit natural gas and oil deposits that were inaccessible before. Cruise-line companies can offer cruises toward the North Pole, and shipping companies and merchant enterprises may save considerable time and expense by shipping their goods and merchandise via the shorter Arctic sea routes from northern Europe to north-east Asia.

Shipping traffic in the Arctic region is still somewhat regionally focused, and a large proportion of the voyages are made in the summer and autumn, when the coastal waters are ice-free and the risk of accidents is smaller. But Russia in particular has been making a strong effort to develop the Northeast Passage through its Arctic coastal waters, which includes the Northern Sea Route, and thus make it more attractive for trans-Arctic voyages. New icebreakers are to keep the shipping routes open in the winter as well. The construction of ports and connected rail networks is expected to facilitate the transport of raw materials from the Russian Arctic. As a result, shipping traffic on the Northern Sea Route has already expanded immensely.

In 2017, around 10.7 million tonnes of freight were transported by ship through Russian coastal waters. In 2018 it increased to 20.18 million tonnes, and in 2019 to around 31.5 million tonnes. However, for complete trans-Arctic voyages from Europe to Asia, or vice versa, the savings have been relatively minor so far because of the high additional costs associated with sailing through Arctic waters, such as ice-worthy ships and specially trained crews. Furthermore, some of the Russian marginal seas are so shallow that only smaller ships can travel through the ice-free passages, which drives up the costs per tonne of freight.

Shipping experts therefore believe that shipping and trading companies will not invest in regular trans-Arctic service through the Northern Sea Route until profit-making transport is guaranteed. Models indicate that this will not be possible even for smaller freight ships until 2035, and for larger ships probably not before 2051. Until then the transport of goods from Europe to Northeast Asia will continue to traverse the much longer southern sea route, from the Mediterranean through the Suez Canal and the Indian Ocean.

4.20 > Shipping traffic through the Northeast Passage has mainly been limited to regional transport so far, including the transportation of liquid gas from the Arctic to Europe or East Asia. But the further and earlier in the year the sea ice recedes, the more attractive it becomes as an alternative to the Suez Canal route. In January of 2021, for the first time, three LNG tankers made the passage in winter without the help of an icebreaker. Further voyages of this kind will follow.

Cruise tourism – amusement at the expense of the environment, people and the sea

In the 1960s and 1970s, as more and more transatlantic travellers began opting for planes instead of ships, the passenger-ship industry had to find a new business concept to attract people back to their ships. US-ship owners looked to their fellow countrymen's appetites for gambling and leisure. These were the formula for success in Las Vegas. Why wouldn't ships be able to function as a combination hotel, bar and casino? The idea paid off beyond all expectation. Blackjack, poker and duty-free shopping attracted people to the sea in droves, and since the 1990s, cruise tourism has become the foundation for the fastest-growing travel sector worldwide. According to the Cruise Lines International Association (CLIA), international participation in cruise tourism increased during the period from 1990 to 2018 from 3.8 million to 28.5 million passengers, half of them from North America and one-quarter each from Europe and the rest of the world. The growth continued until the outbreak of the corona pandemic in 2020, when the number of passengers fell to around seven million.

Up to that time, according to the German Environment Agency, there were over 500 cruise ships in operation worldwide, the largest of which could carry more than 6000 passengers and 2200 crew members. These floating cities are still operating today, primarily in the Caribbean and the Mediterranean Seas. But the traffic on secondary routes in Asia, Europe and the polar regions had also increased significantly by 2020, so that experts now speak of a global branch of industry. In 2018, the cruise-ship branch employed 1.18 million people and generated a total aggregate value of USD 150 billion.

The largest share of cruise-line income is reaped by three corporate groups: the Norwegian Cruise Line Holdings, the Royal Caribbean Group, and the Carnival Corporation & plc. Together they control 77 per cent of the market. The tourism profit chain has been perfected by these three companies to such an extent that the coastal resort locations the ships visit hardly profit from mass tourism any more. The passengers only spend a short time on land. For the most part they eat, drink, shop and relax on board, even though, in most cases, the cities they call on, or nations in the case of island states, have financed the expansions of ports and supply facilities that made it possible for the ships to dock there in the first place.

Only the cities that serve as departure and destination ports still profit to a meaningful extent from the ship passengers, but even here the ship companies have taken over the cruise terminals as well as taxi and bus lines that bring the tourists to the ship at the beginning of the trip and back to the train station or airport at the end. In the Caribbean, ship companies have even bought entire islands so that they can offer shore excursions while taking in 100 per cent of the resulting profits.

The destination cities and, above all, the environment pay a heavy price for the expansion of the cruise-ship industry. The most severe consequences include:

