MedCruise
Professional Development Course 2022

Introducing basic concepts of environmental aspects in cruise traffic

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www.medcruise.com

#PortsTogether #PDC2022

Index

Preamble

Dear Friends, so happy to welcome you to Galataport Istanbul!

Sustainability is at the core of our mandate, the most important pillar of MedCruise Association, and it is approached in a holistic, human manner. Collaboration-innovation-implementation of different actions defines the #MedCruise4OurPlanet vision.

Figen Ayan

MedCruise President

Besides numerous collaborations with international sustainable key players (CLIA, European Commission, GSTC, AIVP, ESPO, IAPH, Save Soil, WWF), innovative eco-conscious approaches (80/20 printing ratio, one registration one tree campaign, etc.), LNG or shore power mapping, MedCruise's management has decided thanks to our skilful and dedicated SVP Ms Francesca Antonelli to focus the first MedCruise Professional Development Course ("PDC2022") on sustainability, naturally. This 2022 edition of the MedCruise Professional Development Course is an introduction to the most current and relevant issues but also the global and European legislations targeting to be accessible for everyone. For professionals who are not necessarily environmental experts aiming at the end of the day to provide our participants with the necessary terminology and knowledge in order to follow, understand, discuss and take environmental-related decisions for the benefit of their respective companies and create a better planet altogether.

I am even happier that this special PDC2022 is organised in the town I decided to make my home almost 30 years ago. Moreover, I cannot wait to guide you all through another personal love of my life, Galataport Istanbul, which is proudly Platinum LEED certificated and a socially sustainable port, as you will see in the following days.

Again, welcome and a sincere thank you to our SVP Francesca Antonelli, MedCruise Secretariat, Asli Deger for making this PDC2022 happen and, of course, our fantastic experts who accepted to guide us and put light on the crucial sustainable matter, which is concerning us all, as long as we live on our beautiful planet.

"Shore-side Power Capability", "Exhaust Gas Cleaning Systems (EGCS)", "LNG", or "Advanced Wastewater Treatment Systems"... In our beloved association, we are all familiar with this type of terminology in some way, but... Do we know how to explain to our stakeholders the definitions, the implications of these terms, and the challenge of implementing them in the reality of our beloved industry, in our ports, and our destinations?

For more than five years now, except perhaps during the COVID-19 pandemic, the main theme of every event and meeting around our industry has been the important topic of sustainability: economic, social and environmental. The people who represent the ports and associate members of MedCruise are not always experts in environmental issues. In fact, our work ranges from port operations to port handling, to commercial management, to additional ship, crew and passenger services and many other areas: we are as diverse as our beloved association. That is why the 2022 edition of the MedCruise Professional Development Course (PDC) has been dedicated to the technical sustainability solutions that the cruise industry is facing. The cruise industry is pioneering innovative solutions to achieve the goal of net zero carbon cruises: a considerable amount of financial, research and human resources are being invested in meeting this challenge, which is common to all stakeholders in the industry. Training and development programmes for the people who make up the wider MedCruise family are essential to the success of this traffic on the wide geographical area represented by MedCruise and provide opportunities for us to improve our skills, enhance our productivity and work for the good of the industry, our ports and destinations and to be up to date not only on these important technological changes in our industry but also in ethics, safety or quality standards.

To help us in this purpose, we have counted on an expert of recognised international prestige, Miguel Nuñez, who MedCruise has invited to a first initial part in which we have familiarised ourselves with the terminology, definitions and basic aspects of this vast subject. As a result of this PDC held in Istanbul in November 2022, Miguel Nuñez and MedCruise have decided to edit this guide.

Hopefully, it will serve as a reference manual and inspiration to further explore this important and necessary subject.

Miguel is a PhD in Naval and Ocean engineering, Msc in Naval Architecture and Maritime Engineering, both at the Universidad Politécnica de Madrid, and a M.A. in Maritime Law and Shipping. He also holds various post-university degrees including advanced statistics and port management.

Miguel has been surveyor in the Classification Societies ABS and BV, inspector and PSCO at the Spanish Maritime Administration and Paris MoU. He was Head of Unit of Technology and Technical Support in the General Directorate Merchant Marine, Maritime Affairs Attaché of the Embassy of Spain in London and member of the PermanentRepresentation of Spain to the IMO.

He also served as Project Officer at the European Maritime Safety Agency and is currently Head of Unit Regulatory Affairs and International Cooperation at the Ministry of Transport, Mobility and Urban Agenda, Spain. He has worked in the development of regulations at EU Council and IMO regulations for more than 15 years covering all IMO matters. He has chaired groups at MSC Committees and PPR, SDC, III Subcommittees.

He has also participated in IMO, WMU, EC and FAO technical cooperation projects and has been the author of some papers for internationally recognised journals and conferences in relation to safety and sustainability. He is currently one of the negotiators at IMO on IMO GHG policy and at the EU “Fitfor55” for the maritime domain representing Spain.

Disclaimer

The content of this document does not necessarily reflect the official opinion of the Ministry of Mobility and Transport of the Spanish Government. Responsibility for the information and views expressed in this paper lie entirely with the author.

Introduction

Cruise ships require a lot of energy, both for moving through water and for ancillary services (i.e. generators for electricity to deliver on-board services). They require a lot of power.

1

1.1 A short description

The high demand of energy in the sector is normal since sometimes they carry close to 3000 passengers with 500-1000 crew members at any time. This power is delivered by 4 stroke and 2 stroke engines. Two stroke engines are often used for main propulsion, they are reversible, and 4 stroke for power generation. Electric Power generation is produced with multiple Diesel Generator (DG). In a (DG) the diesel engine prime mover drives the alternator. The alternator supplies 3-phase power usually of either 6.6 kV or 11 kV to the main high voltage busbar from where it is either used directly or stepped-down to lower voltages.

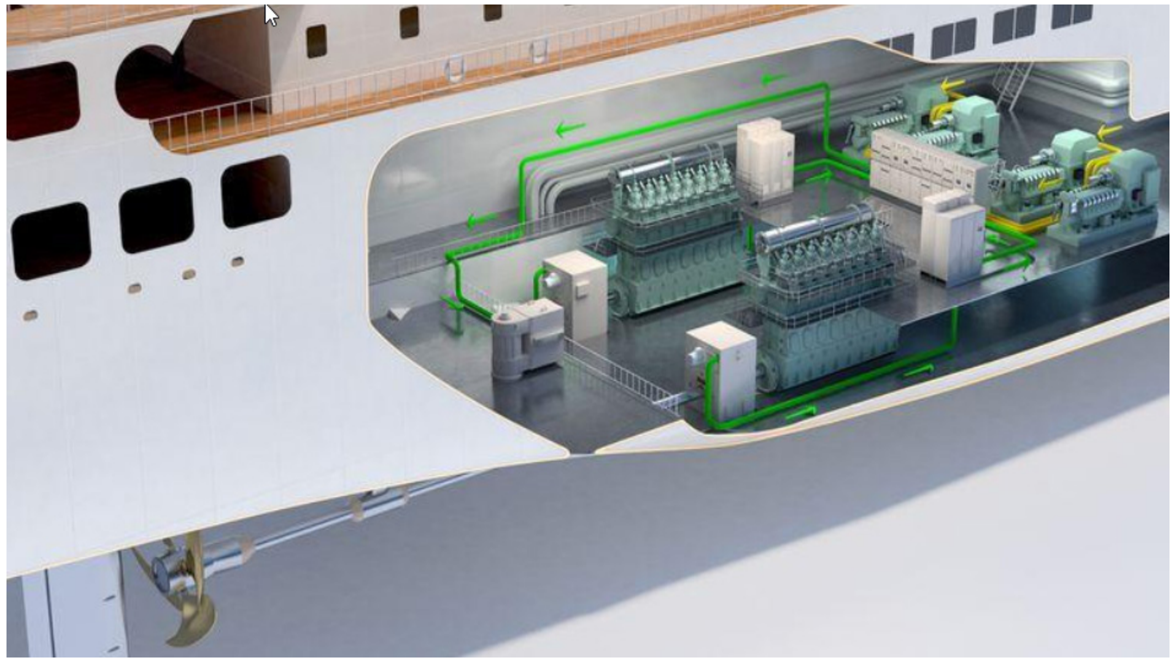
However, many cruise ships are using diesel electric propulsion turning all power, mainly from four stroke engines, into electricity. Hence the propulsion plant of cruise ships may consist of large electrical synchronous propulsion motors and associated equipment for speed and direction control which are very large consumers.

These generator sets are larger and much more powerful than the DG sets found on a typical cargo vessel. These are usually 5 or 6 in number and the power rating can be anywhere between 9-15 megawats (MW) for each, which is approximately around 10 times the power rating of the DG's on cargo ships.

A large part of the power of the ship is consumed by the large air-conditioning plant that takes care of passenger comfort in suites and public spaces and another part for propulsion. The fuel burnt depends on speed and ship size, with larger ships consuming more. Even highly efficient propulsion systems, such as the one used in the *Freedom of the Seas*, burn about 4,200 litres of fuel per hour.

Figure 1.1 A small size cruise ship

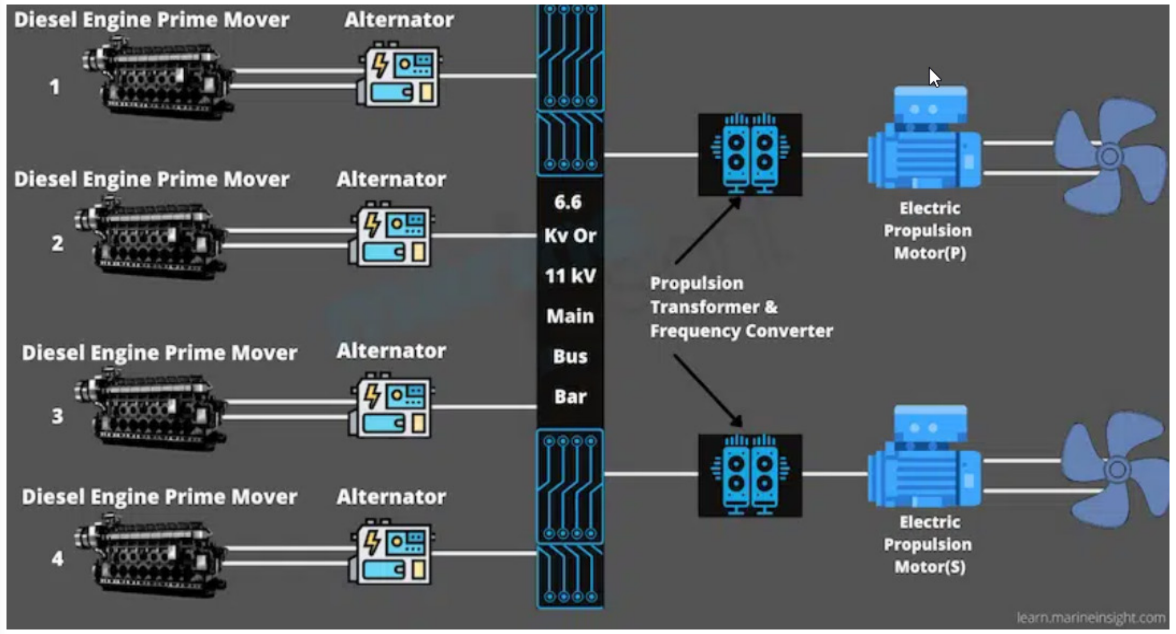
Figure 1.2 Conventional engine room in a cruise ship (source cruisemapper)



Due to their large size, DGs occupy a separate compartment in the ship's machinery space. This is called the DG room. Most modern passenger ships have two separate DG rooms, forward and aft, separated by a watertight bulkhead. Each DG room has its independent air, fuel, lubrication and cooling water supply systems. This is for the purpose of safety and redundancy keeping in mind emergencies like fire and flooding and also for safe return to port.

The largest cruise ship in the world in 2016 was the Harmony of the Seas. Owned by Royal Caribbean, this liner has two four-storey high 16-cylinder engines which would, at full power, each burn 5,213 litres of fuel an hour, or about 250,000 litres a day. In 2018 its record as the largest cruise ship in the world was passed to another Royal Caribbean vessel, the Symphony of the Seas, and the demand has been growing.

Figure 1.3 A cruise ship diesel electric plant (source Marine Insight Warniq Asrar)



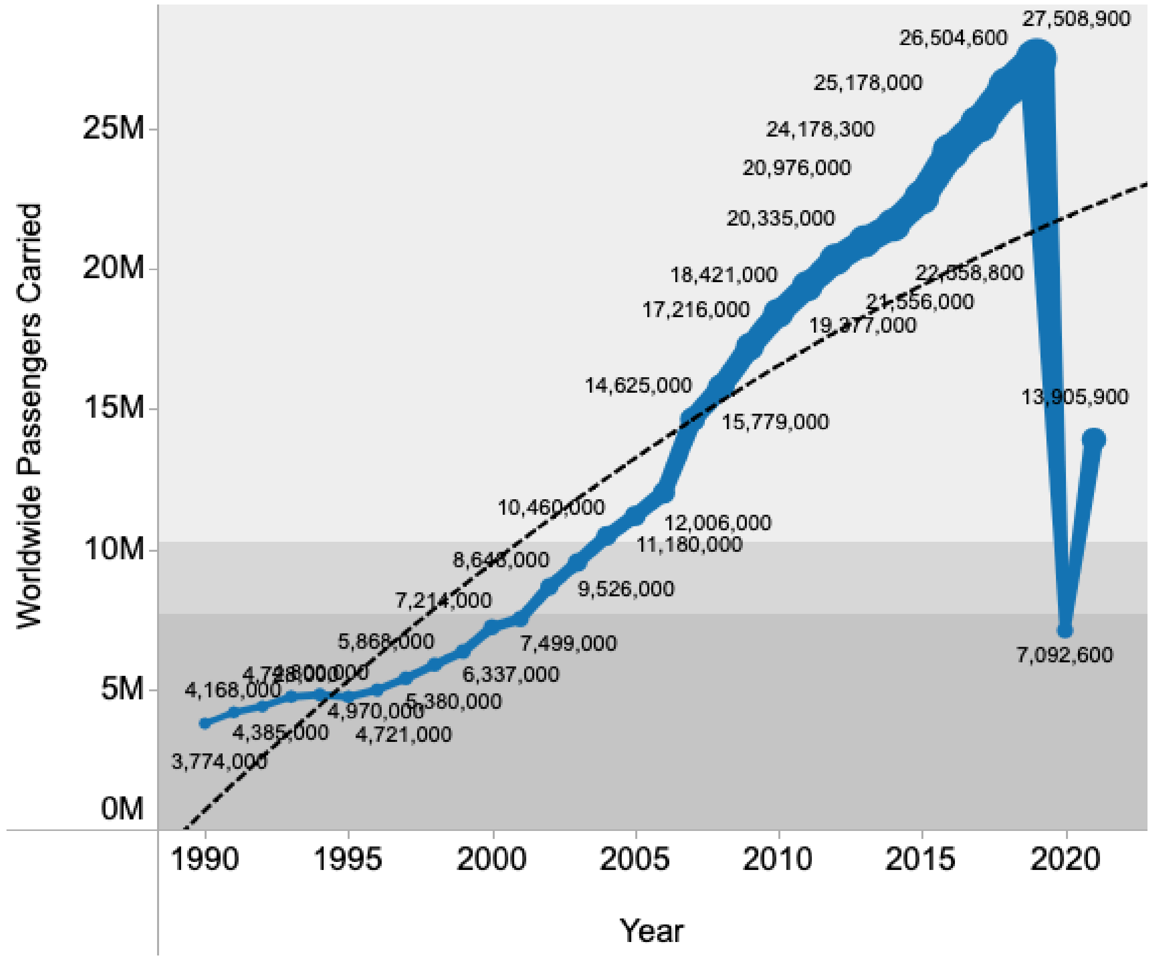


Figure 1.4 Worldwide passengers carried (source Cruise Market Watch)

For a long while, many people believed that the oceans could absorb anything that was thrown into them, but this attitude has changed along with greater awareness of the environment.

Many items can be degraded by the seas, — but this process can take months or years.

There are different types of waste that can be generated on board a ship, including cargo residues, garbage (e.g. food waste, plastic, domestic waste), oily waste, sewage or ozone depleting substances.

For many the of ship-generated waste types, there is a variety of waste flows and possible onboard treatment methods that can contribute to sustainable and sound management. Ships use different treatment methods and often only treat part of a waste stream. Part of the waste may be legally discharged into the sea, outside special protected areas, and under certain conditions, such as at a minimum distance from the coast. Waste that cannot be reused on board or legally discharged at sea under international MARPOL standards must be delivered to port reception facilities (PRFs), when available in ports. These play an important role in the whole process of waste management by collecting and treating it, and often adding value to it.

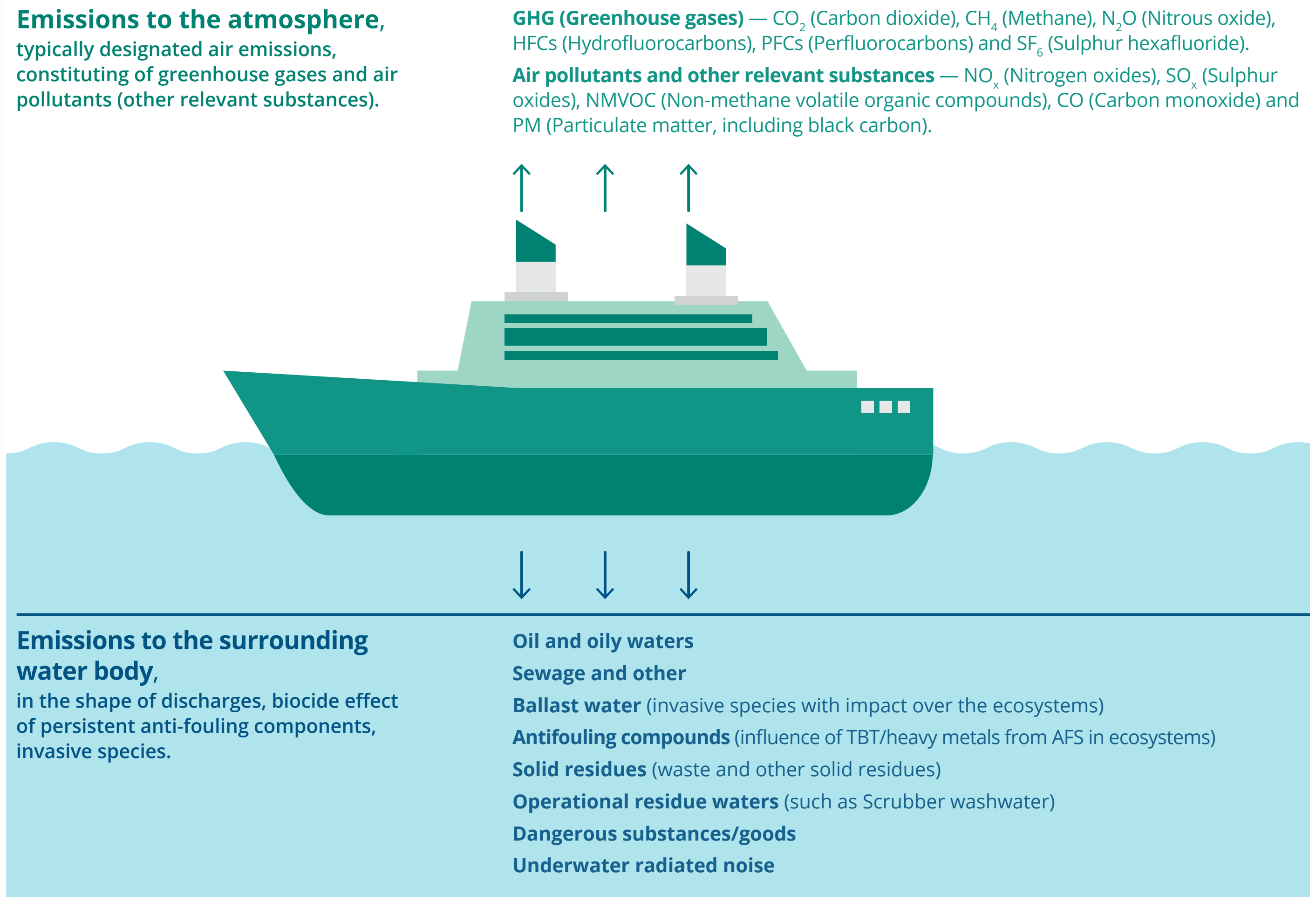


Figure 1.5 An overview of emissions from a cruise ship (EMTER report)

Cruise ships carrying several thousand passengers and crew have been compared to “floating cities,” in part because the volume of wastes produced and requiring disposal is greater than that of many small cities on land.

During a typical one-week voyage, a large cruise ship (with 3,000 passengers and crew) is estimated to generate 800 tons of sewage; 3.780 tons of grey water (wastewater from sinks, showers, and laundries); more than 492 litres of hazardous wastes; 8 tons of solid waste; and 94 tons of oily bilge water. Those wastes, if not properly treated and disposed of, can pose risks to human health, welfare, and the environment.

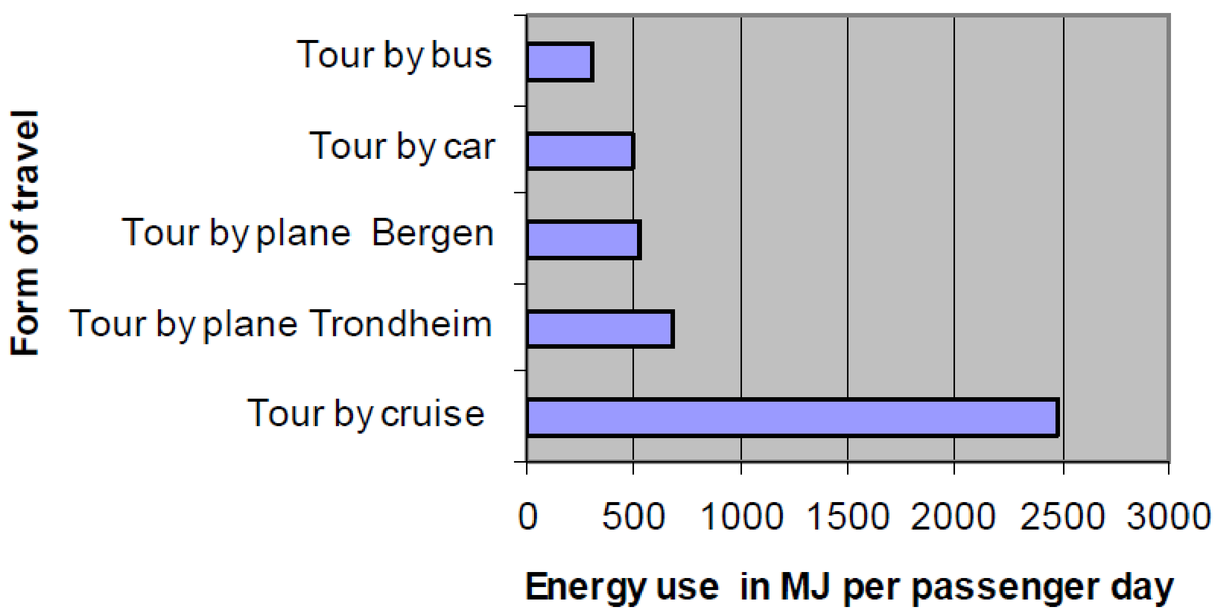


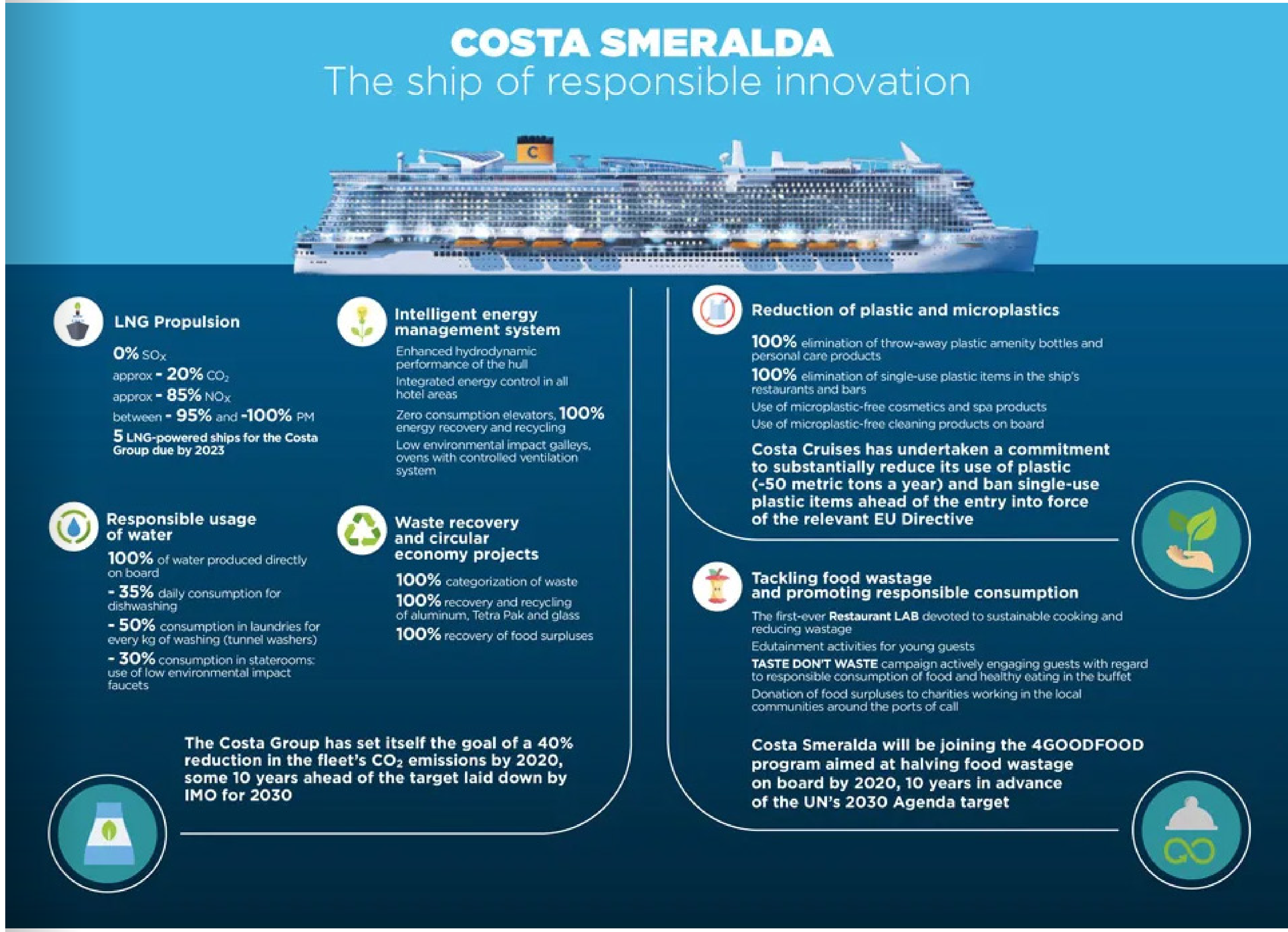
Figure 1.6 Energy use per passenger day for different forms of tourist travels from Germany to Norway (Vestlandsforsking-note nr. 2/2011)

Overall, the sector contributed emissions of 35 Mt CO_2[1] in 2012, up from 27.8 Mt CO_2 in 2007. This increase has prompted research into the environmental sustainability of cruise tourism and has resulted in calls to regulate the sector, specifically about climate change.

Although cruise ships account for only a small share of the global shipping emissions, they are increasingly discussed in other sustainability contexts, specifically concerning local and regional air pollution.

[1] Carbon dioxide (CO_2) is a naturally occurring gas and is also a by-product of burning fossil fuels (such as oil, gas, and coal), of burning biomass, of land use changes (LUC) and of industrial processes (eg, cement production). It is the principal *greenhouse gas (GHG)* produced by, or resulting from, human activities that affects the earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a *global warming potential (GWP)* of 1.

Figure 1.7 Costa display for responsible innovation (source Costa)



As an example, in relation to energy use though cruises are only a small segment of global tourism, they represent the most energy intense form of tourism on a per passenger-km basis.

In this regard to the cruise ship industry, a key issue is demonstrating to the public that cruising is safe and healthy for passengers and the tourist communities that are visited by their ships. This has triggered many campaigns and policies at group level (CLIA) or company level (COSTA, RC, etc).

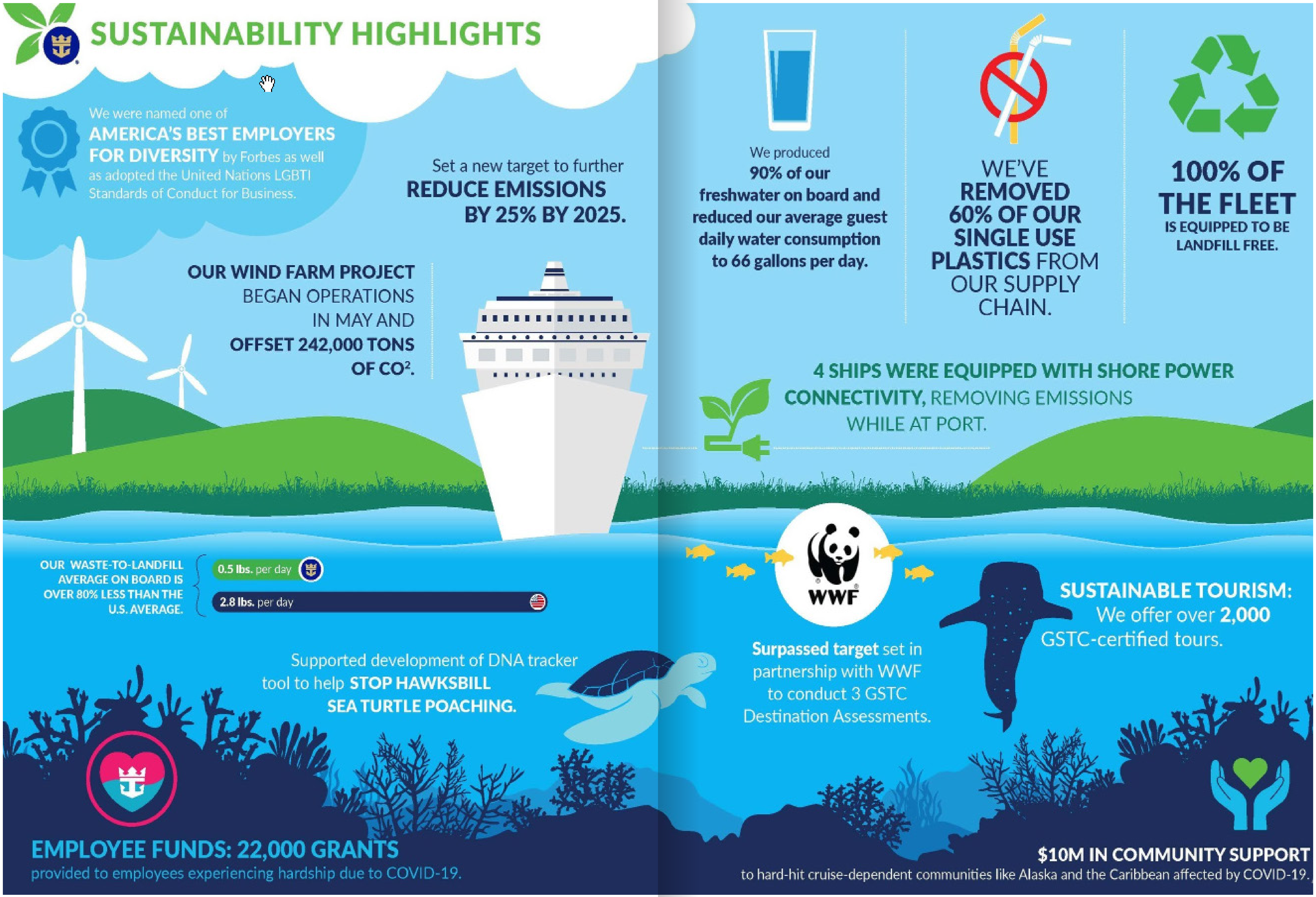


Figure 1.8 Royal Caribbean display for sustainability highlights (source Royal Caribbean)

1.3 The Mediterranean and Adjoining Seas from the environmental point of view. A perspective for shipping

Its basin expands up to 2.6 million square kilometres with an average depth of 1,460 meters, and a maximum depth of 5,267 meters. It occupies an area of approximately 2,510,000 square km and its marine ecosystem hosts around 4-18% of the world's marine biodiversity washing the shores of more than 20 countries. It is one of the most important tourism destinations in the world but its water resources, ecosystems, food safety, health and human security are under threat.

As an example, 200,000 tons of plastic is dumped in the sea each year, representing more than 60% of all the trash found at the bottom of the sea. Densely populated coasts, a lack of environmental awareness, maritime transport and a high influx of tourists are contributing to this problem. It is not only the floating plastic that is a problem, but also microplastics that come from a variety of sources.

The temperature rise in the Mediterranean is higher than current global warming trends (+1.1°C). Climate change also results in decreasing precipitation, sea-level rising, ocean acidification, sea temperature rise, and higher risks of soil degradation, quality, and erosion.

As of 2020 8.33% of the Mediterranean Sea is under protection status although 97.33% of the total Mediterranean surface under protection status is located in EU member countries water, the cumulative surface of no-go, no-take or no fishing area represents only 0.04% of the Mediterranean but the latest trends in data collected will lead to more marine protected areas in the region. In addition, the Mediterranean sea is MARPOL special area in relation to oil, garbage and lately sulphur emissions.

Taking this into consideration the cruise industry needs to be a model for the environmental protection of this sea basin

Regulatory framework, challenges and opportunities

In this chapter the international regulatory framework is explained together with the issue of sustainability, including circular and blue economy.

2

2.1 Environmental standards and international measures

Maritime transport needs to be considered in its global dimension. As an example, ships are European if they are registered in and flying the flags of European Union (EU) Member States or owned by EU companies but flagged in other countries. These ships trade domestically within an individual EU Member State, between EU Member States or internationally. However, the environmental pressures arising from maritime activity are worldwide.

Regions such as the EU has laws in place to regulate shipping and its environmental impacts in its Member States. While several international organisations regulate maritime transport, the International Maritime Organization (IMO), a United Nations specialised agency, plays the most important role. There are also several regional agreements that contribute to the protection of the marine environment in neighbouring and EU seas.

a. International Conventions

The IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. It provides a framework for cooperation among governments in order to regulate technical matters affecting shipping engaged in international trade. The IMO adopts under its conventions standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships.

An international maritime convention is not binding until it enters into force following its ratification by a minimum number of states (as established in the convention’s articles). In the case of IMO conventions, this requirement for a minimum number of state ratifications is also coupled to a requirement regarding the percentage of the world’s merchant fleet that they represent.

2.1 Environmental standards and international measures

This means that the entry into force of a convention usually takes several years following its adoption, as is the case for the Ballast Water Management Convention, adopted in 2004 which entered into force in 2018 (BWM Convention, 2004). Some conventions still have not entered into force, such as the International Convention for the Safe and Environmentally Sound Recycling of Ships, which was adopted in 2009 (Hong Kong Convention, 2009).

Standards within conventions may also be phased in, retroactively applied to all ships, only applied to certain ships depending on their size or applied to ships already constructed after the specified date or entry into force of the requirement. In the case of ships constructed, this may be defined in the standards as “ships the keels of which are laid”, or “which are at a similar stage of construction”.

Such a definition may in some cases trigger unintended consequences, potentially further delaying the application of standards. Sometimes although the construction of the ships in question is completed well after the entry into force of the new requirements, ships will be subject to previous standards because their keels were laid before the entry into force and sometimes this is used to skip compliance with more complex or expensive requirements.

b. Regional Conventions

International conventions, such as the Oil Pollution Response and Cooperation Convention (OPRC) and OPRC-HNS Protocol, for hazardous noxious substances, already promote cooperation among the Parties through the establishment of bilateral and multilateral agreements. These multilateral agreements, adopted either by riparian countries (Baltic Sea and North-East Atlantic Ocean) or under the auspices of the United Nations Environment Programme (UNEP) Regional Seas Programme (Mediterranean Sea and Black Sea), are key instruments for fostering cooperation between neighbouring countries around a sea basin in the protection of the marine environment.

These instruments improve regional and cross-regional coherence in the implementation of laws at national level and establish structures for cooperation to increase the efficiency and effectiveness of national responses.

Regional Agreements for the protection of the marine environment promote the ecosystem approach to the management of human activities to assess the relevance and efficiency of their strategies and action plans in achieving good environmental status of the marine environment. There are four European regional sea convention treaties currently in force that include sustainable development as part of their guiding principles.

- North-East Atlantic: OSPAR Convention, protection of the marine environment
- Barcelona Convention for the Mediterranean Sea[2]
- Helsinki Convention for the Baltic Sea
- Bucharest Convention for the Black Sea

[2] REMPEC is a regional activity centre of the Barcelona Convention, initially established under the 1976 Emergency Protocol and whose role was extended under the 2002 Prevention and Emergency Protocol of the Barcelona Convention to assist the Mediterranean coastal states in ratifying, transposing, implementing and enforcing international maritime conventions. REMPEC is also an emergency centre to assist the Contracting Parties in dealing with a pollution incident.

2.1 Environmental standards and international measures

c. EU environmental laws

Since the late 1990s, the EU has adopted an increasingly comprehensive body of EU rules applying to ships trading in EU waters or sailing to or from EU ports. Unlike the IMO's rules, on which they are often based, the laws also apply to ships on domestic voyages. They are generally "flag blind" or "flag neutral", requiring compliance from all ships, irrespective of the country they are registered in. These EU laws are coherent with the international framework, and some go beyond the environmental standards set by the IMO. An example of this is waste reception facilities in ports. Others ensure early implementation of newly adopted IMO rules that are not yet in force in the EU policy framework.

In certain cases, the differences between the IMO and EU rules have disappeared over time as the international standards have become more stringent. As a result of the overall framework for implementation monitoring and enforcement, which is enshrined in the EU treaties, the EU laws, as opposed to international treaties, often provide stronger and clearer enforcement obligations, hence contributing to increased maritime safety and environmental protection and a level playing field (equal level of competence) among the EU Member States.

EU environment policy is based on the Treaty on the Functioning of the European Union. The underpinning objectives and principles, which are binding on all EU Member States, embody more than 200 laws and acts under the following broad categories: air quality, waste management, water quality, nature protection, industrial pollution control, chemicals, noise, climate change, industrial risk management, and civil defence and other horizontal legislation.

A subset of these laws (directives and regulations) provide the rules and standards for the prevention of pollution from all ships registered under flags of EU Member States, sailing to or from EU ports or trading domestically in EU waters and for the protection and conservation of the marine environment by EU Member States.

2.2 Sustainability

Figure 2.1 Sustainable development goals in focus (source IMO)

Starting in the second half of the 20th century, measures have been put in place to mitigate the various pressures from maritime transport on the marine environment in order to reduce their impact. The threats oceans face are global, and the current governance system for the management of human activities impacting all areas needs to ensure long-term sustainability or equity in resource allocation and to create the conditions for maximizing economic benefits.

At the same time the society is becoming more conscious of the value of the resources and services provided by ocean space, resulting in a rise in public concern around the world and the maritime transport faces a crucial decade to transition to a more economically, socially and environmentally sustainable sector.

2.2 Sustainability

The adoption of the Sustainable Development Goals (SDGs) and the 2030 Agenda (the 2030 SDGs) in 2016, following the merging of the Millennium Development Goals (MDG) and the sustainable development agenda from 2012, provides an opportunity in the implementation of holistic frameworks for their maritime and fisheries sector.

SDGs are designed to work with indicators but their determination is not a straightforward process, although there have been some initiatives by different stakeholders to trigger the 2030 SDGs in the maritime transport sector; however, the interactions among the goals has not been assessed in detail and further work is needed in the maritime domain.

From a top-down approach, the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDG), mandated by the United Nations Statistical Commission as of May 2019, assigned Tier I, II indicators (which are conceptually clear and with available methodology, with or without data, respectively), and only assigned one Tier III indicator to the IMO (an indicator for which there is no established methodology or standards, or methodology/standards are being developed or tested for the indicator). At UN, in general, this is being faced with commitments from countries and companies. In the meantime, shipping companies and the IMO have been making use of the SDGs with different ambition and for different purposes.

At the level of the EU Sustainable development has since long been very relevant and the EU Treaties give recognition to its economic, social and environmental dimensions that should be tackled together. Sustainable development has been mainstreamed into EU policies and legislation, via the EU Sustainable Development Strategy, the EU 2020 Strategy, and through the EU's Better Regulation Agenda. The 2030 Agenda is being somehow used to catalyse an EU joint approach between the internal and external dimensions of its policies and coherence across EU financing instruments, e.g by the adoption of more stringent standards at international and EU levels. Looking ahead, the maritime transport sector continues to evolve, becoming more sustainable and responding to current environmental challenges such as air pollution or carbon emissions.

As an example, from the environmental point of view, most ships calling in the EU have reduced their speed by up to 20% compared to 2008, thereby also reducing emissions. In addition, non-traditional fuels and energy sources, such as biofuels, batteries, hydrogen or ammonia, are emerging as possible alternatives for shipping, with the potential to decarbonise the sector and lead to zero emissions. Onshore power supply (OPS), where ships shut down their engines and connect to a power source on land while berthed at port, which is key for cruise ships, can also provide a clean source of energy in maritime ports.

a. Blue Economy

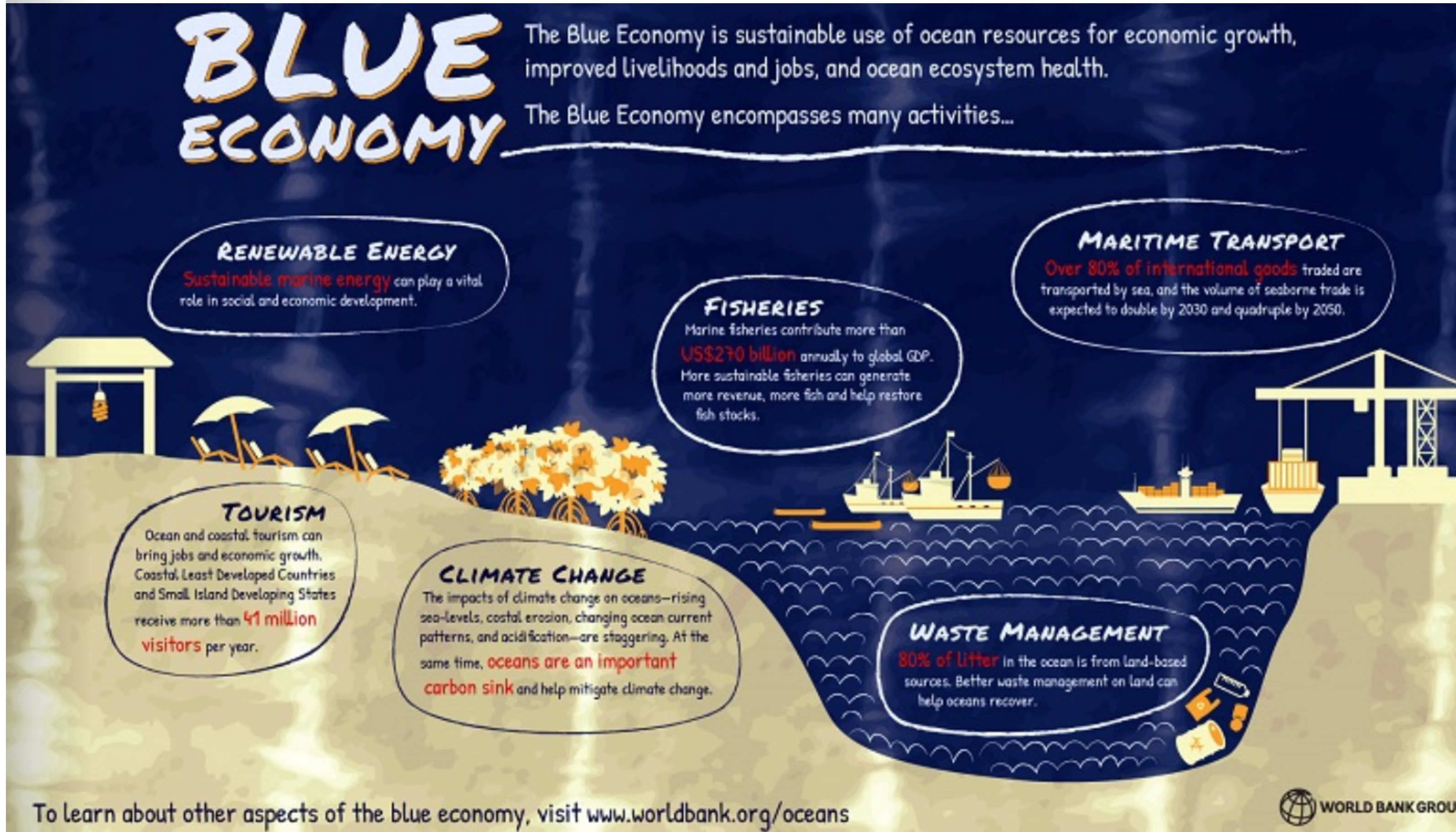
It draws from scientific findings that ocean resources are limited and that the health of the oceans has drastically declined due to anthropogenic activities. These changes are already being profoundly felt, affecting human well-being and societies. Although the term "blue economy" has been used in different ways, it is understood as comprising the range of economic sectors and related policies that together determine whether the use of oceanic resources is sustainable. An important challenge of the blue economy is thus to understand and better manage the many aspects of oceanic sustainability, ranging from sustainable fisheries to ecosystem health to pollution.