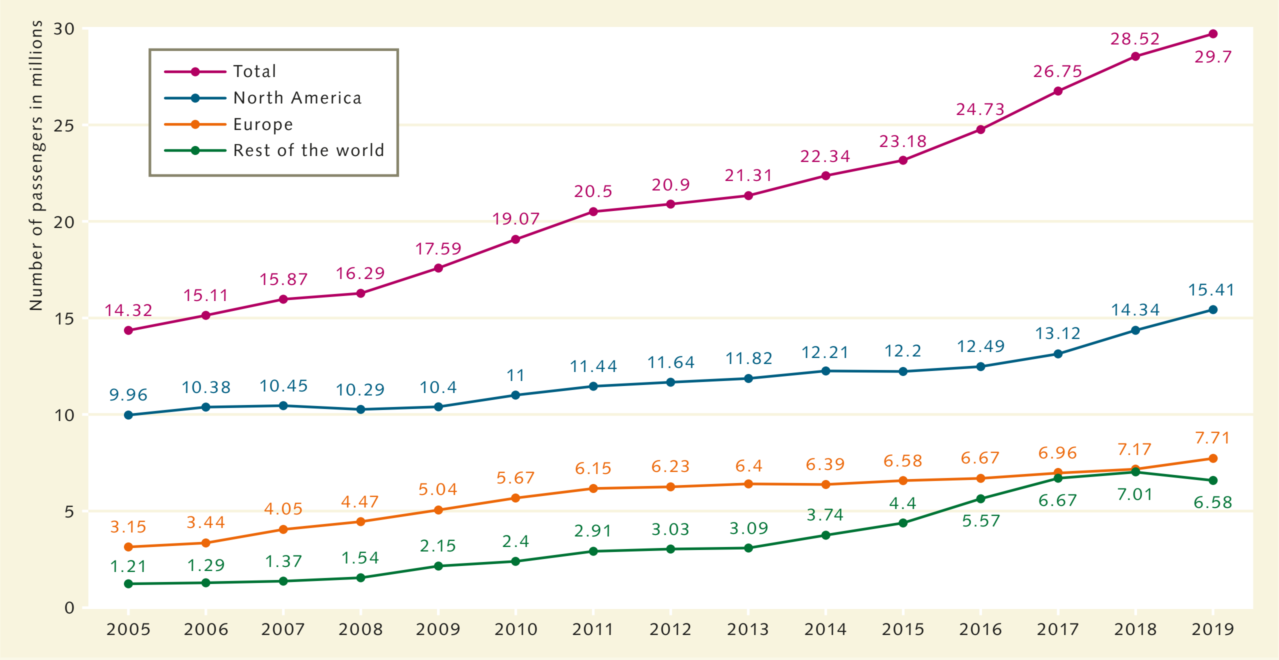
- **Massive waste arisings:** An average of 4400 kilograms of garbage is produced each day on the large cruise ships. This is often off-loaded in the transit ports and overburdens local landfills or incineration plants. Reports that ships dispose of the waste on the high seas are also not uncommon.
- **Large quantities of wastewater:** Insufficiently treated wastewater carries nutrients as well as pathogens such as enterobacteria and viruses into the sea, with diverse and complex impacts upon marine biological communities.
- **Major exhaust emissions:** By the burning of fossil fuels, cruise ships release large amounts of gases, particulate matter and other pollutants. In many places, the motors continue to run in the ports in order to supply the ship with electricity, and the port cities have suffered severely from the pollution, especially with regard to air quality. For example, in 2017, before the new IMO fuel regulations came into effect, cruise ships of the Carnival Corporation emitted ten times more sulphur oxides in European waters alone than the more than 260 million passenger cars that travel on European roads.
- **Large volumes of ballast water:** The ballast water of cruise ships also contains wastewater, oil and oil-bearing substances, as well as bacteria and organisms from other regions of the world. When this water is released into the sea there are many largely unpredictable consequences for local ecosystems.
- **Enormous noise and light pollution:** Cruise ships are brightly lit at night and, except for the brief intermediate stops for shore excursions, are constantly underway. The resulting immense light and noise levels are especially stressful for marine organisms and seabirds.

Several years ago, the United States Environmental Protection Agency estimated that every day on board a cruise ship with more than 3000 beds, around 80,000 litres of wastewater, one tonne of garbage, more than 640,000 litres of greywater, around 24,200 litres of oil-polluted bilge water, more than eleven kilograms of batteries, fluorescent lights and medical waste, as well as four plastic water bottles per passenger are produced. With this in mind, and considering that about 70 per cent of the ports visited by cruise ships lie in regions with especially high marine species diversity, the potential damage from improper disposal of this garbage and effluent is very evident.

The industry is reacting to the environmental protection requirements of the IMO and to criticism from scientists and environmentalists with technical innovations. Lower-emission fuels (especially LNG), exhaust filters, wastewater treatment and waste incineration systems, the elimination of disposable tableware, and a shore power supply during port stops are supposed to improve the environmental balance of mass tourism at sea. However, experts seriously doubt that this type of business can truly be carried out sustainably. After all, the ships are bringing countless thousands of people to places that are often no longer able to cope with such a large influx of visitors. This is not only true for small Caribbean islands, but also for large tourist cities like Venice, Barcelona and Palma de Mallorca. And if a destination loses its appeal, perhaps because the coral reefs have died or the island is covered with tourist garbage, the caravan of cruise ships moves on to find a new, as yet untarnished dream destination.

Working conditions on the ships are also often criticized. Most of the employees have only short-term contracts and many work for low wages. When ships were immobilized around the world because of the corona pandemic, many of the workers were not allowed to travel back to their home countries. They were trapped on the ships without pay and with no bargaining power.

The extent to which this industry will be able to recover from the loss of passengers due to the corona pandemic remains to be seen. Some market specialists are predicting a possible end to the golden era, while others see a good chance of a renaissance. The question of whether mass tourism at sea continues to have a future ultimately depends on millions of customers who want to pursue their dream of a sea voyage, while giving little or no thought to the social, ecological and economic footprint that cruise tourism leaves behind.



4.21 > Until the outbreak of the corona pandemic, the cruise-line branch was reporting new passenger records every year. Around half of the holidaymakers came from North America, a quarter from Europe and another quarter from the rest of the world.

4.22 > When the world's largest cruise ship, *Harmony of the Seas*, was being built, thought was also given to fun in the pool. With a length of 66 metres each, the two red tubes are the longest water slides on a ship.

also has very direct impacts. The most important of these include:

- noise pollution from the propeller and motor, and other sounds caused by the ships;
- pollution of the marine environment by exhaust and the illegal dumping of wastewater and garbage;
- the introduction of alien species in the ballast water or attached to the ship's hull;
- pollution of the sea by poisonous anti-fouling coating;
- collisions with large marine mammals.