A significant issue is the realization that the sustainable management of ocean resources requires collaboration across nation-states and across the public-private sectors, and on a scale that has not been previously achieved.

The "blue economy" concept seeks to promote economic growth, social inclusion, and the preservation or improvement of livelihoods while at the same time ensuring environmentally sustainability of the oceans and coastal areas. At its core it refers to the decoupling of socioeconomic development through oceans-related sectors and activities from environmental and ecosystems degradation.

It has diverse components, including established traditional ocean industries such as fisheries, tourism, and maritime transport, but also new and emerging activities, such as offshore renewable energy, aquaculture, seabed extractive activities, and marine biotechnology and bioprospecting.

Figure 2.2 An outlook on blue economy (source World Bank)

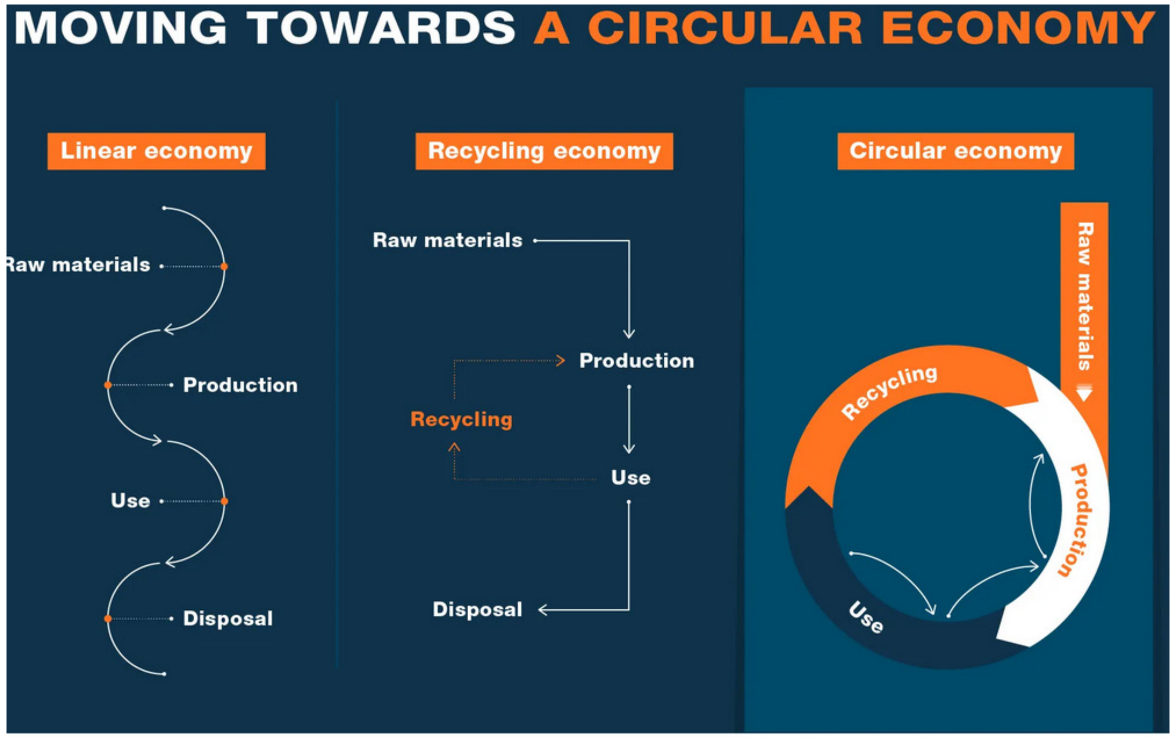


A number of services provided by ocean ecosystems, and for which markets do not exist, also contribute significantly to economic and other human activity such as carbon sequestration[3], coastal protection, waste disposal and the existence of biodiversity.

In order to qualify as components of a blue economy, as it is understood here, activities need to: provide social and economic benefits for current and future generations, restore, protect, and maintain the diversity, productivity, resilience, core functions, and intrinsic value of marine ecosystems be based on clean technologies, renewable energy, and circular material flows that will reduce waste and promote recycling of materials.

[3] Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide.

Figure 2.3 Moving towards circular economy (source Wartsila)



b. Circular Economy

The concept of circular economy is very broad and has multiple definitions. As an example, the European Commission states that a "*circular economy aims to maintain the value of products, materials and resources for as long as possible by returning them to the product at the end of their life while minimising the generation of waste*". Circular economy should be part of the blue economy.

Cruise ships are part of circular economy in areas such as tourism, waste management, the introduction and use of renewable energies to curb climate change.

Nowadays the key topics to deal with are waste management (food wastes to be reused a shore) and climate change (new sources of energy).

Ports play a crucial role as facilitators of the transition to a circular economy. They need to support the creation of a productive and logistical environment in the areas where they are located. However sometimes the strategies are not always adjusted to the type of port and its actual capacity to engage with a circular economy strategy.

Circularity enabled by ports needs to focus on leveraging the port's logistical capacity for linking locations with resources that have to be recirculated with locations with a demand for such resources. Specialised recycling or remanufacturing facilities could be considered.

The areas in which port authorities and companies in the port can intervene to promote a circular economy can be summarised as:

- Circular assets and equipment — optimising capacity and extending the lifetime of port assets and infrastructure, such as buildings, cranes, quays and buoys, through maintenance and smarter use (sharing, renting, etc.), including green procurement;
- Circular flows within ports and between ports and surrounding areas — new uses for would-be waste generated by port activities, such as ship waste and byproducts of industries operating within ports, and port development activities (recycling, upcycling, cascading, etc.);
- Ports and circular markets — ports enabling other industries (both on- and offshore) to become more circular by developing new activities that connect the supply of and demand for circular resources as the material moves through the port.

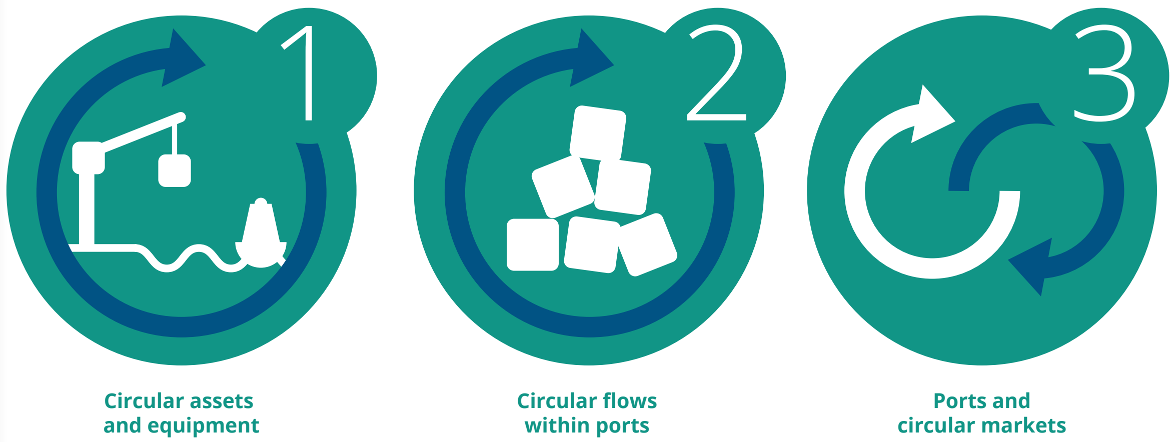


Figure 2.4 Circular Economy at ports (source EMTER)

Pollutions sources and classic areas of concern and beyond

For this topic we will refer to sources of pollution into the water and into the atmosphere, focusing at this point on pollution sources into the water from oil pollution to noise pollution.

3

3.1 Pollution Sources from Ships

The direct impact of shipping on the contamination status of the marine environment is difficult to estimate because of the complex dynamics of pollutants and the various other existing sources of pollution (e.g. direct discharges from land, run-off, atmospheric deposition or other activities at sea, such as the exploration and exploitation of hydrocarbons offshore or deep sea mining). However, the contamination of the seas continues to be a large-scale challenge.

a. Into the water

Water pollution is caused by different sources and types of ship operations, including the use of antifouling biocides on hulls, as well as accidents resulting in acute pollution events. On top of this, the same pollutants emitted to the air can also enter the marine environment through atmospheric deposition, and therefore contribute to the contamination and eutrophication of the marine environment.

An analysis of data on ship movements in European waters reveals that, excluding ballast water, in terms of volume, the largest water discharges from ships come from open-loop scrubbers to remove sulphur oxides (SOx) from the atmosphere (77%). This is followed by grey waters (16%) and to a lesser extent by sewage, bilge waters and other discharges.

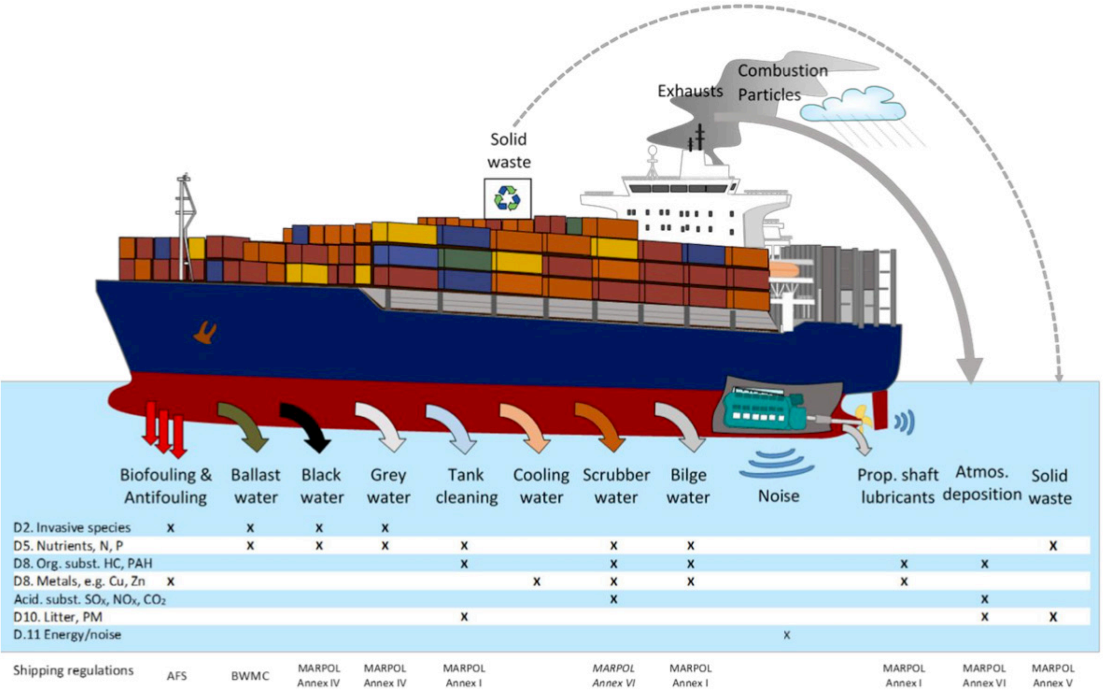


Figure 3.1 Emission and Waste streams (source SHEBA project 2018)

b. Into the atmosphere

As a result of various onboard combustion and energy transformation processes, most markedly for propulsion and energy production, ships emit various air pollutants to the atmosphere. The main ones are sulphur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM) and carbon monoxide (CO). Other air pollutants emitted by ships vary as a result of the nature of their operation, and include, albeit to a much lesser extent, non-methane volatile organic compounds (NMVOCs) and ozone depleting substances (ODSs). These shipgenerated emissions can sometimes be significant in areas of heavy maritime traffic and can also travel long distances.

Air pollutants may be categorised as primary, i.e. those which are directly emitted to the atmosphere, or secondary, which are formed in the atmosphere from precursor pollutants. Key primary air pollutants include the above indicated primary particulate matter (PM), black carbon, sulphur oxides (SOx), nitrogen oxides (including both nitrogen monoxide and dioxides) (NO and NOx), ammonia (NH_3), carbon monoxides (CO), methane (CH_4), non-methane volatile organic compounds, benzene, certain metals and polycyclic aromatic hydrocarbons.

Secondary air pollutants include secondary particulate matter, ozone (O_3) and nitrogen dioxide (NO_2). We will refer to them in detail later in the handout since this is one of the main topics for discussion.

Air quality in ports is highly dependent on the various port activities. Although the impacts of these activities on air pollutant emissions may not be very significant in terms of national totals, they can be significant locally in the regions and urban areas where the ports are located. Air pollutant emissions from ships while in port are produced when the ships are in transit into and out of the port, when manoeuvring, when undergoing unloading and loading operations, and when at anchor. This is key for cruise ships where the hotel needs demand large amounts of energy and produce large emissions because ships' auxiliary engines and boilers are often running at berth.

Interesting to note that many of the topics that were first tackled in atmospheric pollution were linked to port operations and the impact in the local communities living adjacent to the ports, which points at cruise ships due to the privileged position of the quays they use and their proximity to the city centers.

However air pollutant emissions in ports also arise from road transport linked to the port's activities, such as heavy-duty vehicle and passenger transport traffic coming to and from the port and the use of port machinery, such as cranes or heavy machinery, as well as from ship navigation close to coastlines (especially NOx). Industries located in port areas, such gas and oil refineries or chemical plants, also contribute to poor air quality.

Shipping, road traffic and non-road traffic, as well as inland and domestic maritime transport, are sectors for which emissions are estimated and reported under the UNECE Convention on Long Range Transboundary Air Pollution (LRTAP) Convention and reflected in national emissions inventories.

Nevertheless, it is not possible to further disaggregate the various emissions in port to quantify, for instance, those related to maritime transport only. However, based on industrial emissions reported to the European Pollutant Release and Transfer Register (E-PRTR), a decrease can be observed during the period 2008-2017 regarding SOx (around 65%), NOx (around 43%) and PM_{10} (more or less halved) emissions from E-PRTR-listed facilities located within 2 km of ports.

3.2 Oil Sourced Pollution

Oil spills are one of the most concerning sources of marine pollution, as they are difficult to clean up and can last for long periods of time in the marine environment. They can severely pollute marine and coastal habitats, causing damage to the natural environment and the economy. This can also result from inappropriate clean-up operations after an oil spill.

Oil spills can originate from deliberate operational discharges, from negligence, such as poor maintenance of equipment, or from the consequences of an accident or incident, such as a vessel collision or grounding or a pipeline rupture. In general, the most important accidents resulting in oil pollution are those of oil tankers, which transport some 1,800 million tonnes of crude oil and oil and refined products around the world by sea. Most of the time, oil is transported quietly and safely.

The effects of oil on marine life, are caused by either the physical nature of the oil (physical contamination and smothering) or by its chemical components (toxic effects and accumulation leading to tainting). Marine life may also be affected by clean-up operations or indirectly through physical damage to the habitats in which plants and animals live.

The main threat posed to living resources by the persistent residues of spilled oils and water-in-oil emulsions (“mousse”) is one of physical smothering. The animals and plants most at risk are those that could come into contact with a contaminated sea surface.

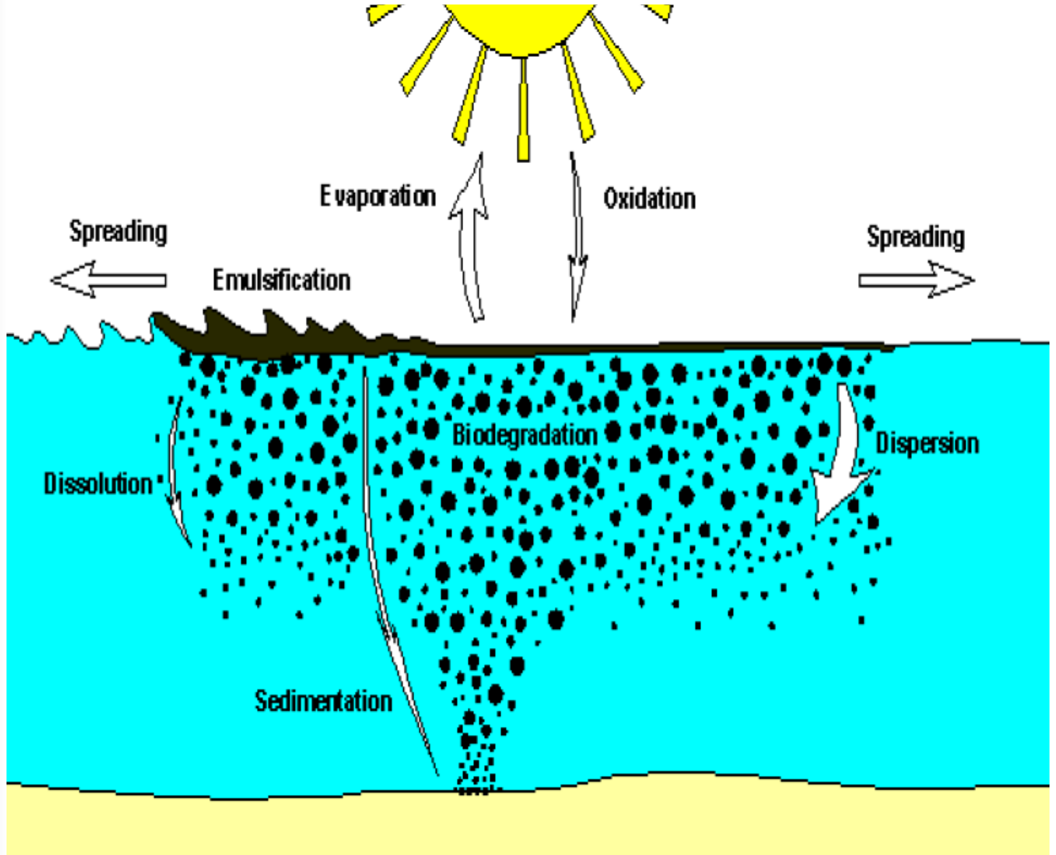


Figure 3.1 Oil behaviour (source MARPOL 73/78, practical guide 2015)

There is a large amount of oil handled in the engine room which is turned into gas or sludge and this sludge needs to be handled properly and this also applies to cruise ships. Failure to do so means that sludge or oil is dumped into the seas. In many cases oil is mixed with water creating bilge waters.

Bilge water may contain solid wastes and pollutants containing high amounts of oxygen-demanding material, oil, and other chemicals, as well as soaps, detergents, and degreasers used to clean the engine room. These chemicals can be highly toxic, causing mortality to marine organisms if the chemicals are discharged.

3.2 Oil Sourced Pollution

Amounts vary, depending on the size of the ship, but large vessels often have additional waste streams that contain sludge or waste oil and oily water mixtures that can inadvertently get into the bilge.

A typical large cruise ship will generate an average of eight to twelve metric tons of oily bilge water for each 24 hours of operation. To maintain ship stability and eliminate potentially hazardous conditions from oil vapours in these areas, the bilge spaces need to be flushed and periodically pumped dry. However, before a bilge can be cleared out in an oil separator and the water discharged, the oil that has been accumulated needs to be extracted from the bilge water, after which the extracted oil can be reused, incinerated, and/or off-loaded in port.

If a separator, which is normally used to extract the oil, is faulty or is deliberately bypassed, untreated oily bilge water could be discharged directly into the ocean, where it can damage marine life. According to US' EPA, bilge water is the most common source of oil pollution from cruise ships. Several cruise lines have been charged with environmental violations related to this issue in recent years. Annex I of the MARPOL Convention regulates the discharges of oil into the water and the Mediterranean Sea is considered a special area for discharges.

Cruise might transport dangerous goods in limited quantities, noting that these ships often need to stock up at every port they visit. This means that they have the potential to cause dangerous goods to be transported to ports all over the world.

3.3 Dangerous goods and hazardous wastes

In addition, cruise ships produce hazardous wastes from a number of on-board activities and processes, including photo processing, dry-cleaning, and equipment cleaning. Types of waste include discarded and expired chemicals, medical waste, batteries, fluorescent lights, and spent paints and thinners, among others. These materials contain a wide range of substances such as hydrocarbons, chlorinated hydrocarbons, heavy metals, paint waste, solvents, fluorescent and mercury vapor light bulbs, various types of batteries, and unused or outdated pharmaceuticals. Although the quantities of hazardous waste generated on cruise ships are relatively small, their toxicity to sensitive marine organisms can be significant. Without careful management, these wastes can find their way into greywater, bilge water, or the solid waste stream.

As the cruise ships begin stocking at various ports they call to, it is important that the people who handle these materials, as well as the people who are associated with the transportation (shippers, forwarders, carriers, etc.), are properly trained according to applicable national and international regulations, meaning in particular International Maritime Dangerous Goods Code (IMDG Code). The IMDG Code lists hundreds of specific dangerous goods together with detailed advice on storage, packaging and transportation. The amendments extend the Code to cover marine pollutants, adding the identifier “marine pollutant” to all substances classed as such. All packages containing marine pollutants must be marked with a standard marine pollutant mark.

3.4 Waste water

Special attention is needed on cruise ships for wastewater. Unlike other vessels, cruise ships dump more wastewater offshore (after passing through a treatment plant), mainly grey water from sinks, laundries, showers and galleys abroad the vessel. Thus, even the most regular activity onboard the cruise ship, such as cleaning utensils and doing the laundry, may cause ship pollution.

a. Grey water

Classified under the head of the greywater, this water accumulation contains not just harmful chemicals but sometimes even metals and minerals. The risk of greywater harming the marine environment is greater because of its high concentration in oceanic waters. Studies show that a large cruise ship releases large amounts of grey water during a single week's voyage and this is dealt with. Cruise ships may generate, on average, 253 litres/day/person of grey water or, approximately 756 m^3 per day for a 3,000 person cruise ship; by comparison, residential grey water generation is estimated to be 141.78 litres/person/day. Interesting to note that the discharge of grey water is not regulated by an international convention in shipping.

b. Sewage (black water)

Part of this waste water is sewage. What is sewage? "Sewage" means: drainage and other wastes from any form of toilets and urinals; drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; or other waste waters when mixed with the drainages defined above. Sewage is wastewater but wastewater will not become sewage unless its wastewater is mixed with it.

Nitrogen discharges, which are mainly from sewage, can also have a significant impact in eutrophic environments (e.g. the Baltic Sea), as they can contribute to nutrient over-enrichment, worsening the eutrophication level. Eutrophication can lead to increased plant growth, changes in the balance of organisms and water quality degradation. Oxygen consumption in bottom waters, especially those with low flushing rates, increases and can result in a reduction in oxygen levels in water (hypoxia). Hypoxia results in a deterioration in the affected ecosystems and the loss of marine life. On top of this, toxins released from harmful algae blooms due to eutrophication can have socio-economic impacts affecting fish stocks and causing shellfish poisoning in humans.

Sewage can be an obvious visual pollution in coastal areas – a major problem for countries with tourist industries. However, it is generally considered that on the high seas, the oceans are capable of assimilating and dealing with raw sewage through natural bacterial action.

Cruise ships generate, on average, 23 litres/day/person of sewage, and a large cruise ship (3,000 passengers and crew) can generate an estimated 41 to 82 m^3 per day of sewage.

Projections show that Ro-pax ships are generating the greatest discharges of nitrogen from sewage and this has been increasing in recent years, especially in the summer period, which is consistent with the increase in seaborne passengers.

The discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land. Sewage which is not comminuted or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land.

Annex IV of the MARPOL convention contains a set of regulations regarding the discharge of sewage into the sea from ships, including regulations regarding the ships' equipment and systems for the control of sewage discharge, the provision of facilities at ports and terminals for the reception of sewage, and requirements for survey and certification.

3.4 Waste water

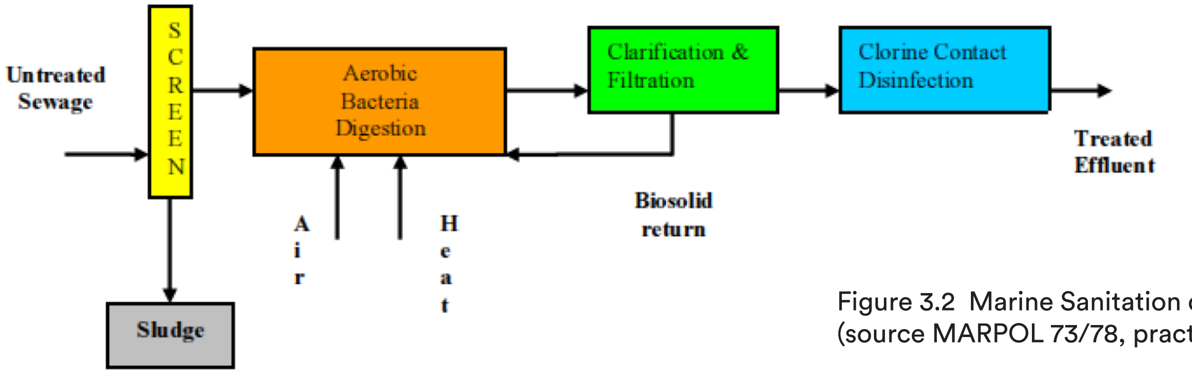


Figure 3.2 Marine Sanitation device for sewage (source MARPOL 73/78, practical guide 2015)

The regulations introduces the Baltic Sea as a special area under Annex IV and adds new discharge requirements for passenger ships while in the area, but not the Mediterranean. The discharge of sewage from passenger ships within a special area will generally be prohibited under the new regulations, except when the ship has in operation a sewage treatment plant which shall be of a type approved by the national Administration.

Most of a cargo and cruise ships with traditional Type II Marine Sanitation Devices (MSD), sewage is treated using biological treatment and chlorination. Some cruise ships do not treat their sewage biologically, but instead use maceration and chlorination. The system also may include screening to remove grit and debris.

Cruise ships typically install up to four systems, allowing one or two to be placed off-line for maintenance at any one time. Cargo ships use one unit only. They may be simple (first example or more complex such as the AWT.

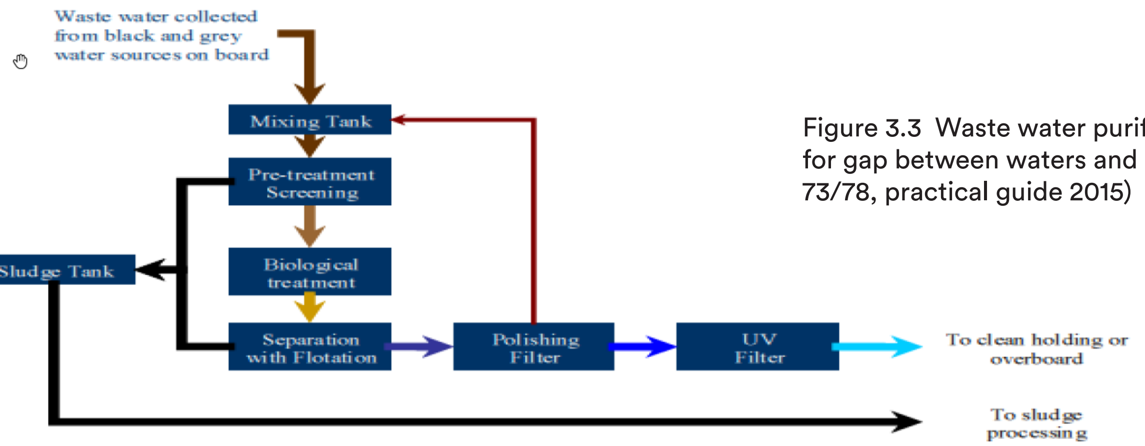


Figure 3.3 Waste water purification system for gap between waters and (source MARPOL 73/78, practical guide 2015)

3.5 Garbage (marine litter)

Garbage from ships can be just as deadly to marine life as oil or chemicals. Because of the transboundary nature of the problem, marine litter can be found in practically all the world's oceans, seas, bays and estuaries and on shorelines even in remote areas far from contact with humans. It is clear that a good deal of the garbage washed up on beaches comes from people on shore holiday-makers who leave their rubbish on the beach, fishermen who simply throw unwanted refuse over the side - or from towns and cities that dump rubbish into rivers or the sea.

A cruise ship's solid waste materials include paper, cardboard, aluminium, etc. For a large cruise ship, about 8 tons of solid waste are generated during a one-week cruise. It has been estimated that 24% of the solid waste generated by vessels worldwide (by weight) comes from cruise ships.

Floating litter can also interfere with navigational safety, as well as causing economic losses to fishing and maritime industries and degrading the quality of life in coastal communities. In this report, marine litter related to fisheries and fishing activities, and to offshore and other marine and maritime industrial platforms, is not considered.

Plastics are included under the litter category and the greatest danger comes it. Plastic can float for years. Fish and marine mammals can in some cases mistake plastics for food and they can also become trapped in plastic ropes, nets, bags and other items. At a global scale, plastic concentrations by volume in beach, subtidal, deep sea and estuary sediments have been reported as being four to five orders of magnitude higher than they are in the water column. Their relevance is evident, as it is estimated that more than 150 million tonnes of plastics have accumulated in the world's oceans, while 4.6-12.7 million tonnes are added every year. it can also be divided in micro and macroplastics. Although there are regional fluctuations in the distribution between the land- and sea-based origin of marine plastic litter (i.e. in the North-East Atlantic, shipping and fishing are very important litter sources), estimates from UNEP attribute one fifth of the source to be linked to maritime transport, industrial exploration and offshore oil platforms, fishing and aquaculture (UNEP, 2009).

The MARPOL Convention sought to eliminate and reduce the amount of garbage being dumped into the sea from ships. Under Annex V of the Convention, garbage includes all kinds of food, domestic and operational waste, excluding fresh fish, generated during the normal operation of the vessel and liable to be disposed of continuously or periodically. Annex V totally prohibits of the disposal of plastics anywhere into the sea, and severely restricts discharges of other garbage from ships into coastal waters and “Special Areas” such as the Mediterranean.

The EU Directive on single-use plastics sets out EU-wide rules targeting the 10 single-use plastic products most often found on Europe’s beaches and seas. It also targets lost and abandoned fishing gear. Together these constitute 70% of marine litter items.

The Directive aims to reduce the impact of plastic products on the marine environment, and prevent and tackle marine litter by, among other things, introducing extended producer responsibility schemes, establishing collection targets and introducing market restrictions for certain single-use plastic products.

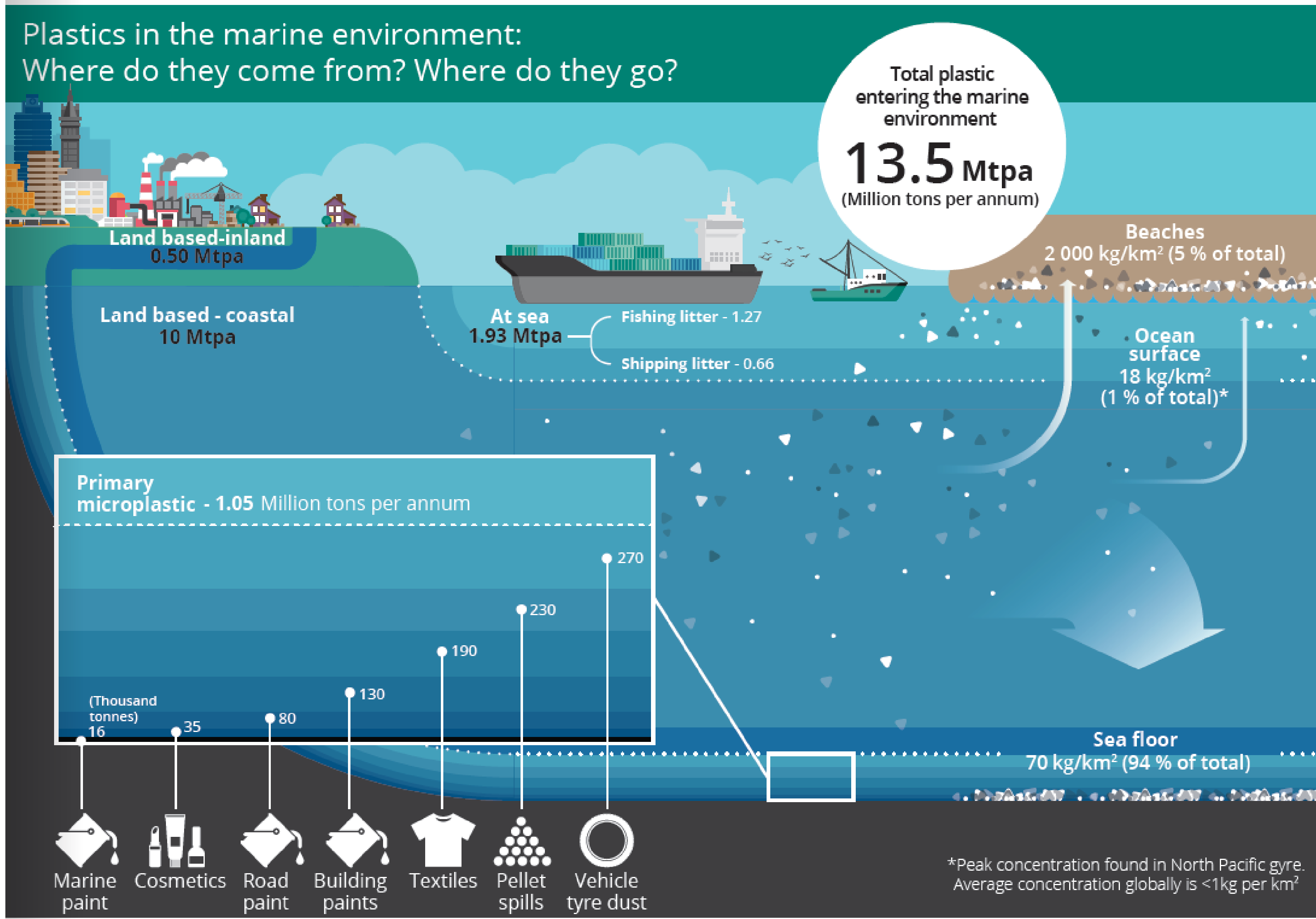


Figure 3.4 Plastics in the marine environment (source Sherrington 2016)

3.6 Non-indigenous species

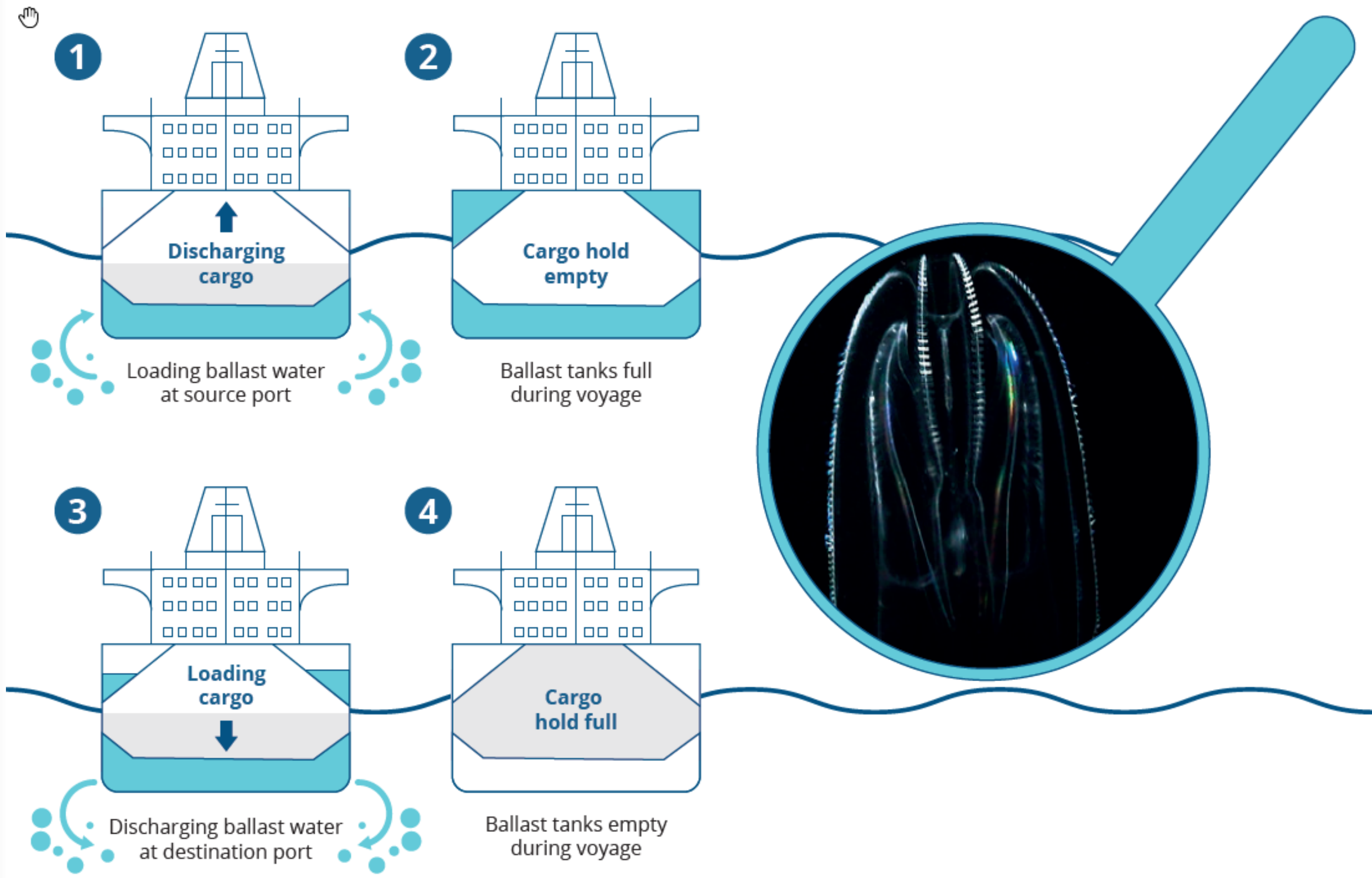
According to the UN Convention on Biological Diversity, nonindigenous species (NIS) are those species introduced outside their natural past or present distribution. Once introduced in a new area they can become ‘invasive’ and have impacts on local ecosystems. Such species may arrive in new areas through natural migration, but they are often introduced by human activities, such as maritime transport, aquaculture and canals. Maritime transport accounts for the largest proportion (up to 49%) of NIS (including invasive species) introductions in the seas around the EU since records began in 1949. Organisms are transported mainly through ballast water (up to 25.5%) and hull fouling (up to 21.2%).

This allows organisms to travel long distances and be released in areas far from their native range, thereby becoming a NIS and, if suitable conditions exist, turning into an invasive species. Approximately 10% of all introduced species will become established and 10% of these will become invasive.

The problem has exacerbated as trade and traffic volumes have expanded over the last few decades and the effects of the introduction of new species in many parts of the world have been devastating.

The Mediterranean Sea is the European sea basin with the highest number of NIS introduced by maritime transport, especially in eastern Mediterranean. One example of such ecological damage would be the massive swell of jellyfish in the Black Sea., while the Celtic Sea (Atlantic subregion) and the Baltic Sea are those with the lowest introductions. Although the number of introduced NIS has increased overall at the European level over the past century, it seems that the rate of new introductions has slowed down since 2005. There are several reasons for this, ranging from increased awareness of the problem, effective policies and new legislation to other reasons such as a decreasing pool of potential new NIS.

Figure 3.5 Ballast water sequence (source EMTER)



a. Ballast water

On ships, ballast is needed to maintain their stability during loading and unloading operations and while the ship operates with partial or no cargo or in rough weather. As ships became larger, they were built to be stable when laden; therefore, ballast water was essential for the safe operation and transit of the ship when unladen.

Ships fill their ballast tanks near the port of departure where various species with a free or floating life stage can be pumped into tanks (e.g. eggs, larvae, spore cysts, adults) and then be discharged with the ballast water in the destination port. On cruise ship ballast is used to maintain optimal draft and sailing conditions, hence the amount of ballast managed is not so important as in cargo ships.

3.6 Non-indigenous species

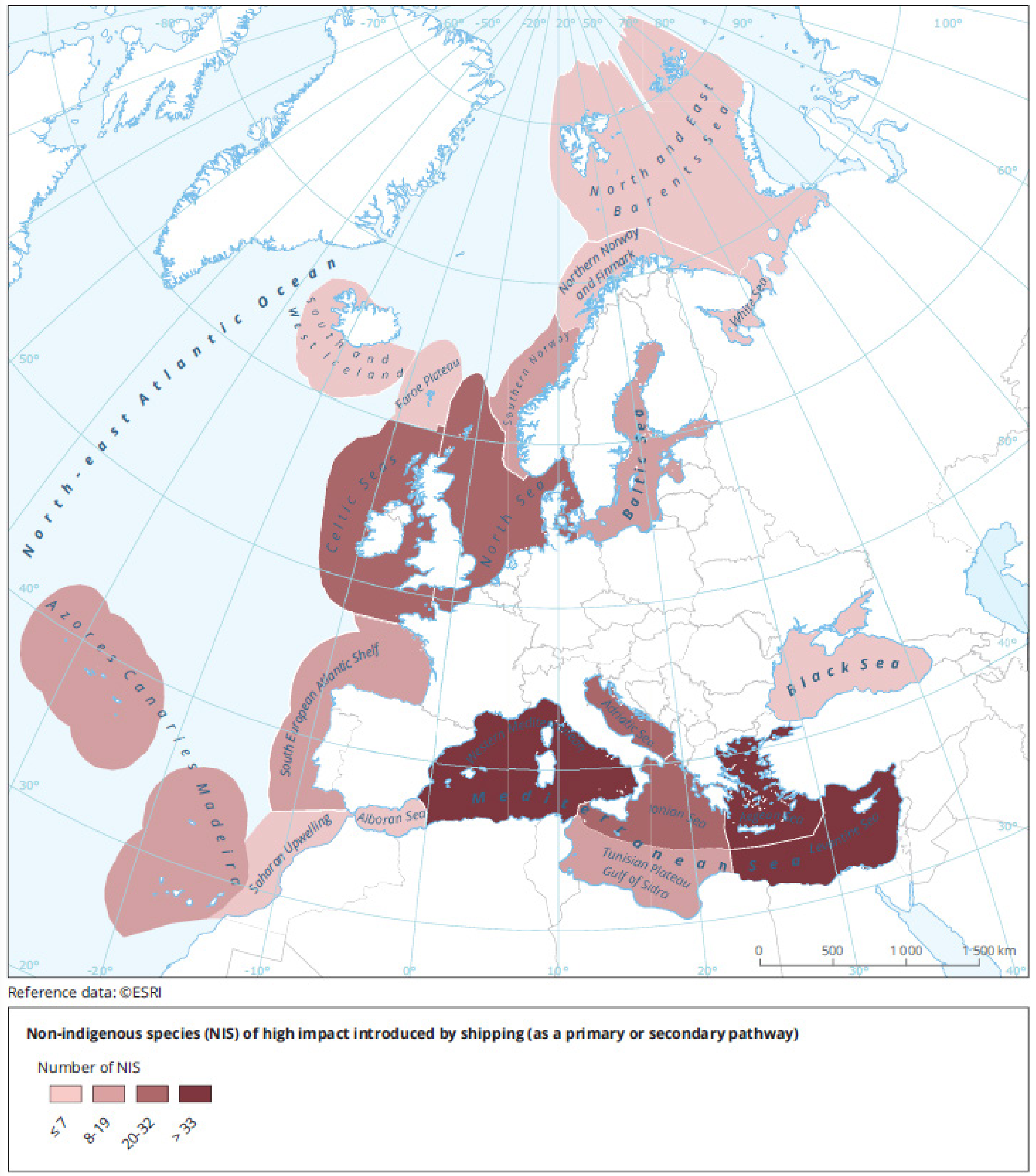
The amount of ballast water released typically carried in a cruise ship is around 1,000 metric tons, which 3-5% of the total ballast carried.

All international sea going ships under the Ballast Water Management Convention (BWM 2004) must implement a “Ballast water management plan” that enables the ship to manage their ballast water and sediment discharge to a certain standard. It includes standard operational guidance, planning and management, as well as additional details including sampling points and systems.

Under the Convention, ships are required, according to a timetable of implementation, to comply with some standards, either procedures for ballast exchange or disinfestation. The system must ensure that only small levels of viable organisms remain left in water after treatment so as to minimise the environmental impact of shipping.

It is also possible for ships to discharge ballast at approved shore reception facilities in ports and therefore ports should have adequate reception facilities for the sediments. Facilities must include safe disposal arrangements, storage and treatment equipment, safe and suitable mooring and emergency arrangements and the necessary reducers for connections to ships.

Figure 3.6 NIS distribution (source ESRI)



b. Biofouling

Sea life such as algae, molluscs and other sessile organisms can travel from one place to another by attaching themselves to a ship’s hull, hereafter referred to as hull fouling, slowing down the ship, increasing fuel consumption and thereby facilitating the movement and dissemination of NIS. Considering that, at global level, in excess of 50% of NIS may have been transported through biofouling, their impacts are likely to be significant; however, there have been very few assessments of NIS introduced by hull fouling alone, as numerous species can be introduced by both ballast water and hull fouling.