Noise in the sea

The sea is not a naturally quiet habitat, especially not in those regions where wind, tides or currents move the water masses and where vibrant life is found. Whales sing and click, more than 800 fish species are known to drum, grunt or bark, seahorses gnash with their skull bones, and snapping shrimp snap with their large claws. These sounds are produced to communicate with other members of their species: to warn the others of danger, to find the perfect partner for mating, for navigation, or to hunt prey. Sending out acoustic signals and being able to hear them are thus important survival traits for many marine organisms, from the very smallest zooplankton to the largest of marine mammals.

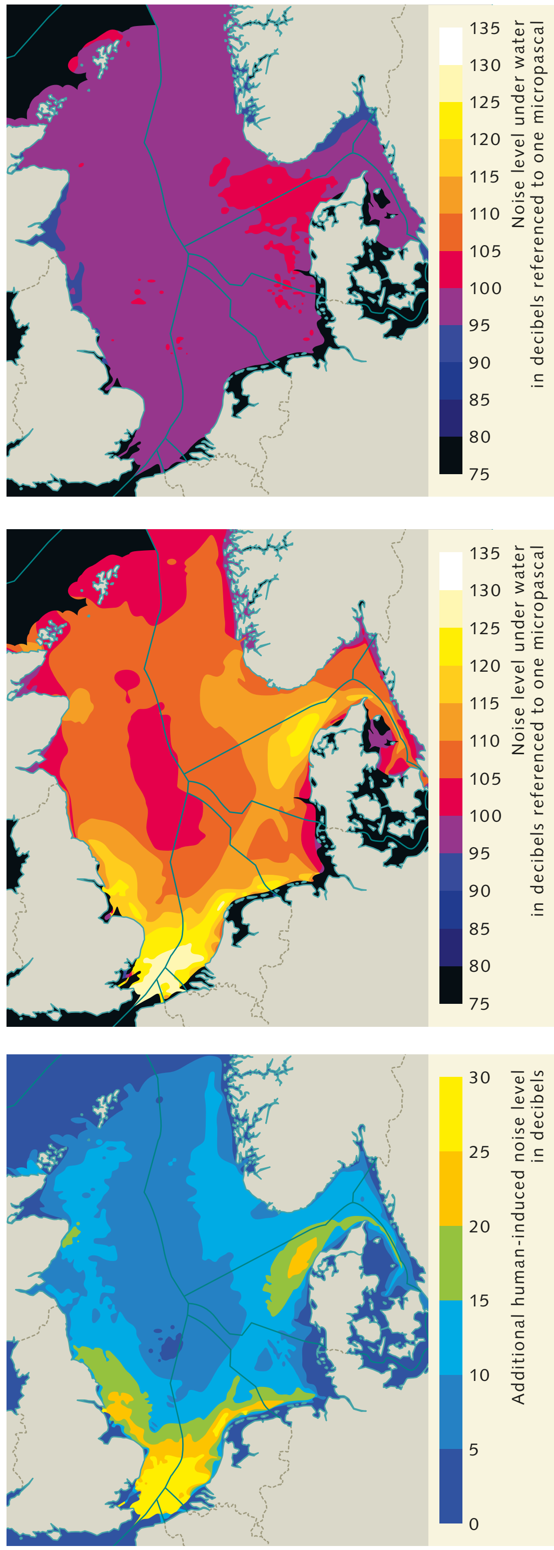
Communication through sound functions in the light-washed surface waters as well as in the darker depths or in cloudy waters. In normal circumstances it is extremely efficient because sound waves propagate five times faster through water than in the air, and lose almost no energy in the process. This means that sounds in the deep seas can travel thousands of kilometres in some cases, a property that baleen whales, among others, take advantage of. Their songs can be heard over distances of hundreds of kilometres. Smaller marine inhabitants like the North Sea painted goby *(Pomatoschistus pictus)*, on the other hand, produce comparatively subdued sounds when they want to communicate with a potential mating candidate. In this case, the fish closely approach one another and communicate over a short distance of about two body lengths.

But successful communication with sounds is becoming increasingly difficult for most marine animals because more and more noises generated by humans are being added to the natural background of sounds in the sea. Researchers distinguish two categories of anthropogenic sound. The first comprises noises that occur unintentionally or as a by-product of human activity. These include the sounds of motors and propellers made by all motor-driven boats and ships, but also noise caused by the beam trawls and nets deployed in trawler fishing. It also includes loud construction sounds on bridges, drilling platforms, harbour and wind-power installations, as well as explosions during naval exercises.

The second category includes sounds that are produced intentionally because humans use them to make underwater measurements. Fishers use echosounders to hunt for schools of fish. Geologists and geophysicists use seismic airguns to study the stratigraphy of the sea floor, and the oil industry uses these same tools to explore for undiscovered deposits beneath the sea.

In extreme cases these activities may produce noises so loud that the sound waves can cause physical harm to marine animals, such as loss of hearing or even death, for example, when an airgun is discharged to search for oil or natural gas. Pile driving for bridges and wind turbines produces intensities that rupture the swim bladders of fish in the close vicinity. Zooplankton die in such large numbers that scientists now use their mortality rates as a benchmark for accompanying studies.