Figure 3.7 Biofouling attached to hull and antifouling to protect it (source Marine Insight)

Biofouling develops slowly on vessels, and its speed of growth is dictated by the anti-fouling coating the vessel has, the frequency of hull cleaning and the exposure to water. Certain areas of a ship, such as the anchor locker, pipework and other sheltered parts, are more likely to be fouled quickly and have a large range of organisms in the fouling that develops. This is because they are in contact with still water for a greater period of time. Laid up or moored vessels can also develop heavy fouling, which can reach on average 5 kg/m^2.

The most frequently represented taxonomic group of NIS is the macroscopic algae, followed by arthropods (crabs, shrimps, barnacles) and filter feeder invertebrates. The Black Sea is the region least affected by NIS introductions through hull fouling, followed by the Baltic, the Mediterranean and the North Seas. Although the figures for the Mediterranean Sea need to be interpreted with caution, comparing the numbers of NIS introduced in the Mediterranean Sea through hull fouling with those introduced through ship ballast water, the Mediterranean seems to be more susceptible to the introduction of species through hull fouling. This may suggest a possible connection with the high maritime traffic density in this area. There are no mandatory conventions applicable to this issue but in general the industry is the first one interested in having a smooth hull to reduce fuel consumption.

c. Antifouling

Anti-fouling paints are used to coat the bottoms of ships to prevent sea life such as algae and molluscs attaching themselves to the hull – thereby slowing down the ship and increasing fuel consumption. In the early days of sailing ships, lime and later arsenic were used to coat ships' hulls, until the modern chemicals industry developed effective anti-fouling paints using metallic compounds.

These compounds slowly "leach" into the sea water, killing barnacles and other marine life that have attached to the ship. However, the studies have shown that these compounds persist in the water, killing sea life, harming the environment and possibly entering the food chain. One of the most effective anti-fouling paints, developed in the 1960s, contains the organotin tributylin (TBT), which has been proven to cause deformations in oysters and sex changes in whelk. The IMO AFS Convention prevents their use and defines "anti-fouling systems" as "a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms", among this biofouling. TBTs and Cybutrene coatings have been incorporated in the Convention.

3.7 Port Infrastructures (as port reception facilities)

With shipping accounting for approximately 20% of global discharges of wastes and residues at sea, reducing discharges of all kind of ship-generated waste and cargo residues into the sea is closely linked with the protection of the marine environment. Ports have a key role to play in order to achieve this goal. The development of adequate port reception facilities (PRF), together with the establishment of systems that provide incentives for ships to use these facilities, are major elements aiming in a process to reduce ships' discharges into the sea.

These facilities mostly receive and collect ship-generated waste, including cargo residues, garbage, oily water and sewage, from the port's regular vessel traffic. In addition, PRFs often process the waste further, by sorting, treating and recycling it. As indicated in chapter 2 this might help stakeholders to concentrate on areas where the circular economy could be enhanced for the benefit of the environment.

In some cases, new products can even be generated and put on the market. Procedures in place must aim at not prolonging the ship's stay in port unnecessarily.

To accommodate the growth of waste delivery, cruise ports must invest in modern facilities that are able to serve the needs of the new generation of cruise vessels and, not least, to handle the produced waste in a most efficient and effective way. On the one hand, cruise ports must comply with their applicable environmental laws and regulations in order to avoid enforcement actions by the responsible government agencies. The presence of societal pressures motivates them to develop "greening" initiatives that go further than just the regulatory approach, mandated under MARPOL conventions and regional regulations. A port authority should invest in improving its environmental performance due to corporate conscience, and not least in order to achieve competitive advantage.In the EU the availability of PRFs in ports is the responsibility of Member

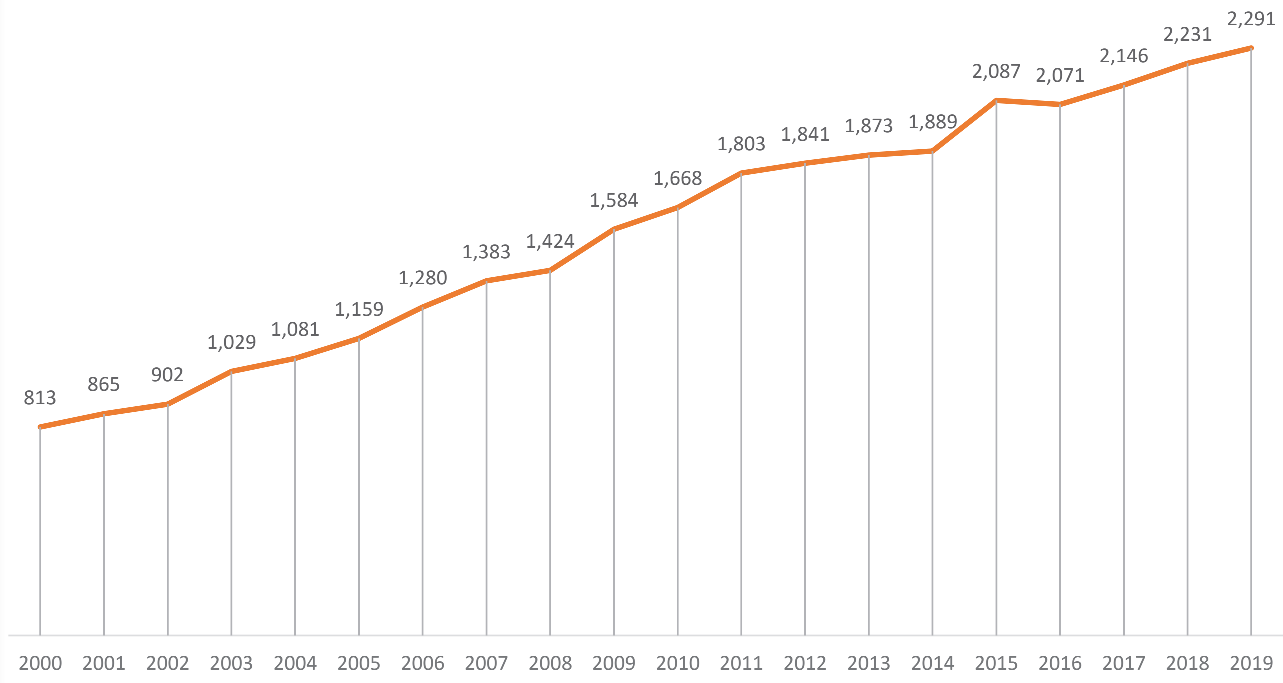


Figure 3.8 Average cruise passenger per call (source Medcruise)

States under the Directive regulating the availability of port reception facilities and such facilities are paid for partly by the ships and partly by the port authorities. To promote responsible waste disposal, part of the costs of the facilities is included in a general "indirect fee" that is paid by every ship using the port, supplemented by a "direct fee" based on the actual amount of waste disposed of. This should promote regular waste disposal and balance the discharge between all ports.

How the waste is processed after disposal at the PRF is of the utmost importance. The following processes have varying impacts on the environment:

- Special advanced treatment, such as incineration, sterilisation, bioremediation or energy recovery;
- Disposal in a port reception landfill; or follow-up processing for recycling or re-use.
- Some types of waste require particularly careful management and disposal, such as expired pyrotechnics, batteries, used wires, ropes and tails, and medical waste.

3.7 Port Infrastructures (as port reception facilities)

It is important for cruise ships to plan onboard waste management properly and have information on the specific reception facilities available at each port called at on the journey. For this purpose, ports publish on their websites and other public databases a list of their PRFs, including maximum amounts that can be accepted, fees and contacts. Once waste has been disposed of, a waste receipt is issued to the master of the ship.

Due to the earlier development of legislation oily waste (MARPOL Annex I) is, in volume, the most important waste stream collected by PRFs. Depending on the quantities delivered in each port, several techniques for processing these oily wastes, such as filtration, centrifugation, dewatering, flocculation or distillation, are being developed. These pre-processed materials are then further treated so that the resulting products contribute to the circular economy. However, measures like a harmonised EU end-of-waste status could be relevant if we are to benefit further from these initiatives.

In the EU, garbage (MARPOL Annex V), is the second most important volume of ship waste collected. The segregation into different waste fractions is often limited on board. Ships may also have difficulty finding segregated reception facilities ashore. The situation is therefore not fully aligned with the environmental rules in force in the European countries where the garbage is received. This generates problems of compliance with the waste management and transport rules in many countries.

Moreover, delivering a mixture of the different waste fractions limits the percentage of waste entering a recycling process. A lot of waste is potentially recyclable and this is key for the cruise industry to contribute towards a circular economy. Between the potential and the reality, there is a gap that can be reduced by improving collaboration between cruise ships and PRFs, supported by legal enforcement and efficient control.

In 2019, the EU adopted a revised Directive regulating the availability of port reception facilities and the delivery of waste to those facilities, aiming to substantially reduce discharges of ship-generated waste and cargo residues into the sea. This Directive covers all waste from all, including residues from exhaust gas cleaning systems and passively fished waste (collected in nets during fishing operations) and ensures the availability of adequate port reception facilities by requiring segregated collection of waste in ports.
The Waste Framework Directive and the Regulation on shipments of waste establish procedures and control regimes for the shipment of waste, depending on the origin, destination and route of the shipment, the type of the waste and the type of treatment to be applied to the waste at its destination. These regulations apply to shipments of waste between Member States or in transit to third countries and to waste imported from or exported to third countries or in transit in the EU from or to third countries.

3.8 Ships Recycling

Figure 3.9 Cruise ships being scrapped (source Foxnews)

3.8 Ships Recycling

Many large ships are dismantled in ship recycling facilities located outside the EU, some of which operate under poor environmental standards and safety conditions. Some of the techniques may involve so-called “tidal beaching”, by which the ship is taken ashore on a high tide and therefore becomes easily accessible from the beach. This process exerts pressures on the environment, as hazardous materials that may be present on board, such as oils, asbestos or toxic paints, could be released into the local environment, disrupting biodiversity. There have been local attestations of significant pollution of the surrounding environment from such activities and its resultant impacts on wildlife, farming and communities. There are many different cruise ship scrapyards or ship breaking facilities around the world. The most prominent scrapyards that dismantle cruise ships include facilities in: Alang, India, Aliaga, Turkey, Gadani, Pakistan and Chittagong, Bangladesh.

At international level the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 (the Hong Kong Convention) is not yet into force. The Convention is aimed at ensuring that ships, when being recycled after reaching the end of their operational lives, do not pose any unnecessary risks to human health, safety and to the environment. It intends to address all the issues around ship recycling, including the fact that ships sold for scrapping may contain environmentally hazardous substances such as asbestos, heavy metals, hydrocarbons, ozone-depleting substances and others. It also addresses concerns raised about the working and environmental conditions at many of the world’s ship recycling locations. Regulations in the new Convention cover: the design, construction, operation and preparation of ships so as to facilitate safe and environmentally sound recycling without compromising the safety and operational efficiency of ships; the operation of ship recycling facilities in a safe and environmentally sound manner; and the establishment of an appropriate enforcement mechanism for ship recycling, incorporating certification and reporting requirements.

In parallel, the EU Regulation on ship recycling rules aims to reduce the negative impacts linked to the recycling of ships registered under the flag of an EU Member State and to ensure that, as of 31 December 2020, ships calling at EU ports or anchorages either possess an inventory certificate (for ships registered under the flag of an EU member state), or a certificate of compliance (for ships flagged in non-EU Member States). These prove that the ship in question has an approved inventory of hazardous materials on board. This Regulation lays down requirements that ships and recycling facilities must fulfil to make sure that ship recycling takes place in an environmentally sound and safe manner.

According to the new rules, the installation or use of certain hazardous materials on ships, such as asbestos, ozone-depleting substances, polychlorinated biphenyls (PCBs), perfluorooctanesulphonic acid (PFOS) and anti-fouling compounds, is prohibited or restricted. Each ship, irrespective of its flag, is required to have on board an inventory of hazardous materials approved by its flag state by 2020. From 2019 onwards, large commercial seagoing vessels flying the flag of an EU Member State may be recycled only in safe and sound ship recycling facilities included in the European List of ship recycling facilities.

However, since 2016 the number and size of ships registered under the flag of an EU Member State, at the time of recycling, has been steadily declining. This is partly because ships registered under flags of EU Member States may, for economic reasons, be flagged out to registries in third countries to avoid being recycled in the facilities included in the European list of ship recycling facilities.

3.9 Underwater radiated noise

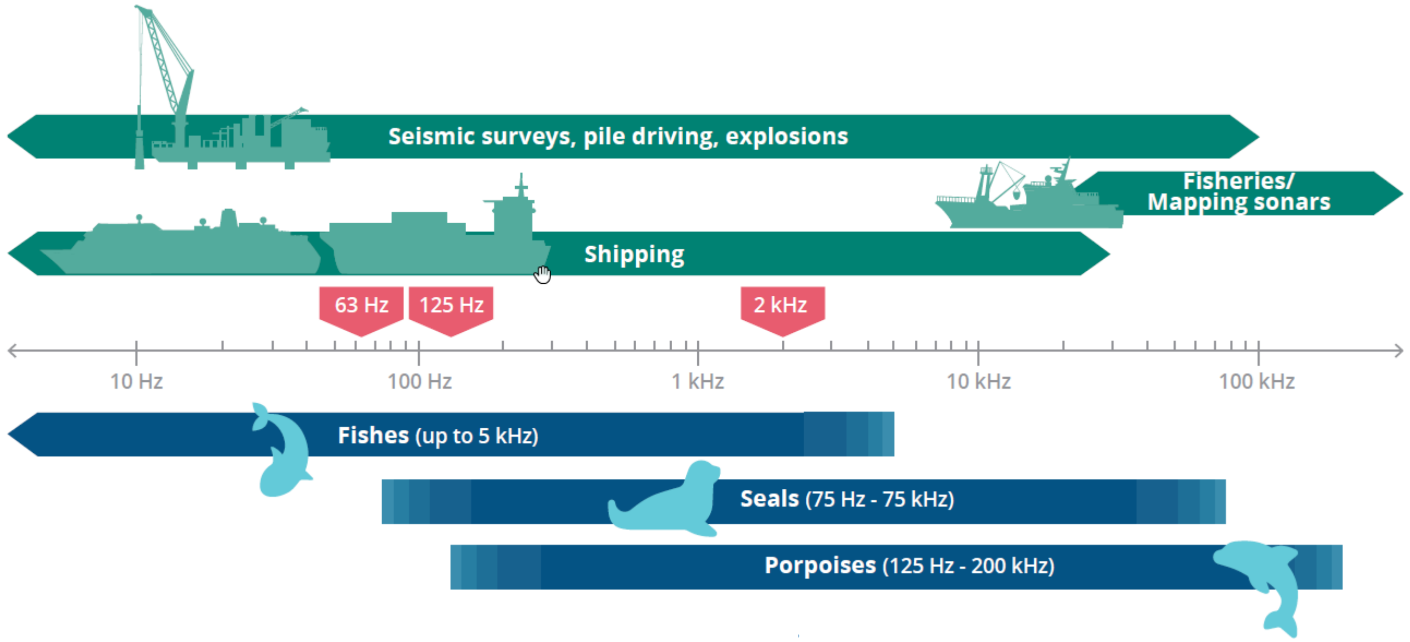


Figure 3.10 Underwater radiated noise frequencies
(source HELCOM 2018 as modified by Scholk Schlome and BIAS)

Underwater noise from shipping is increasingly recognised as a significant pollutant, affecting marine ecosystems on a global scale. Measurements in the last 50 years have shown that noise in the oceans is rapidly increasing. There is also documented scientific evidence linking noise exposure to a range of harmful effects on marine mammals, sea turtles, fish and invertebrates. The range of noise frequencies emitted by commercial ships interacts with the frequency that is critical for various marine species, potentially masking the sounds made by these animals and having undesirable consequences. This is particularly the case with cetaceans, which are highly vocal and use sound for communication, food-finding, reproduction, detection of predators and navigation.

The impact affects species that are at serious risk of extinction, those that are commercially important and those that are critical for supporting ecosystems.

There has been some progress on underwater noise, but many knowledge gaps remain, making it difficult to quantify the link between ship traffic, underwater noise and its effects on the overall marine habitats. The policy and operational measures to limit underwater noise pollution are still in development.

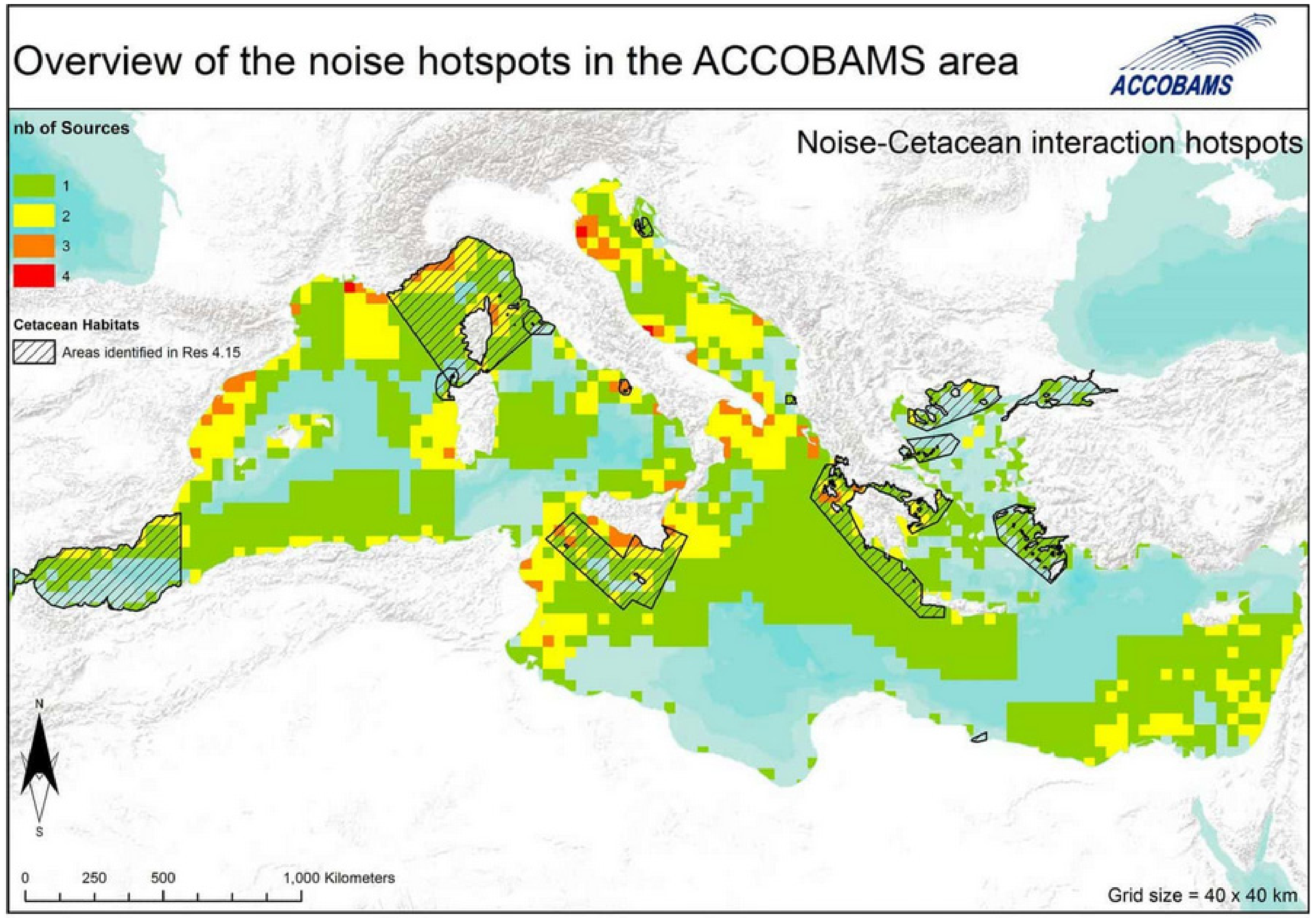
The main sources of underwater noise from ships are caused by the propeller (both cavitating[4] and non-cavitating propeller), machinery (i.e. main and auxiliary engines) and the movement of the hull through the water. The relative importance of these three categories depends on many factors related to the ship type and operation profile and the sea conditions.

Several research projects and studies have been launched to further understand the propeller's cavitation mechanism and noise generated and to find technical solutions to mitigate its negative consequences. In general cruise ships are silent ships in terms of radiated noise into the ship, but this may not be the same for radiated noise into the water that may harm mammals.

The North West Mediterranean Particularly Sensitive Sea Area in waters of Spain, France, Italy and Monaco to be approved in 2024at IMO may be the first one dealing with cetaceans to avoid collisions with ships aiming to reduce underwater noise in the near future too.

[4] Cavitation is bubbles caused by excessive propeller speed or loading. The water vaporizes or boils due to the extreme reduction of pressure on the back of the propeller blade. Many propellers partially cavitate during normal operation, but excessive cavitation can result in physical damage to the boat propeller's blade surface due to the collapse of microscopic bubbles on the blade.

Figure 3.11 Noise hotspots in the Mediterranean (source Accobams)



There are other areas under consideration related to marine environment relation to physical disturbance of the seabed such as dumping, wake induced turbulence and anchoring which with the permanent alteration of the hydrographic conditions and the loss of seabed habitats.

It can also produce relevant changes in local currents and wave energy, which in turn affect the overall coastal ecosystems that would need to be taken into account.

4 Atmospheric pollution

In the previous section we referred to sources or pollution referring mainly to water pollution and other issues such as port reception facilities in an overall perspective. Atmospheric pollution was broadly described. However, climate crisis and the development of measures to abate and deter atmospheric pollution need special attention.

4.1 Annex VI MARPOL Convention

Emissions from ships have been considered a problem since the early 1990s. Firstly, emissions of HFCs and CFCs covered by the Montreal Protocol of 1987 drew attention to the alarming degradation of the ozone layer. But these were not the only gases that should be reduced or banned. The main air pollutants associated with health impacts on the population are SOx, NOx, PM (including black carbon) and ozone. SOx and NOx have direct impacts on health and furthermore undergo different chemical reactions in the atmosphere that lead to the formation of fine particles known as sulphur and nitrogen aerosols. These fines particles, along with PM, can enter the lungs and then pass into the blood system causing damage to various organs and eventually lead to premature death. It is therefore necessary to prevent and control the emissions of other gases such as VOCs, NOx and SOx, other PM such as black carbon and GHGs[5].

Due to the international nature of shipping, regulations have normally started at the level of the IMO. In relation to atmospheric pollution, despite general regulations related to land sectors, maritime regulations have evolved in parallel, sometimes triggered by regional legislation from the US or the EU with horizontal application.

To tackle atmospheric pollution a Protocol to the MARPOL Convention was adopted in 1997, the so-called Annex VI, which entered into force in 2005. Initially, the priorities were established in the prevention of emissions of NOx, CFCs and HCFCs, and SOx to later expand to GHG. In order to deal with all the problem, we will follow the order established by the amendments to the MARPOL Convention.