Researchers generally distinguish between impulsive and continuous sound. The former has a short duration, but for marine organisms it is completely unpredictable. For this reason, the animals cannot adapt their behaviour. With continuous sound, on the other hand, adaptation is theoretically possible. This type of sound may be produced, for example, during the extraction of raw materials, but it occurs most commonly in marine areas with heavy ship traffic or near ports. Noise measurements in the North Sea by European researchers have shown that the regular ship traffic in the English Channel and beyond increases the natural sound level, which is caused predominately by wind in the southern North Sea, from 100 decibels to 130



4.23 > By its very nature the North Sea is a loud region. Winds and waves produce a natural underwater noise level of up to 100 decibels, as shown in the top map. Due to human activity, especially shipping, the noise level is increased by as much as 30 decibels (middle and bottom map). It is particularly loud along the shipping lanes in the English Channel and at the entrance to the Baltic Sea.

decibels. This may not seem like a lot at first but, because of the logarithmic nature of the decibel scale, a volume increase of only three decibels is equivalent to twice the intensity. Just for comparison, the intensity of a normal conversation between two people has a decibel level of 65, while screaming produces a level of around 80 decibels. Although the difference is only 15 decibels, the intensity level of screaming is 30 times that of the normal conversation. Applied to the increased noise level in the North Sea, this means that it is about 1000 times louder for marine life with ship traffic than without.

For various reasons related to measurement techniques, however, a conversion factor is necessary for comparing the loudness of noises above to those beneath the water surface. As a general rule, the volume measured above the water surface plus a constant of 61.5 decibels gives the corresponding volume under the water. This means that a sound with a volume of 70 decibels above the water is exactly as loud as a sound with 131.5 decibels underwater. As a result, from a human perspective, the background noise of ship traffic in the English Channel (130 to 135 decibels) can be compared to the noise level in a large, open-plan office (about 75 decibels).

But for the inhabitants of the sea, the increased noise level represents an enormous barrier to communication and a severe stress factor, comparable to the situation of two humans standing on opposite sides of a heavily travelled highway trying to share information crucial to their survival. The comprehension of long complex sentences is not possible under these conditions. Instead, they can only shout out catchwords to each other, gesticulate wildly or abandon the conversation entirely.

Marine animals react in ways very similar to this. Grey whales and minke whales call louder when ship noise can be heard. Painted gobies abandon one of their two mating calls and pay more attention to their partner's courtship movements, while seals and beluga whales dive to try to escape the noise. As a result of these and other behavioural reactions, some animals may eat less, which has a direct impact on their health and growth rates. Others may notice enemies too late, make the wrong choice of mate, produce fewer offspring or avoid certain marine areas altogether.

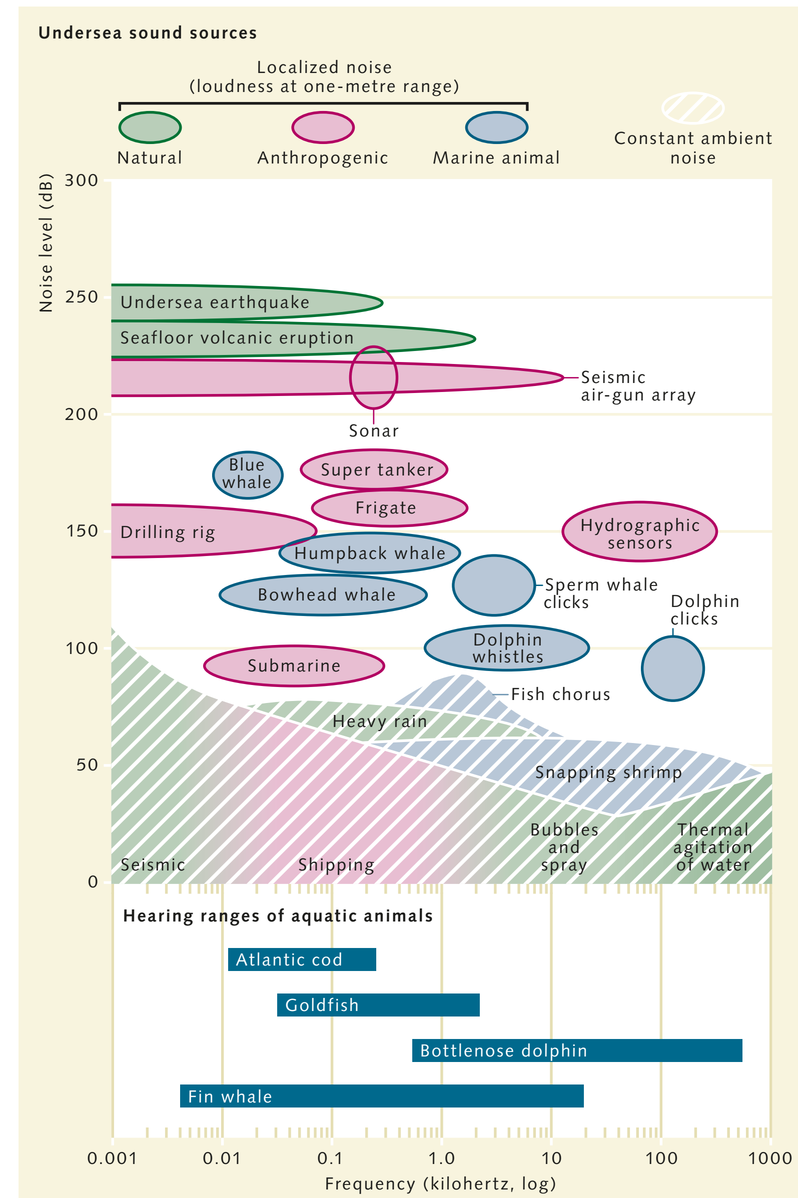
Ship noise therefore disturbs not only in the short term, it also causes long-term harm within the marine environment.

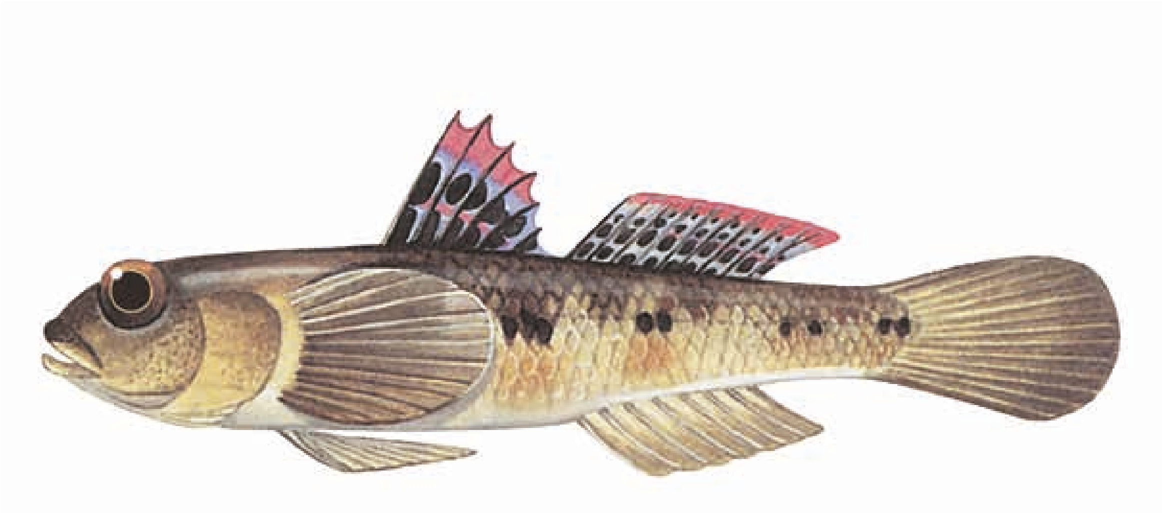
In order to stop this trend, the IMO adopted guidelines in 2014 to reduce underwater noise from ships. These address the following sources of noise:

- **Shape of the propellers:** The propellers are the greatest source of noise from a ship, because the churning of the water produces a lot of small bubbles that then collapse noisily. The number of bubbles can be reduced by better propeller design.
- **Suspension of the engines and other machine parts:** The transfer of engine noise and associated vibrations to the ship's hull and thus to the water can be mitigated, for example, by installing shock absorbers in the engine and gearbox mounts and by installing damping panels. The IMO also recommends vibration-damping suspension systems and mounts for other components such as pumps, pipes and air conditioners.
- **Design of the ship's hull:** The loudness of a ship is also influenced in part by the shape of its hull, because under certain conditions air bubbles can also form on the hull. But with the help of special software these flaws in hull shape can be detected and eliminated during the planning and design phase. It is also important that the design and position of the ship's propeller are carefully coordinated with the shape of the hull.
- **Cruising speed:** Extensive experimental trials have indicated that the cruising speed of a ship has a considerable influence on the noise level. The studies show that noise pollution is reduced by 40 per cent when the speed of the ship is reduced by only ten per cent. A slowdown programme in the Port of Vancouver has shown that the hunting success of the indigenous killer whales is improved by as much as 22 per cent when ferries, recreational boats, freighters and fishing boats limit their speed to eleven knots instead of 17.
- **Ship maintenance:** The hull and the drive propellers of a ship need to be cleaned regularly to remove any irregularities on the surface. Rough surfaces slow the ship down, and cause it to require more energy for propulsion. This results in more noise on the ship and in its marine environment.

In the European Union, the Marine Strategy Framework Directive of 2008 applies. This stipulates that, by 2020 at the latest, underwater noise must be limited to a level that does not harm the marine environment. However, achieve-

4.24 > Underwater noise created by humans extends over the entire range of frequencies at which marine animals communicate, and it is often so loud that it has a permanent impact on their lives.





4.25 > The painted goby likes it quiet. A laboratory experiment has shown that even low levels of additional noise are sufficient to disturb the mating ritual of these fish. The researchers are concerned that noise pollution produced by humans in the sea is having negative consequences for the fish.

ment of this target is still far from being realized. For example, although the year 2020 has already long passed, the responsible German authorities are still working on an approach by which the current state of noise in the sea can even be assessed. There is obviously still much to be done.

Ship exhaust and garbage

Port cities are among the places with the worst air quality. This is mainly because of the enormous amounts of sulphur oxides, soot particles, nitrogen oxides, aromatic hydrocarbons, heavy metals and other pollutants that are released by the combustion of heavy fuel oil and marine diesel oil. Sulphur oxides (SO_X), for example, are harmful to humans and the environment. Not only do they cause respiratory problems and lung cancer, they are also a leading cause of acid rain, which has negative consequences for forests, crops, and aquatic organisms. They are also contributing to accelerated acidification of the oceans.

The heavy oil formerly used as fuel in marine shipping contained particularly high levels of sulphur. Up to 3.5 per cent was allowed, which is equal to 3500 times the amount of sulphur content permitted in European road traffic. Since 1 January 2020, however, a stricter regulation has been in force according to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL Convention). This states that ships outside of designated Emission Control Areas (ECAs) are only allowed to use fuel with a maximum sulphur content of 0.5 per cent. If the fuel used exceeds this value, the ship has to be fitted with an effective exhaust filter system (scrubber) and have it turned on. In the North and Baltic Seas, as well as in EU ports, the limit has been 0.1 per cent sulphur content since 2012. Compliance with these rules is monitored by MARPOL member states and their designated authorities. In their roles both as flag states and as port nations, these have the authority and the responsibility to inspect ships and enforce the MARPOL regulations.

The MARPOL Convention also regulates the handling of waste that is produced on board ships. Accordingly, with certain exceptions (food waste, non-hazardous cargo residues, cleaning agents and additives as well as animal carcasses), no waste may be disposed from ships into the sea. Since January 2013, this rule has been in force worldwide. In the Baltic and North Seas, the applicable regulations are even stricter because, like Australia's Great Barrier Reef, these two seas have the status of particularly sensitive sea areas. Such areas are worthy of enhanced protective regulations based on their unique animal and plant communities, due to certain social, economic or cultural characteristics, or because of their importance for science. In these areas, for example, the disposal of any animal cadavers generated during a voyage is not allowed. Discharging food waste into the sea that is not pulverized is also prohibited.