[5] Greenhouse gases are those within the earth's atmosphere that contribute towards global warming as listed in the latest report of the Intergovernmental Panel on Climate Change

4.2 Ozone Depleting Substances

Included within the definition of ozone depleting substances (ODS) are the chlorofluorocarbons (CFC) and halons used respectively in older refrigeration and fire-fighting systems and portable equipment. ODS were also used as the blowing agent in some insulation foams. Refrigerants are used in various types of machinery, including those for air conditioning and cargo cooling processes, and various gases are used including hydrofluorocarbons (HCFCs).

Hydrochlorofluorocarbons (HCFC) were introduced as an intermediate replacement for CFCs but are themselves still classed as ODS. As part of a world-wide movement, the production and use of all these materials is being phased out under the provisions of the Montreal Protocol.

The controls in MARPOL regulation do not apply to permanently sealed equipment without charging connections or removable components; this typically covers items such as small, domestic type, refrigerators, air conditioners and water coolers. However, no CFC or halon containing system or equipment is permitted to be installed on ships constructed on or after 19 May 2005 and no new installation of the same is permitted on or after that date on existing ships. Similarly, no HCFC containing system or equipment is permitted to be installed on ships constructed on or after 1 January 2020 and no new installation of the same is permitted on or after that date on existing ships.

4.2 Ozone Depleting Substances

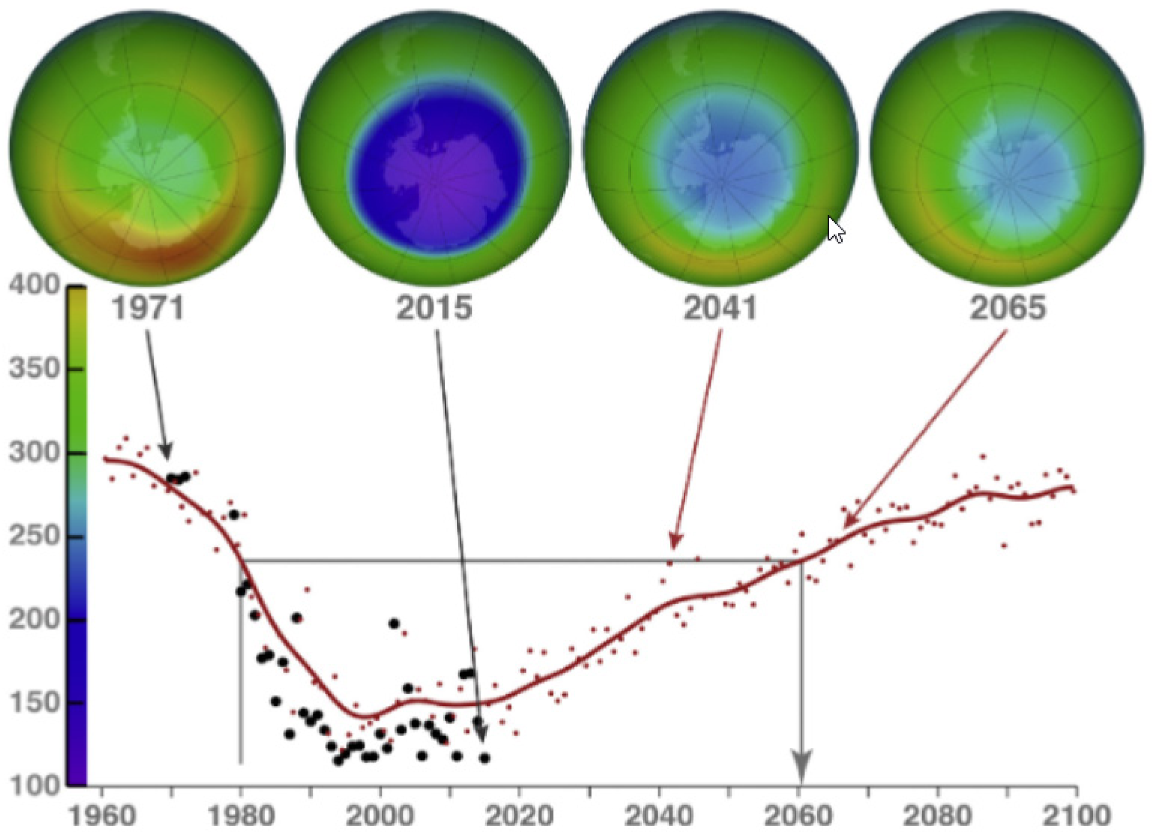


Figure 4.1 Evolution of total ozone the atmosphere (source The Antarctic ozone hole: An update: Physics Today: Vol 67, No 7)

Existing systems and equipment are permitted to continue in service and may be recharged as necessary. However, the deliberate discharge of ODS to the atmosphere is prohibited. When servicing or decommissioning systems or equipment containing ODS the gases are to be duly collected in a controlled manner and, if not to be reused onboard, are to be landed to appropriate reception facilities for banking or destruction. Any redundant equipment or material containing ODS is to be landed ashore for appropriate decommissioning or disposal. The latter also applies when a ship is dismantled at the end of its service life.

4.3 Nitrous Oxides

NO_2 is also a precursor gas, forming new particles in the air or condensing on to pre-existing particles to form secondary PM (i.e. secondary inorganic aerosols) and NOx are formed from nitrogen and oxygen precursors during the combustion process in the ship's main engines. Together, these two compounds constitute 99% of the engine's intake air.

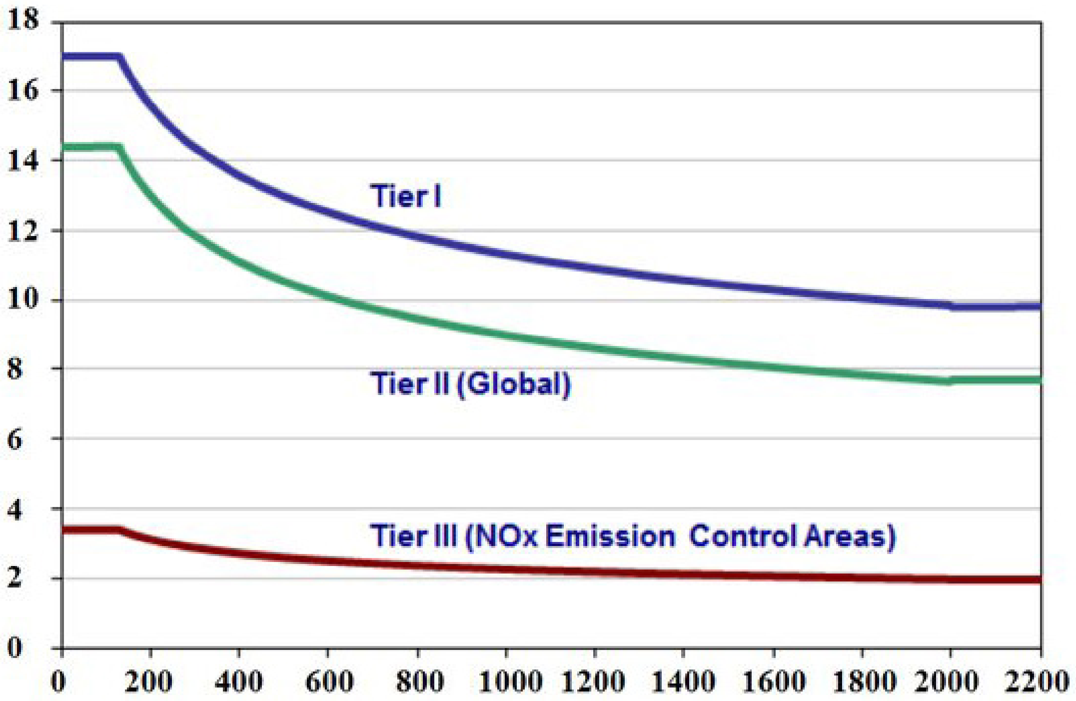
Oxygen is consumed during the combustion process, with the amount of excess oxygen available being a function of the air and fuel ratio that the engine is operating under. Nitrogen largely remains in the combustion process; however, a small percentage will be oxidised to form various NOx. When measured in the exhaust duct of a marine diesel engine, NOx emissions would normally comprise nitric oxide (NO; about 95%) and NO_2 (about 5%). The latter, initially formed as NO, further oxidises after combustion of fuel in the engine.

The formation rate of the majority of NO is largely dependent on the peak temperatures achieved in the engine cylinders (the higher the combustion temperature, the peak pressure, the compression ratio and the rate of fuel delivery, the greater the amount of NOx formation). Because of this, the control of NOx emissions requires engine adaptation, meaning in general worse combustion, or the use of after-treatment technologies. NOx reduction is also reduced by lowering the engine speed.

NOx emissions from ships are regulated at international level in Annex VI introducing NOx control limit (g/kWh) requirements on ships with marine diesel engines of over 130 kW output power. The specific controls are applied in three levels (Tiers), based on the ship's construction date and operation area. Within a Tier, the actual NOx limit value is determined based on the specific engine's rated speed.

4.3 Nitrous Oxides

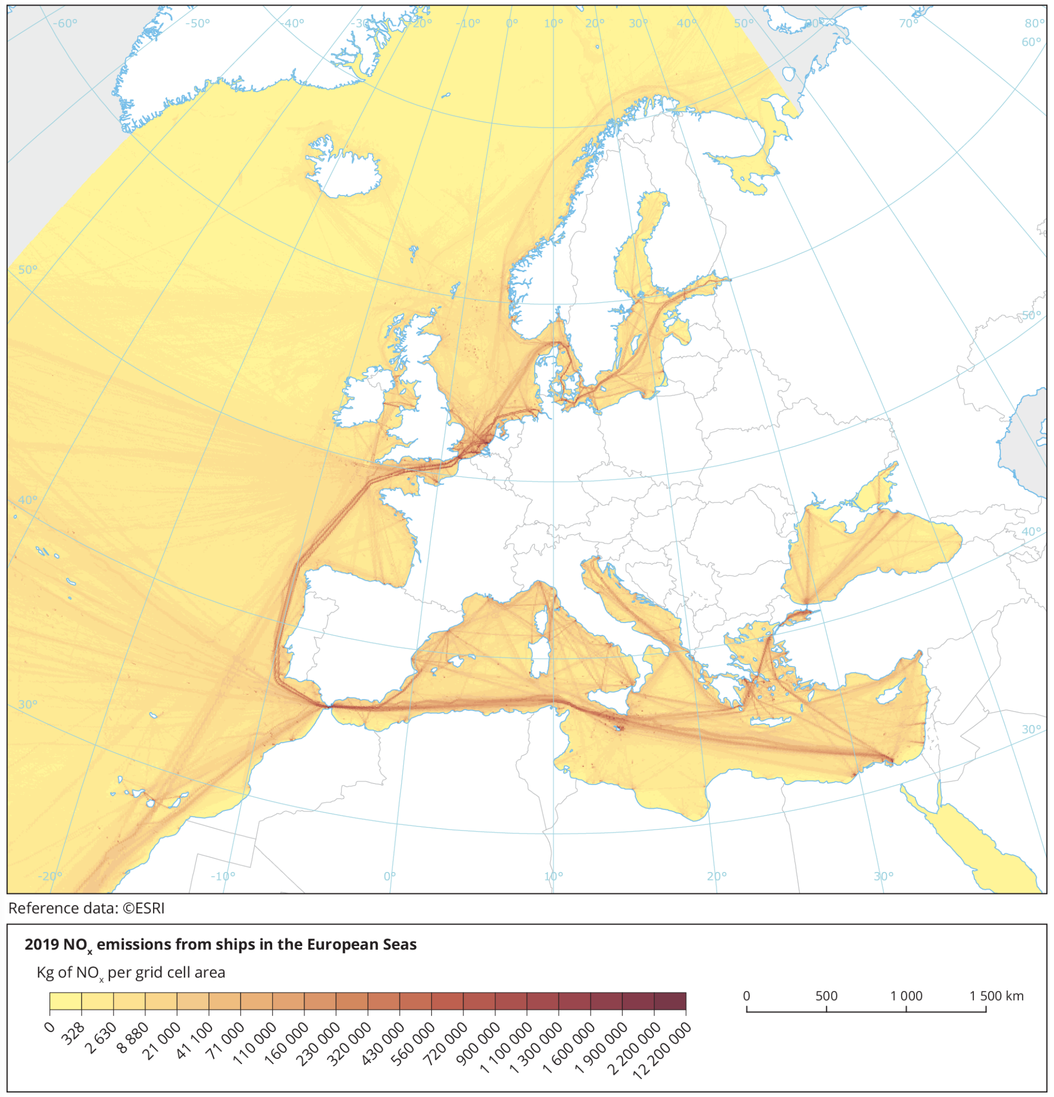
Figure 4.2 NOx tiers (source IMO)



The most stringent control limits, Tier III, apply only to ships operating in nitrogen emission control areas (NECAs) and constructed after their entry into force. Tier III represents almost an 80% reduction in NOx emissions compared with Tier II limits but only applies to new ships and in restricted sea areas. In order to achieve Tier III there are two options: catalysers (SRCs) and exhaust gas recirculation (EGRs). At EU level, current laws in the field of marine water and air quality set out obligations to be achieved by Member States covering a whole range of pollutants, including NOx.

The existing international requirements will affect NOx shipping emissions in the EU at a slow pace. This is mainly because the more stringent MARPOL Annex VI NOx standards (Tier III) will apply only to ships constructed on or after 1 January 2021 and operating in the EU nitrogen emission control areas (NECAs). At this point in time the only ones are North American waters, the Caribbean waters of the US, the North and Baltic Seas, while discussions are starting to consider the Mediterranean Sea a NECA.

Figure 4.3. NOx emissions (source ESRI)



The benefits of Tier III standards in the NECAs in the Baltic and North Seas and of the Tier II standards in other seas may be partly offset by increases in fuel consumption. It is interesting to note that NOx emissions are linked to the engine combustion parameters and NOx increases as the combustion parameters are closer to the optimal. It is also interesting to note that engines using Liquefied Natural Gas (LNG) easily comply with Tier III, therefore cruise ships using LNG comply with NOx requirements.

4.4 Sulphur Oxides

The combustion of marine fuels containing sulphur contributes to air pollution in the form of SOx and particulate matter (PM), which harm human health and the environment. Combustion of oil and coal, in which sulphur is naturally present in small quantities, has for decades been recognised as the dominant source of SOx emissions. The main SOx emission from ships is SO_2 resulting from the use of marine fuels in the main and auxiliary engines but also in other combustion machinery on board, such as oilfired boilers.

SO_2 is a pollutant that can affect the respiratory system and the functions of the lungs. It causes irritation of the eyes; it also contributes to acid deposition, which, in turn, can lead to potential changes in soil and water quality. The subsequent impacts of acid deposition can be significant, including adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation. Acid rain falling in cities may cause significant damage to buildings and the architectural heritage.

As a secondary PM precursor, SO_2 also contributes to the formation of particulate aerosols in the atmosphere.

The sulphur oxides emission is due to the presence of sulphur compound in the marine fuels used in marine engines on board vessel. The better the grade, the lower will be the sulphur content as it is removed by refining of the fuel. In the past there has been a large amount of pressure on the cruise industry due to its SOx emissions.

Regarding SOx, the EU regulatory framework has been very strict on sulphur content, accelerating the use of low sulphur fuels in ports. At the level of the IMO there was a schedule to progressively limit the sulphur content of the fuels used in ships. From 1 January 2020 the limit value is 0.50% m/m. However, the limitation of sulphur is made via distillates or mixtures and has triggered discussions of availability and the potential safety risks globally. It is believed today that fuel oil availability is not a problem.

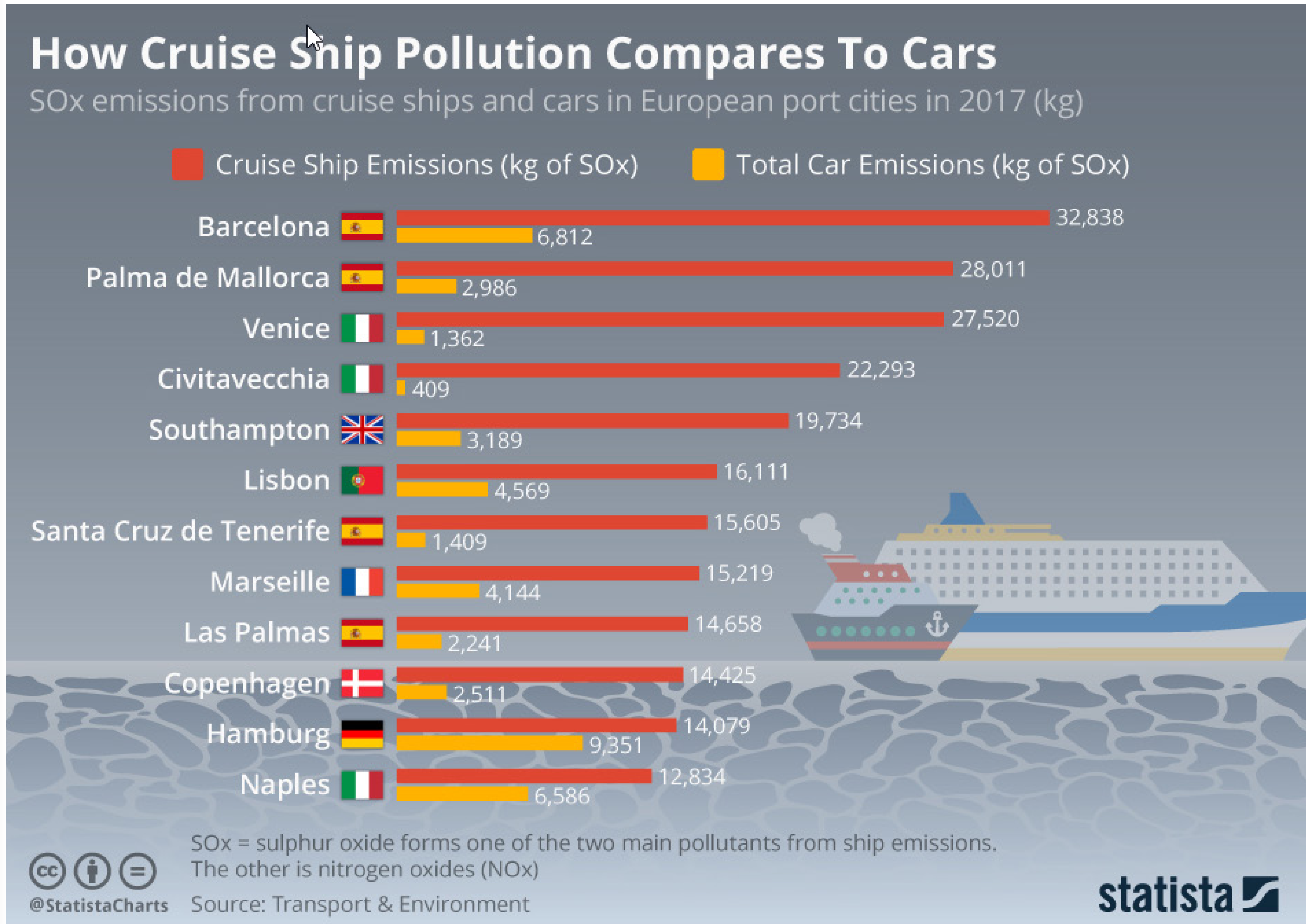


Figure 4.4 A comparison between cruise ships and cars in SOx emissions (source Statista)

There are emission control zones of SOx (SECAs) where the content of sulphur from marine fuels is set at 0.10% m/m. By mid December 2022 a SECA will be adopted for the Mediterranean sea to enter into force in 2025 similar to that in the Baltic and some North America areas.

Instead of using low sulphur content fuels one of the possibilities to comply is established by the regulations allowing the use of accessories, devices or types of fuel that can get emissions equivalent to the limit values. The most common one is scrubbers normally known as (EGRs).

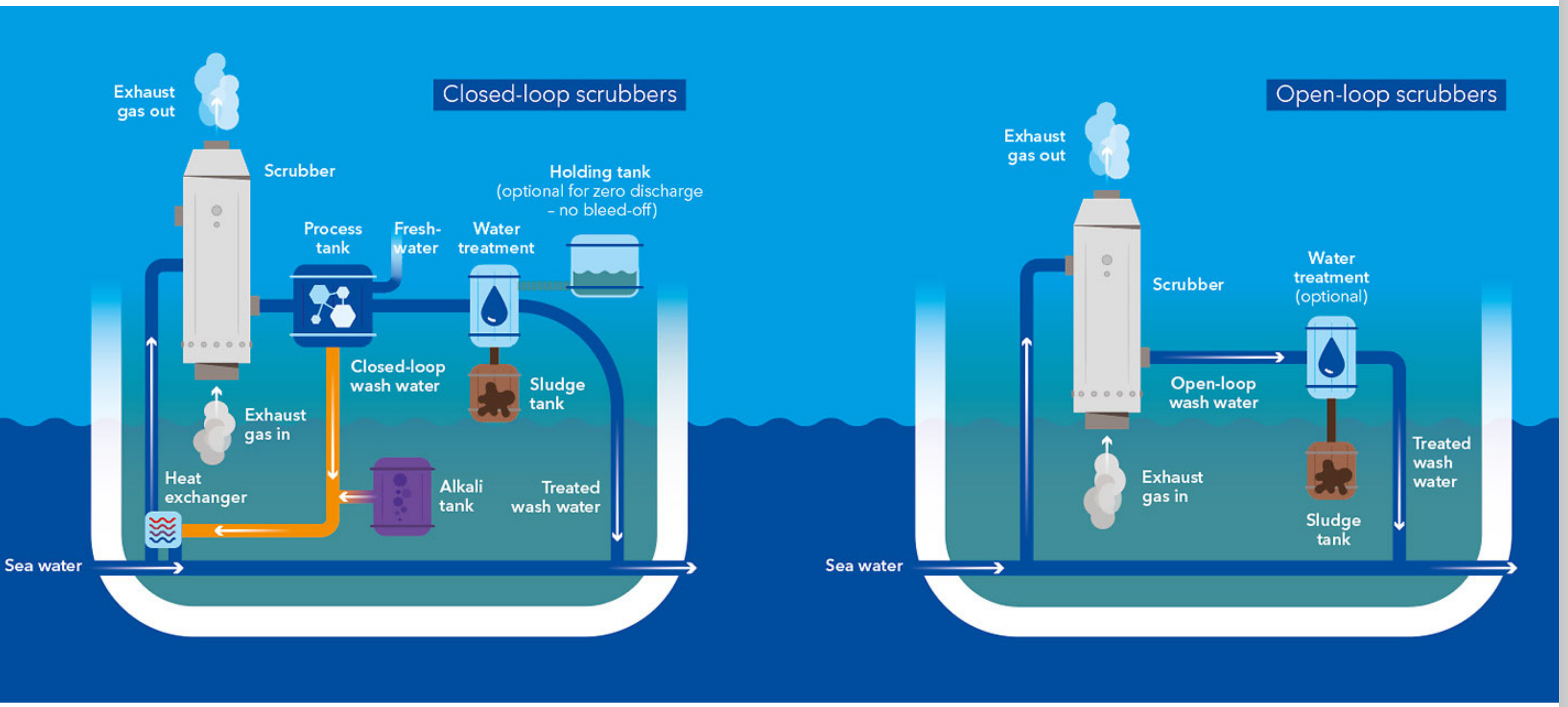


Figure 4.5 Closed loop vs Open loop scrubbers (source DNV)

These are sea water cleaning systems for exhaust gases to remove SOx to obtain a maximum emissions of 6.0 g SOx/kWh and thus reducing emissions.