According to MARPOL, ships with a net tonnage of 400 or greater, or those with at least 15 persons on board, are required to keep a Garbage Record Book. It must document every discharge of garbage, regardless whether it is carried out at sea or in a port, including details of the time, precise ship's position, and the kind and amount disposed.

Ballast water
Merchant ships carrying little or no cargo take on ballast water to ensure sufficient draught and to improve stability. Before they can be loaded again with goods, they have to discharge the ballast water. In this way, organisms in the water are introduced into new habitats.

During ship inspections, the accuracy of these records is an obligatory part of the relevant check.

In spite of the clear provisions of the MARPOL Convention, significant amounts of garbage and other refuse are still dumped into the sea. The primary reasons for this include the illegal disposal of garbage at sea by ships, poor waste management practices on board, and the absence of appropriate receptacles for ships' garbage and sewage in the ports. Some crews also dump their garbage at sea in order to avoid paying the disposal charges in the ports, which can sometimes be quite high. Calls are therefore increasing for port operators around the world to stop charging for garbage disposal as an additional cost, but to include it as a fixed component of the basic port-use fee for all ships, regardless of whether or not each individual ship disposes of its garbage or wastewater properly in the port. In this way there would no longer be a reason for the illegal dumping of garbage. There is, however, a downside to this procedure. If the garbage fee is no longer calculated according to the total amount arising, there is no longer a pressing financial motivation to generate less garbage on board.

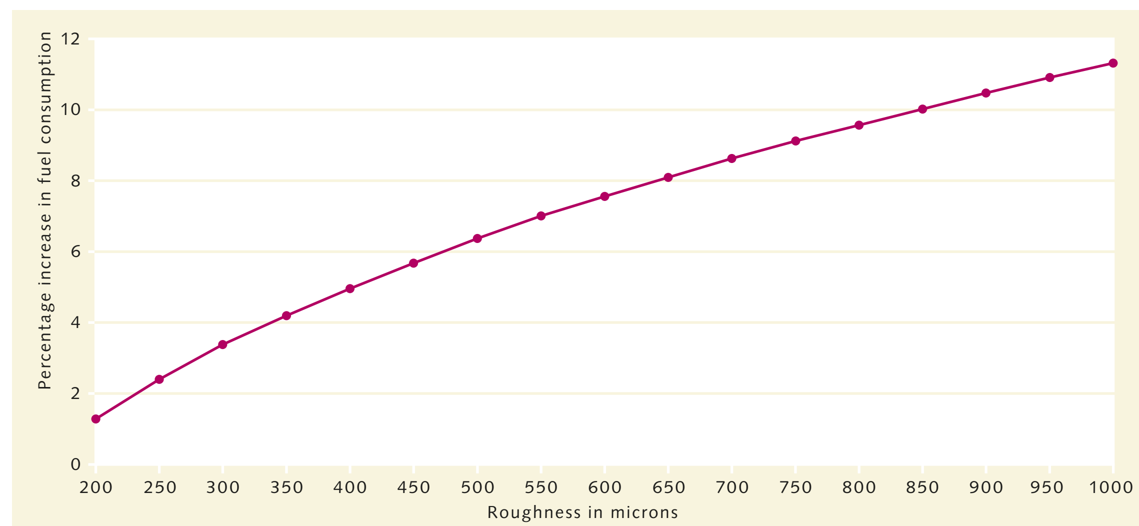
The IMO also recognizes a great deal of room for improvement in this area, and is now working with the Food and Agriculture Organization (FAO) on a new plan of action that aims to reduce the ship-generated input of plastic refuse into the oceans. Because sewage is also often dumped in the open sea, which contributes to eutrophication of the oceans, institutions such as the German Federal Maritime and Hydrographic Agency (BSH) and the Helsinki Commission (HELCOM) for the protection of the Baltic marine environment are compiling best-practice approaches and technical solutions that can be applied to improve sewage disposal.

Alien species in tow

Shipping traffic is one of the major causes for the spread of exotic or non-native marine organisms in the world. The immigrants travel from one marine region to another either in the ships' ballast water or attached to the hull or other exposed underwater surface. Although it was previously believed that most of the immigration was related to the discharge of ballast water, it is now known that as much as 69 per cent of all introduced species are due to growth on the ships' hulls.

Biofouling is the term that specialists use to refer to the unwanted attachment of microorganisms, algae and marine animals to ships' hulls, offshore drilling rigs or aquaculture installations. Arriving at the next port of call, or the one after, the invasive organisms fall from the outer hull of the ship, or they produce offspring that are released into the water column. If the environmental conditions in

Exhaust scrubber
Purifying ship exhausts by means of scrubber systems is not a sustainable approach, for this gives rise to liquid effluents polluted with contaminants and heavy metals that the ships generally discharge directly into the sea. In 2020 some 4300 ships worldwide operated exhaust scrubbers. They generated at least ten billion tonnes of effluent per year.



4.26 > As algae and other organisms grow on a ship's hull, its surface becomes rougher. This causes more friction between the hull and water, which means that more fuel is required to propel the ship through the water.

Range of representative coating and fouling conditions	
Description of condition	Average coating roughness in microns
Hydraulically smooth surface	0
Typical as applied anti-fouling coating	150
Deteriorated coating or light slime	300
Heavy slime	600
Small calcareous fouling or weed	1000
Medium calcareous fouling	3000
Heavy calcareous fouling	10,000

4.27 > A thin biofilm of tiny algae and microorganisms is enough to double the roughness of a ship's hull. If mussels attach themselves to the hull, the roughness is ten times as great.

the new location are favourable when this happens there is often nothing to prevent the new settlement, especially when there are no natural enemies or pathogens in the new area, and there are sufficient numbers of the introduced organisms to reproduce rapidly.

The introduction of non-native species can have very diverse impacts on the local marine environment. Sometimes the newcomers blend into the existing local communities without a problem, but in other cases they can completely disrupt them, become a nuisance, and cause fundamental changes in habitats and food webs – often with catastrophic consequences for the local marine economy and the coastal populations.

As an initial step to mitigate the spread of such invasive species by shipping, the IMO member states have adopted an International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). This came into effect in September 2017 and requires, for example, that crews follow a ballast-water management plan tailored to their ship type, and maintain logs of every action taken. Over the long term, most ships will also have to be equipped with a water treatment system for the ballast water. As a clear guideline, whenever possible, ships should only discharge ballast water in marine areas that are at least 200 nautical miles from the nearest coast and in waters deeper than 200 metres.

However, this does nothing to eliminate the danger of the spread of alien species by fouling. To address this problem, a much broader and multi-sectoral approach is necessary. The forms of biofouling, according to experts, are extremely diverse, and the consequences and possibilities for combating it are too complex to allow for a simple solution. Furthermore, with the escalating use of the oceans by humans, the number of man-made surfaces to which organisms are able to attach is increasing, with a corresponding danger of displacement of the organisms. There are not only more ships, recreational boats, drilling rigs and aquaculture installations, but also drifting plastic garbage, fishing nets and much more.

The IMO has therefore issued guidelines for dealing with fouling, and in 2018 initiated a major research programme in cooperation with the United Nations Environment Programme and scientific partners. It is called GloFouling (the "Glo" stands for global) and it aims to develop tools and best-practice solutions in the fight against biofouling, and to identify ways of sharing information among scientists, officials and industry, and of implementing packages of measures from the national to local levels. The initiators also hope that the successful reduction of biofouling on ships' propellers and hulls will lead to improved energy efficiency and thus to significant reductions in fuel consumption and emissions by marine traffic. Studies suggest that the cleaning of propellers and hulls as well as the use of anti-fouling paints would result in energy savings of up to ten per cent.

But the latter method has had harmful environmental impacts in the past. Effective anti-fouling paints developed in the 1960s contained tributyltin (TBT) and other highly poisonous organotin compounds. This is one of the most poisonous chemicals to ever be purposely introduced to the environment by humans. Mussels, barnacles and algae that come into contact with TBT ship coating are killed. However, for a long time it was not recognized that the poison was leaching out of the anti-fouling coating, especially during harbour and shipyard work, and accumulating in the river and marine sediments as well as in the food webs. It thus became a threat not only for the bottom fauna in rivers and seas, but over time also for fish, marine mammals and ultimately humans.

For this reason, the use of tributyltin and other organotin compounds in anti-fouling paints has been prohibited since the IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention) came into effect in 2008. The development and testing of efficient but environmentally sound anti-fouling strategies and systems is a topic of current research. Until these can be developed, the ships' hulls and propellers must be cleaned every six to seven months, either by divers and robots in open waters or during layovers in the shipyards.

On collision course

Collisions with ships and other seagoing vessels are presently one of the greatest dangers for whales. For species like the North Atlantic right whale *(Eubalaena glacialis)*, whose migration route along the east coast of the US intersects with heavily travelled shipping lanes, it is an issue of basic survival. There are now only around 400 of these baleen whales left in the world. With every animal that is killed the total extinction of this species becomes more likely. According to the International Whaling Commission (IWC), humpback whales in the Arabian Sea, fin and sperm whales in the Mediterranean Sea, blue whales off Chile and Sri Lanka, Bryde's whales in the Gulf of Mexico, as well as the grey whales off the west coast of North America and whale populations around the Canary Islands are seriously endangered.

The collisions of whales with large ships such as tankers, cruise ships or cargo ships usually go unnoticed by humans, however, which makes quantification of the problem extremely difficult. However, the animals suffer severe external and internal injuries that often lead to death. The incidents can usually only be documented when carcasses wash up onto the shore and investigations are carried out to determine the cause of death. The cases

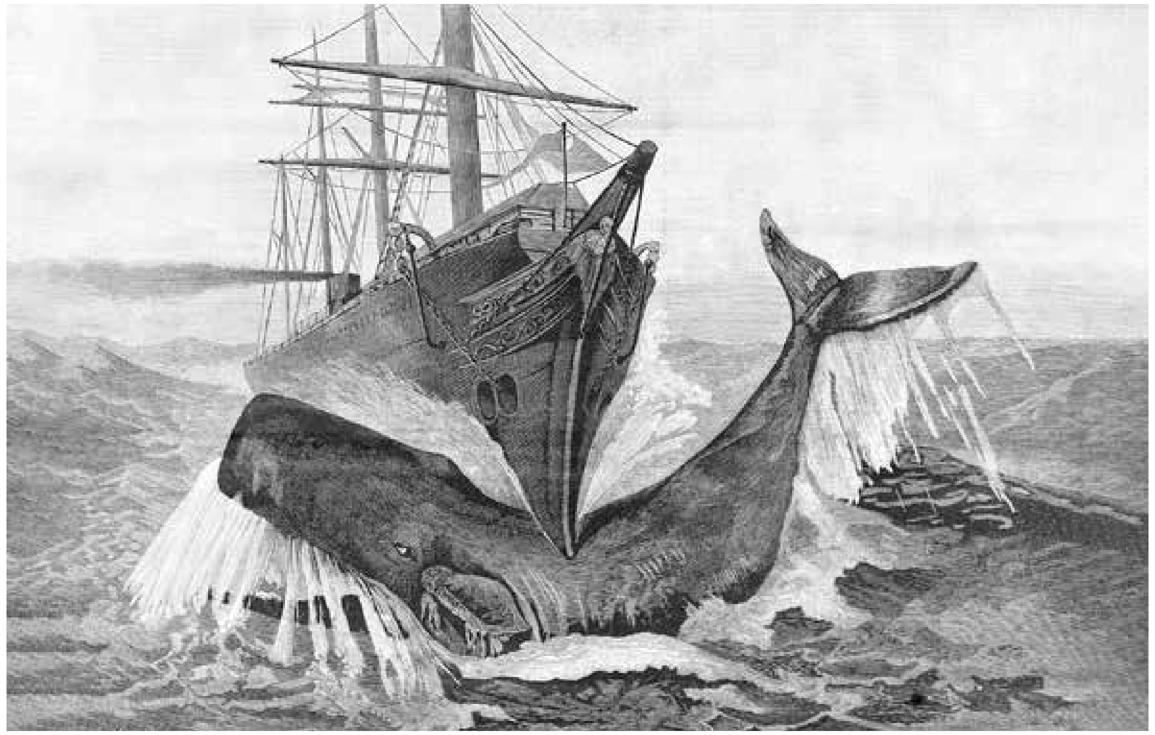
4.28 > Cleaning robots such as the *HullSkater*, developed in Scandinavia, will remove fouling and grime from ships' hulls with little effort in the future. Its use will eliminate the need for divers.