The deployment of scrubbers led to two systems “open loop”, which discharge into the water, and “close loop” which do not discharge into the water but generate a solid waste that needs to be discharged.

The global discussions are now on the level of pollution caused by open loop scrubbers, their use in ports and the assessment of the areas where they may be used and in the future. Closed loop scrubbers, in the absence of new technologies, might be the only way forward. In the Mediterranean these are being banned on a piecemeal approach by Port Authorities.

4.5 Particulate Matter

Particulate matter (PM) includes a wide variety of solid and liquid particles, some visible, such as dust, pollen, soot or smoke, and others microscopic. A broad classification can be made as follows: PM_{10}, inhalable particles of 10 µm diameter and smaller; $PM_{2.5}$, fine particles of less than 2.5 µm diameter; and $PM_{0.1}$ ultra-fine particles of less than 0.1 µm diameter. An average human hair is about 70 µm in diameter. Of these, $PM_{2.5}$ (which by definition includes the ultrafine particles) poses the greatest risk to health and is often the cause of reduced atmospheric visibility-. $PM_{2.5}$ from shipping forms during the various combustion processes on board.

In ports an increase in PM_{10} (PM with a diameter of 10 µm or less) and $PM_{2.5}$ concentrations can also be observed due to loading, unloading and bunkering operations.

The discussions on particular matter on cruise ships are often mixed with the discussions on sulphur. This is because there is a direct relationship between the SOx and NOx emitted by ships and the resulting PM. A fraction of SO_2 emitted from the engines reconverts into SO_3 which almost immediately forms sulphates ($PM_{2.5}$). In the atmosphere, SO_2 is also transformed into particulate sulphate ($PM_{2.5}$).

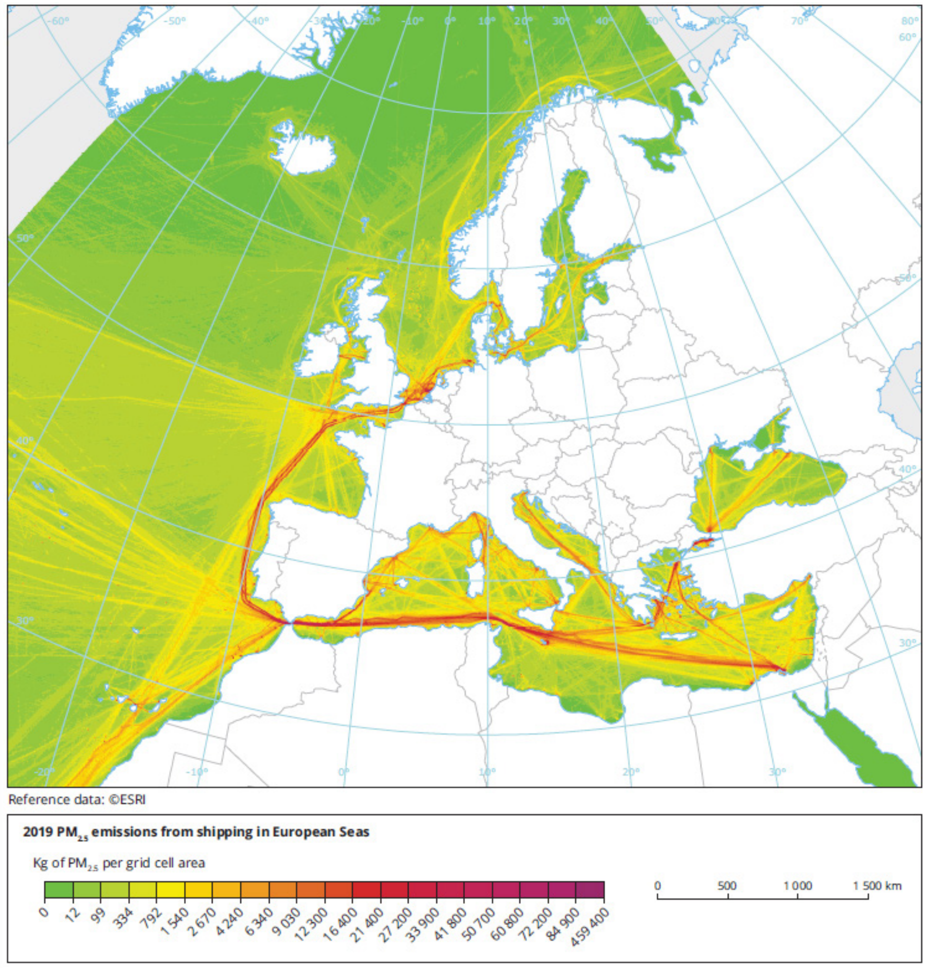


Figure 4.6 PM2.5 emissions from shipping in European Seas

Black carbon (BC), also known as “soot”, is a small, strongly light-absorbing dark particle emitted following the incomplete combustion of organic carbon-based fuels. With a diameter between 20 nm and 50 nm, it is one component of $PM_{2.5}$ mass, the contribution of which is dependent on the combustion source.

As a result of its dark colour, BC absorbs a high proportion of incoming solar radiation, directly warming the atmosphere, where it has a short atmospheric lifetime — days to weeks — before sinking to the ground or being washed out by rain. The strength of this light absorption varies with the composition, shape, size distribution and mixing state of the particle. As a fraction of PM, BC also contributes to the adverse impacts of PM on human health.

When BC settles on snow or ice, it darkens them and reduces their ability to reflect sunlight, leading to increased heat absorption and melting. Substantial pressure has been exerted on the cruise ship industry due to its black carbon emissions, which is mainly sorted out using light fuel distillates.

The climate change effects of BC emissions from shipping are increasingly well understood. Estimates indicate that BC was responsible for 6.85% of the global warming[6] contribution from shipping in 2018, while CO_2 contributed 91.32%. The impact on warming at a regional level can be more pronounced. This is the case in the Arctic, where direct emissions of BC from ships contribute more to warming than elsewhere. This adds to temperature increases in the Arctic that are already much faster than in other parts of the world

Engines using LNG do not produce soot, therefore cruise ships using LNG are in compliance with SOx and PM requirements.

Current regulations on the sulphur content of marine fuels and NOx emission controls also affect trends in emissions. In particular, lower sulphur content marine distillate fuels should also reduce $PM_{2.5}$ emissions, however the IMO cannot reach a direct agreement on black carbon control.

[6] Global warming refers to an increase in global surface temperature expressed relative to a baseline (eg pre-industrial times 1850 to 1900) and averaged over a specified period (eg 20, 30 or 100 years)

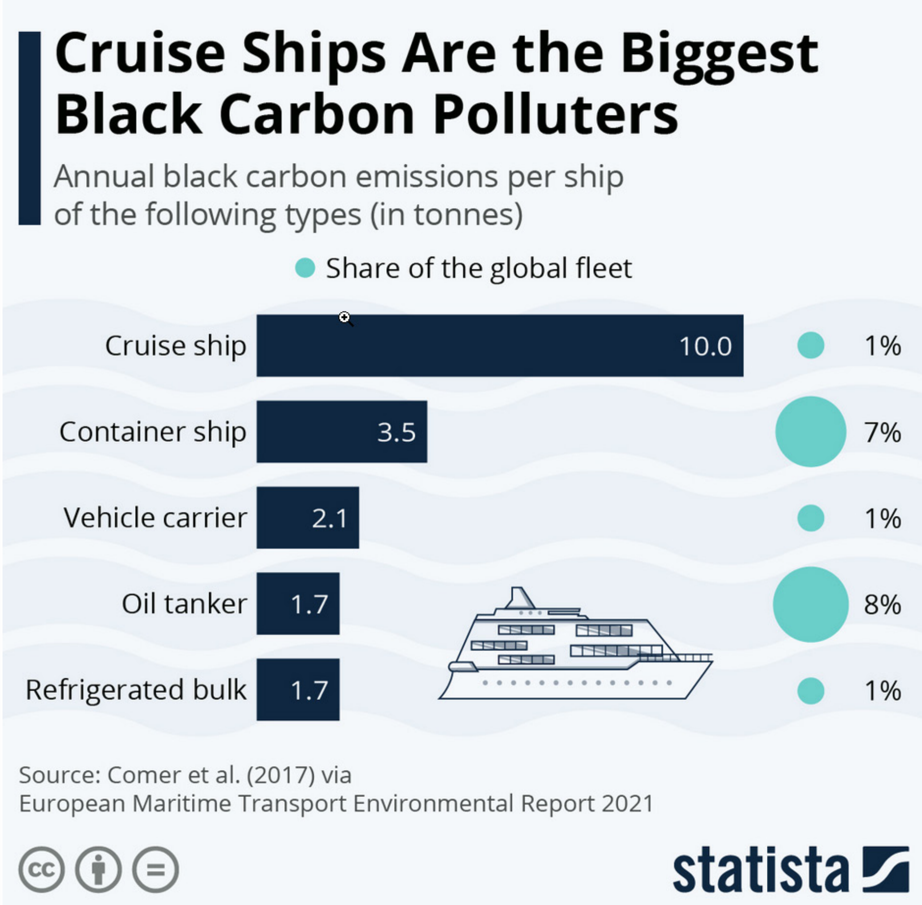
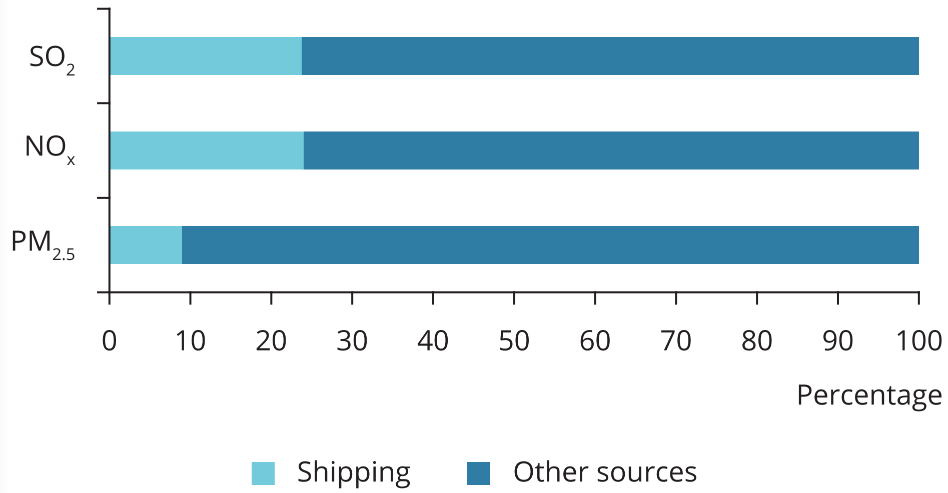


Figure 4.7 Cruise ships in focus for black carbon (source Statista)



Note: No_x, nitrogen oxides, $PM_{2.5}$, particulate matter with a diameter of less than 2.5 μm, SO_2, sulphur dioxide.

Source: EEA (2020b).

Figure 4.8 Proportion of air pollutant emissions from shipping versus other sectors for the EU 27 and Uk in 2018 (source EEA 2020b EMTER)

4.7 Incineration

Incineration is used on cruise vessels to burn wastes. It is very important to note that some substances are prohibited: residues of cargoes subject to MARPOL Annex I, II or III or related contaminated packing materials; polychlorinated biphenyls (PCBs); garbage, as defined by Annex V, containing more than traces of heavy metals; refined petroleum products containing halogen compounds; sewage sludge and sludge oil either of which are not generated on board the ship; and exhaust gas cleaning system residues.

Shipboard incineration of polyvinyl chlorides (PVCs) is prohibited, except in shipboard incinerator for which an IMO Type Approval Certificates is provided.

Despite the above Shipboard incineration of sewage sludge and sludge oil generated during normal operation of a ship may also take place in the main or auxiliary power plant or boilers, but in those cases, shall not take place inside ports, harbours and estuaries.

In cruise ships food is sometimes incinerated, reducing the overall volume of the waste onboard. Reducing waste is an economic method that may be employed by the companies as large wastes being carried around means more will be unnecessary fuel usage, however the problem is that atmospheric pollution is increased.

4.8 Fuel Quality and Availability

The issue of fuel quality and availability was normally considered to ensure safety conditions on board in the 80s. At that point in time nuclear power and coal were discarded as marine fuels. LNG was a marginal fuel used in LNG carriers. Fuel oil quality was something that was just controlled at private level, mainly after bunkering, and fuel samples were taken and analysed for liability purposesand to prevent damage to the engine However, with the development of IMO regulations for the prevention of atmospheric pollution there was a need to regulate FO quality because of SOx and also to ensure air quality.

In terms of atmospheric pollution the most important aspects to take care about was due to blends of hydrocarbons derived from petroleum refining, which have to be free from inorganic acid; not including any added substance or chemical waste which jeopardized the safety of ships or adversely affects the performance of the machinery, or harmful to personnel, or contributes overall to additional air pollution. In case it was not derived from petroleum it should not exceed the applicable sulphur content set forth in or cause engine to exceed the applicable NOx emission limit. However, the use of biodiesels such as FAMES to reduce SOx and in the future to lower GHG emissions and the need to mix fuels to lower the sulphur content makes fuel quality a a more important issue, which will be key in the future due to the need to lower GHG emissions. In this regard biofuels will be a way forward for some years and the discussion on fuel oil quality will continue.

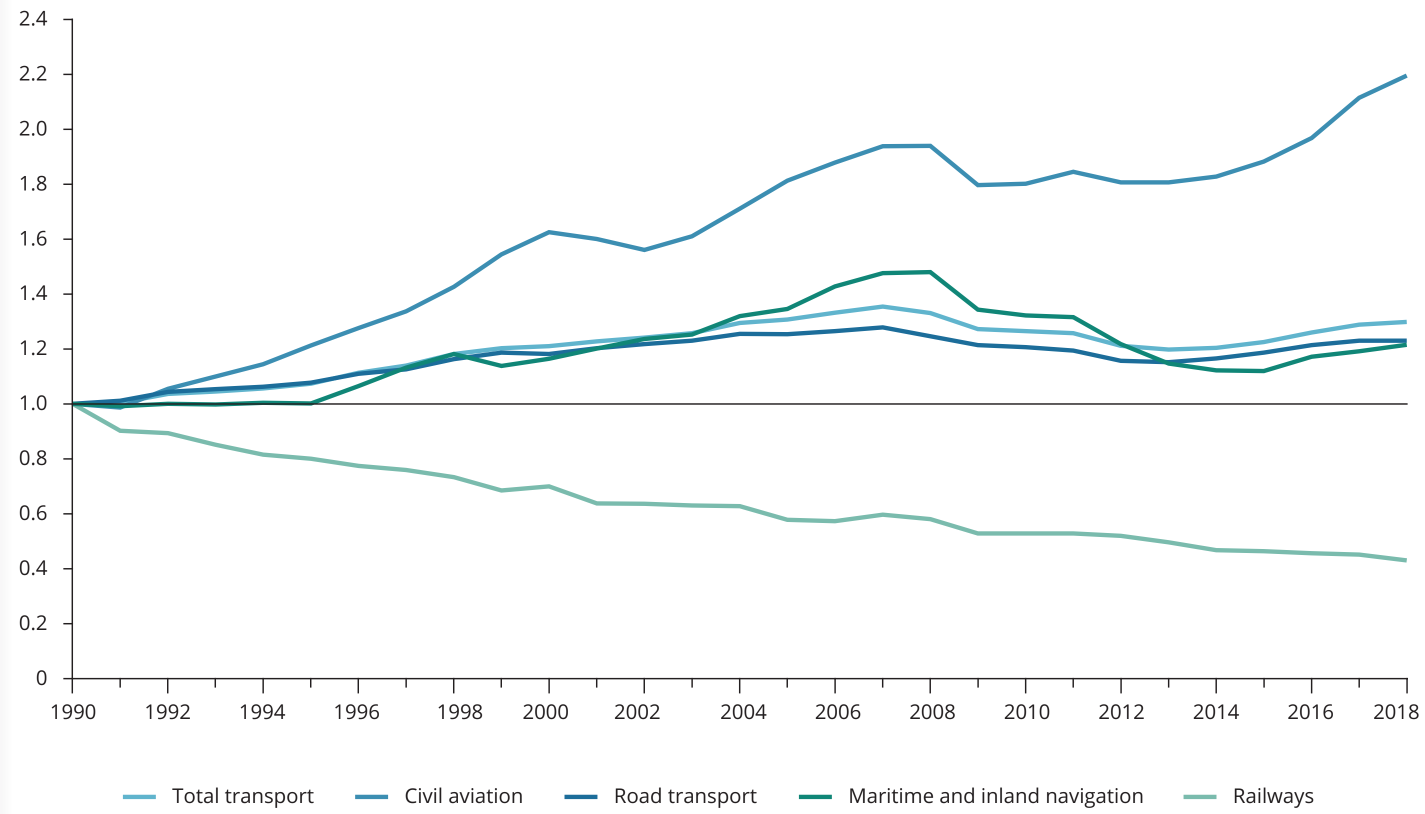
Green house gases. An outlook

Addressing GHG in detail was one of the pending issues in the maritime sector until the end of the 2010´s. The maritime industry is put on focus due to the need to reduce overall greenhouse gas emissions, and this is probably the most interesting discussion that will take place in the shipping fora in the next 10 years.

The issue greenhouse gases (GHG) is triggering a revolution in the sector where due to the market forces and the amount of energy needed to move a ship while shipping is considered a hard to abate sector. In accordance to the Fourth IMO GHG Study 2020, the international shipping sector accounts for an estimated 2.89% of the global GHG emissions.

GHGs coming from ships include for the most part carbon dioxide (CO_2) as the result of the combustion of mainly fossil fuels[7] in the ship's combustion machinery (e.g. engines, auxiliary engines, boilers). Methane (CH_4) may be emitted to the atmosphere by ships using gas or dual fuel engines or from the cargo tanks in liquefied natural gas carriers and LNG fuelled ships.

Figure 5.1 EU GHG emissions comparison from transport by mode (source EMTER)



[7] Fossil fuels are carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.

5.1 General concepts. Global Warming Potential and CO_{2eq}

Refrigerants are used in various types of machinery, including those for air conditioning and cargo cooling processes, and various gases are used including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). All of these GHGs affect global warming and climate change. Another gas that will be relevant in shipping is nitrous oxide (N_2O) which may be relevant when ammonia(NH_3) is used as a fuel.

These gases have different global warming potential (GWP), which is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO_2 for a period of time. GWP is 1 for CO_2. For other gases it depends on the gas and the time frame. Methane has GWP over 100 years of 27.9 meaning that, for example, a leak of a tonne of methane into the atmosphere is equivalent to emitting 27.9 tonnes of carbon dioxide in a 100 years period. Similarly a tonne of nitrous oxide, from manure for example, is equivalent to 273 tonnes of carbon dioxide in a 100 years period. Carbon dioxide equivalent[8] (CO_{2e} or CO_{2eq} or $CO_{2\text{-}e}$) is calculated from GWP and for any gas, it is the mass of CO_2 that would warm the earth as much as the mass of that gas.

[8] Carbon dioxide equivalent ($CO_{2\text{-}eq}$)[1] emissions is a metric measure used to compare emissions from various greenhouse gases (GHGs) and other substances based on their global warming potential (GWP). Equivalent emissions are calculated by multiplying the mass of a substance by the GWP of that substance. It provides a way to compare the impact on global warming of different substances. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas.

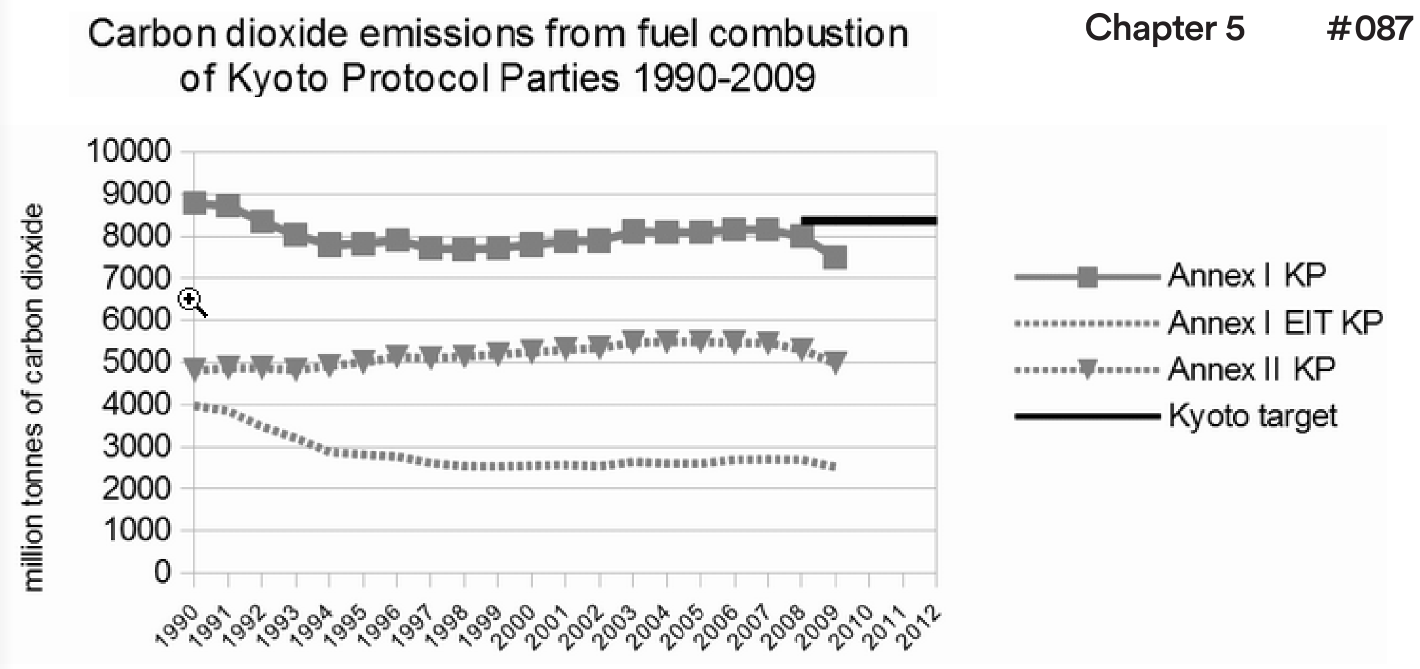
For the purpose of this document we may estimate that fuel oil, when combined with air in the engine is mostly turned into CO_2 together with NOx, SOx and particulate matter. One ton of liquid fuel will be turned into roughly 3 tonnes of CO_2, but other fuels will be different. This issue is a little more complex for methane which is known as LNG in its liquid form. When burning methane (CH_4) CO_2 is produced and it has a CO_{2eq} of 1, however CH_4 coming from LNG has been handled on board the ship and it doesn't fully burnt. Once evaporated part of it may leak into the atmosphere or not burn by the engine. These are called fugitive emissions. Although the carbon equivalent of 1 ton of CH_4 fully burnt may be lower than 1 ton of liquid fuel oil (15% lower), the fugitive emissions of CH_4 may increase the CO_{2eq} produced in the whole process because that CH_4 has a GWP higher than CO_2. This may increase the emissions and have a total CO_{2eq} similar or higher, meaning that the benefits will be compensated by the penalties due to fugitive emissions. This is one of the reasons why the maritime industry may consider LNG as a transitional fuel and why there is so much preassure on fossil LNG as a fuel.