most frequently documented are collisions between large whales and all types of vessels. However, smaller species such as killer whales or dolphins are just as endangered as the grey, blue or humpback whales.

In order to reduce the risk of collisions with ships, the IWC has suggested the following measures over the past 20 years, some of which have already been implemented:

- creation of an international database on collisions between ships and whales;
- development of high-tech warning systems, such as heat detection systems to identify whale blows, buoys that can automatically detect whales, and microphone systems that locate whales and report their presence in real time to an information system;
- identification of high-risk areas where special precautions need to be taken for the protection of whales. These include, for example, the waters around the Canary Islands and off the east coast of the USA, as well as in the Gerlache Strait of the Antarctic Peninsula (cruise-ship tourism);
- identification of particular whale populations whose stocks are at risk of collision with ships;
- development of guidelines to help shipping mitigate the risk of collisions.

These guidelines recommend steering clear of areas with large numbers of whales, or planning the itinerary with reasonable foresight so that collisions can be avoided. In the Gulf of Maine, for example, an area highly frequented by large whales, shifting the shipping lane to the Port of Boston by just a few kilometres to the north would suffice to reduce the risk of collisions with the rare right whale by 58 per cent, and with other baleen whales by 81 per cent. If ships can not steer around the high-density whale territories, they may be directed to reduce their speed to less than ten knots in critical areas. At lower speeds the danger of collision is greatly reduced. Special observers on the ship's bridge as well as information and warning systems like Whale Alert, used off the east coast of the US, can help to verify the presence of the animals in time to avoid a strike.



4.29 > The danger of ships colliding with marine mammals has been a problem since people first went to sea. This drawing, made in 1886, appeared in the US magazine *Scientific American*, and illustrates the collision of the Dutch steam ship *Waesland* with a whale.

Conclusion

A key industry under pressure

In recent decades, international merchant shipping has been geared towards continuous growth. Larger, faster, always more. This has been the motto of the industry that transports between 80 and 90 per cent of all goods traded worldwide, making it the backbone of our global consumer society. For a long time, the climate and environmental impacts of this development were simply accepted. The industry's key role and the steadily growing importance of shipping for global production and supply chains made this possible.

But with the signing of the Paris Climate Agreement and increasing global awareness of the environmental and climate impacts of the transportation industry, maritime shipping now stands at a crossroads. Its highest regulatory body, the International Maritime Organization (IMO), has set a target to cut the greenhouse gas emissions of the merchant fleet in half by 2050, as compared to the emissions in 2008. Carbon dioxide emissions in particular are to be reduced by 70 per cent.

Operational adjustments such as reduced cruising speed and regular hull cleaning have a tangible fuel-saving effect, but these alone are not sufficient to achieve the emissions goal. A radical transformation of the entire industry is necessary. What is needed initially is major investment in the development of new propulsion systems and alternative fuels to replace the hitherto prevalent heavy fuel oil and marine diesel oil. Ammonia and hydrogen currently appear to be the most promising alternative fuels, but practical solutions for their use in maritime shipping are still lacking.

The next step is to equip the fleet with the new technological systems or to replace it from scratch, a process that will also cost a lot of money.

Globally uniform regulations, a supranational tax on greenhouse gas emissions, and strict controls by the flag and port states are vital in order to substantially boost research and development activities and provide investors with the planning security they so vitally need.

At the same time, coastal nations are facing the challenge of protecting their ports from the consequences of advancing climate change. In view of the rising water levels and the increasing frequency of extreme weather events in the future, the highest priority attaches to protective measures designed to mitigate the impacts of storm, flooding and extreme heat events.

Intensive efforts are also being made to combat the growing problems caused by coastal erosion. Some leading international ports like Rotterdam are developing their own climate goals and strategies to drastically reduce the high greenhouse gas emissions of all their port operations and all associated industries.

In addition, the direct environmental impacts of shipping, such as pollution by exhaust fumes, solid waste, liquid effluent and noise, and the issue of invasive species are gaining more attention. Some of these issues have already been recognized for decades and are being progressively addressed through international regulation. Scientists are just beginning to discover others, however. Noise pollution by shipping traffic, for example, has much broader consequences for the marine environment than was previously known.

The danger of collisions with large marine mammals is also comparatively new on the agenda. A number of studies suggest that anticipatory planning of routes in combination with slower speeds in areas of high animal density will be the most successful strategies.