5.2 From Tokyo Protocol to Paris Agreement

The Kyoto Protocol was an international treaty from 1997 which extended the 1992 United Nations Framework Convention on Climate Change (UNFCCC). It commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that global warming is occurring and that human-made CO_2 emissions are driving it. The Kyoto Protocol implemented the objective of the UNFCCC to reduce the onset of global warming by reducing greenhouse gas concentrations in the atmosphere to *"a level that would prevent dangerous anthropogenic interference with the climate system"* The Kyoto Protocol applied to seven greenhouse gases that were listed.

The Protocol was also based on the principle of common but differentiated responsibilities (CBDR): this principle acknowledges that individual countries have different capabilities in combating climate change, owing to economic development, and therefore placed the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases in the atmosphere.

The Protocol's first commitment period started in 2008 and ended in 2012. All 36 countries that fully participated in the first commitment period complied with the Protocol. However, nine countries (Austria, Denmark, Iceland, Japan, Lichtenstein, Luxembourg, Norway, Spain and Switzerland) had to resort to the flexibility mechanisms by funding emission reductions in other countries because their national emissions were slightly greater than their targets. The United States did not ratify, Canada withdrew and the EU got a bubble commitment with only three GHGs to be included – CO_2, CH_4, and N_2O – with other gases such as HFCs regulated separately. The financial crisis of 2007–08 helped reduce the emissions and there was a second commitment up to 2020.



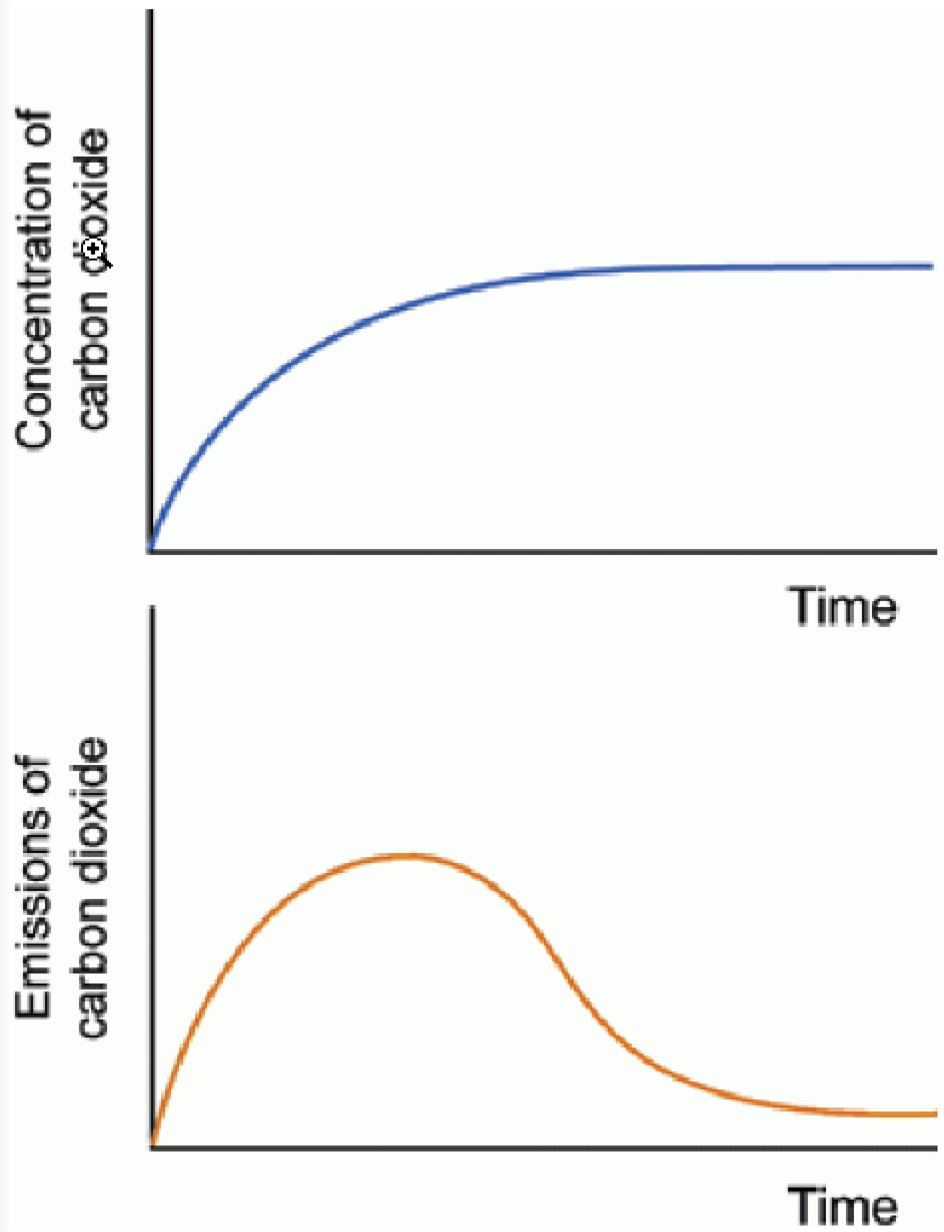


Figure 5.2 and 5.3 Evolution of the emissions in time and how the emissions evolved until 2010 (source Wikipedia)

5.2 From Tokyo Protocol to Paris Agreement

The United Nations Climate Change Conference in Copenhagen in December 2009 was the opportunity to agree a successor to Kyoto that would bring about meaningful carbon cuts. After many negotiations world leaders agreed in a climate summit was held out of which emerged the Paris Agreement of 2015, the successor to the Kyoto Protocol.

The Paris Agreement's long-term temperature goal is to keep the rise in mean global temperature to well below 2 °C (3.6 °F) above pre-industrial levels, and preferably limit the increase to 1.5 °C (2.7 °F), recognizing that this would substantially reduce the effects of climate change. Emissions should be reduced as soon as possible and reach net-zero[9] by the middle of the 21st century. To stay below 1.5 °C of global warming, emissions need to be cut by roughly 50% by 2030. This is an aggregate of each country's nationally determined contributions.

It aims to help countries adapt to climate change effects and mobilise enough finance. Under the Agreement, each country must determine, plan, and regularly report on its contributions. No mechanism forces a country to set specific emissions targets, but each target should go beyond previous targets. In contrast to the 1997 Kyoto Protocol, the distinction between developed and developing countries is blurred, so that the latter also have to submit plans for emission reductions.

In the meantime, in order to approach science to policy, the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) prepare a comprehensive review and recommendations with respect to the state of knowledge of the science of climate change; the social and economic impact of climate change, and potential response strategies and elements for inclusion in future international conventions on climate.

[9] Net zero greenhouse gas (GHG) emissions describes when GHG emissions resulting from human activities are either zero or are balanced by GHG removals resulting from human activities over a specified period. The quantification of net zero GHG emissions depends on the GHG emission metric chosen to compare emissions and removals of different gases, as well as the time horizon chosen for that metric. Net zero means reducing emissions and balancing the remaining residual emissions through removal rather than using *offsets* and/or *insets*. The GHG removal can be achieved either by removing the GHG emissions when the fuel is produced or after combustion.

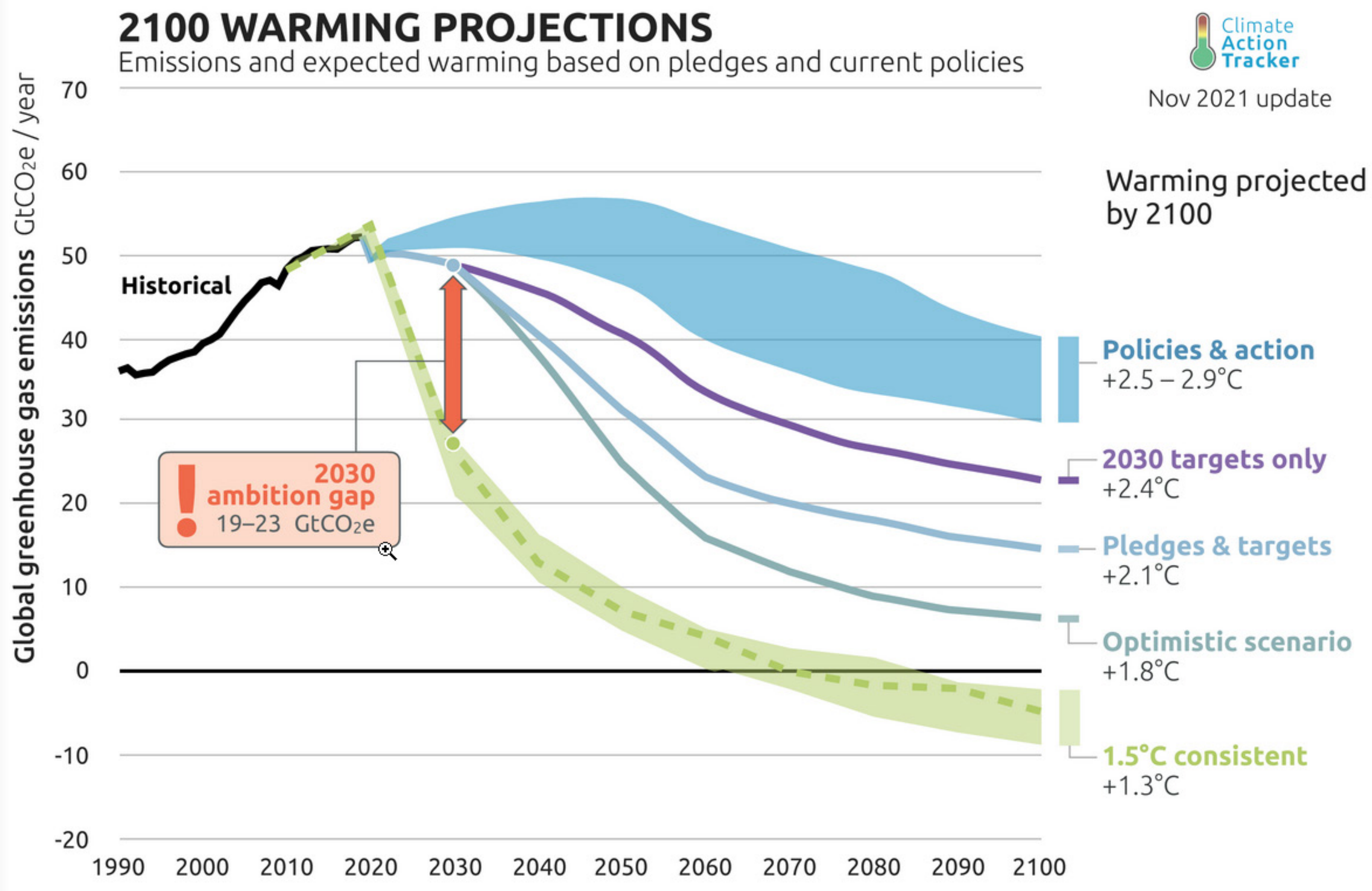


Figure 5.4 2010 Warming projections (source Climate Action Tracker)

What was the role of shipping in this matter? IMO had been submitting fuel oil data consumption to UNFCC since 1994. Looking at the greenhouse gas (GHG) inventories, which are produced under the United Nations Framework Convention on Climate Change (UNFCCC), the contribution from maritime transport could then be calculated. Due to the international nature of shipping this sector, together with aviation, is out of the Paris Agreement.

This stems from the pressure from the IMO in 2009 indicating that unlike land-based industries, which are regulated mainly through national legislation, shipping requires global regulations if it is to function. Hence it was agreed that it was up to the IMO to develop on global measures.

Efficiency, monitoring and data collection towards a global strategy

In this chapter we will refer to technical and operational measures developed by the IMO in an attempt to reduce and to measure and collect data.

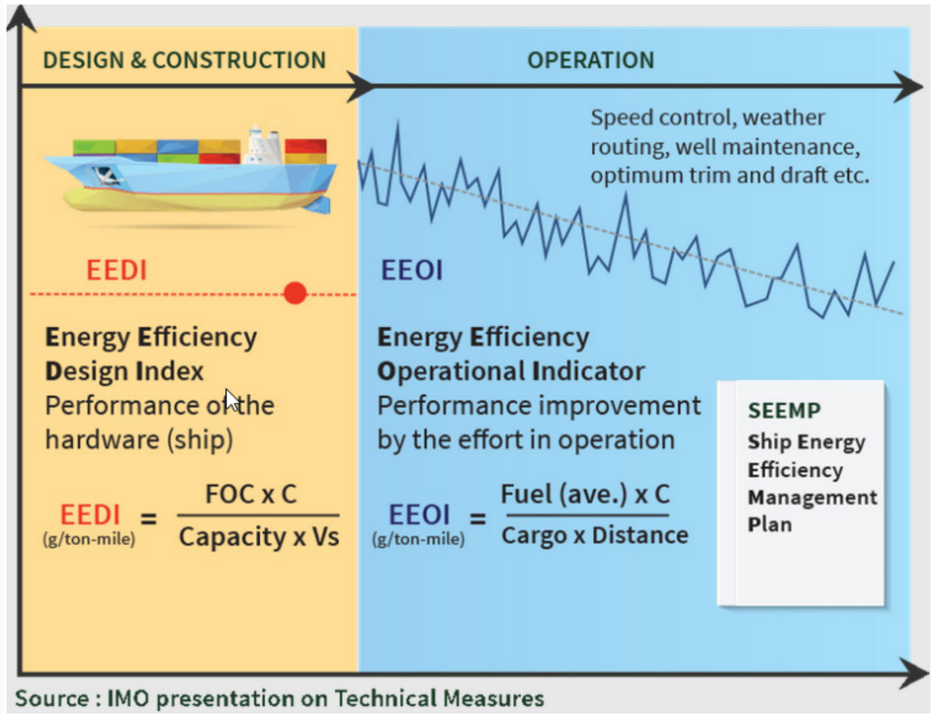
6

6.1 Energy Efficiency Design Index

One of the first attempts to lower GHG emissions from ships were linked to the efficiency. In 2008 IMO introduced the concept of Energy efficiency design Index (EEDI), which is a technical measure applicable to new ships only. This stems from the idea that ships are very efficient in terms of grams per CO_2 per tonxkm, probably the most efficient, and the fact that 80% of the goods are transported by sea.

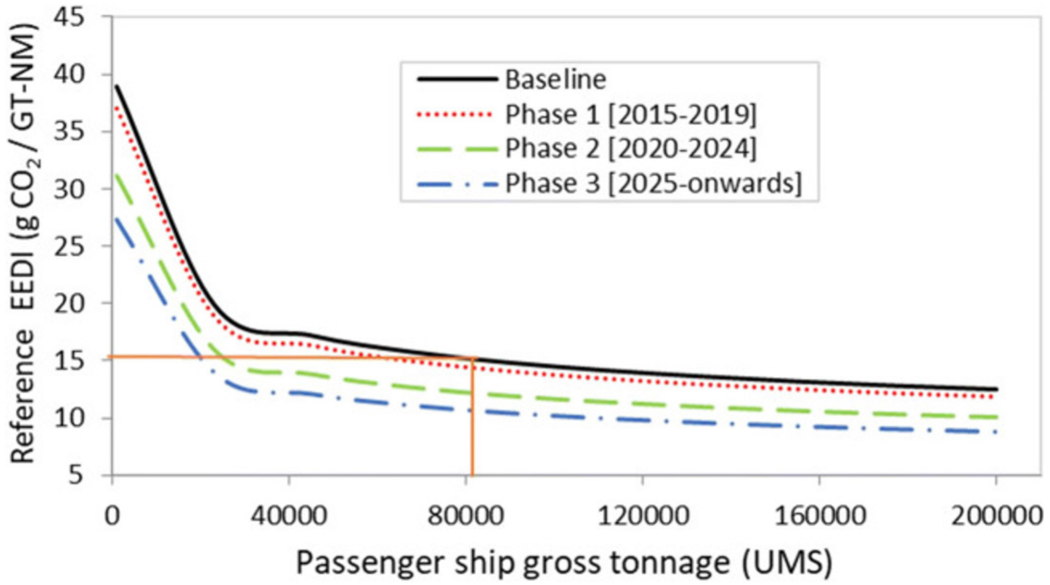
The idea is to calculate the tons of CO_2 emitted per cargo capacity (reference values deadweight[10]- DWT- or GT) at a speed (obtained from sea trials) and therefore the performance of the ship.
The higher the CO_2 emitted the less efficient the ship is, however if the "cargo transported" and/or speed is "high[11]" then the efficiency is high.

Figure 6.1 Different IMO indexes, on the left the EEDI (source IMO)



[10] Deadweight tonnage or tons deadweight (DWT) is a measure of how much weight a ship can carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew
[11] As far as it is achieved with low power, because of the cubic relation between power and speed could have an opposite effect

Figure 6.2 Passenger ships referenced EEDIs based on tonnage (source Evaluation of the environmental and economic impacts of diesel electric propulsion on board ships: a case study passenger vessel)



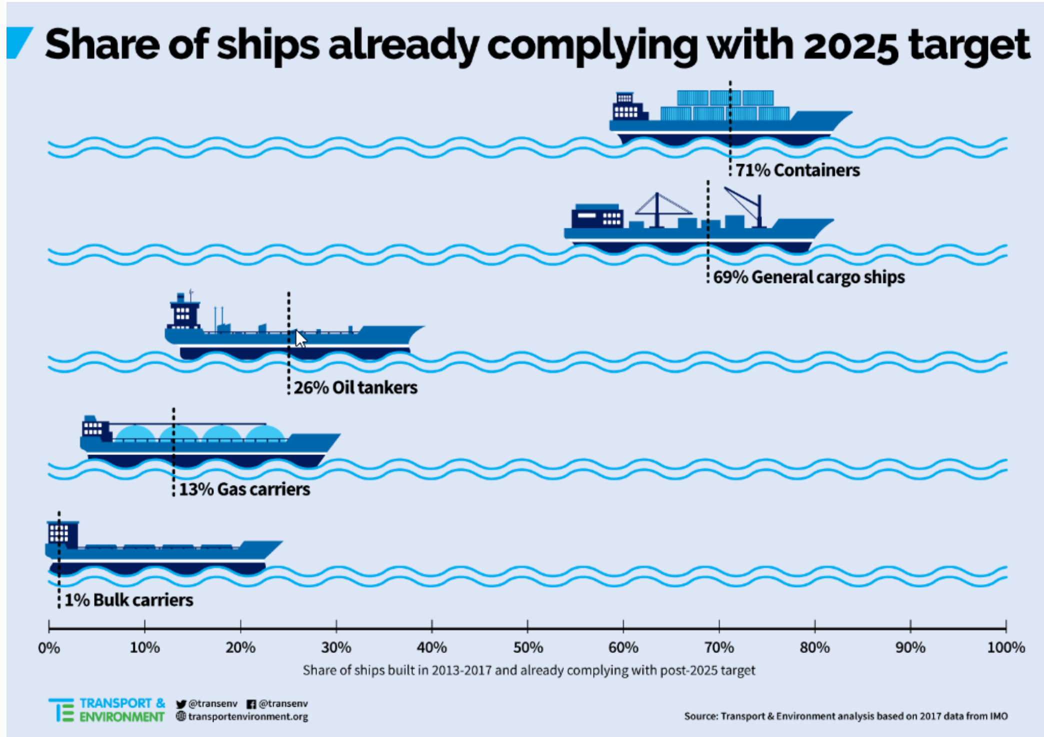


Figure 6.3 Efficiency, Ships outperforming (source Transport and Environment)

The index is calculated determining the CO_2 emitted by the main engine running at a speed at 75% of its rating and the auxiliary engines at full cargo capacity and at reference speed. However, the ship is not always fully loaded, speeds are not always the same and the CO_2 emitted depends on some adjustments.

With the world fleet reference curves from 2008 onwards are calculated, and a ship needs to be below the curve with an attained index. The lower the EEDI, the better.

These indexes were designed for the main ship types and in the passenger ship sector only for Ropax and diesel electric cruise ships. Conventional passenger ships .(not diesel electric propulsion -see pictures in Chapter 1 to this document- or RoPax) were not an easy task, considering that the energy used is very high and they don't have an EEDI.

There were different phases depending on the date of constructions being Phase 3 the one applicable to ships from 2025, however it became obvious that the index was very easy to beat for some ship types such as containers.

There were some attempts to develop mandatory indexes for existing ships such as the EEOI, which is indeed used at EU level for calculations and proxies, however the sector was very reluctant to reveal the real cargo transported.

6.2 Ship Energy Efficiency Management Plans

When the EEDI index was adopted there were other measures to encourage for fuel and emission savings such as the ship energy efficiency management plan (SEEMP), which sets the frame for an operational measure that didn't have fixed goals. However, it is obvious that a company operating a ship wishes to reduce its consumption as much as possible, while increasing the speed and or time spent at sea, since fuel costs may go up to 50% of the Operational expenses of a ship, depending on the fuel prices, and above crew costs.

SEEMP will become important from 2023 as indicated in the following Chapter. One of the questions to be able to reduce emissions was how to obtain a reference value for a ship. A cruise ship is a "volume ship" where most of the space is air and has a relatively low displacement and a low deadweight, while at the same time is typically sailing at medium or large speeds. On the contrary a tanker or a bulk carrier are "displacement ships", with a large part of the hull underwater and low speeds carrying large volumes or weights. The SEEMP allows a ship to set GHG reductions based on its performance.

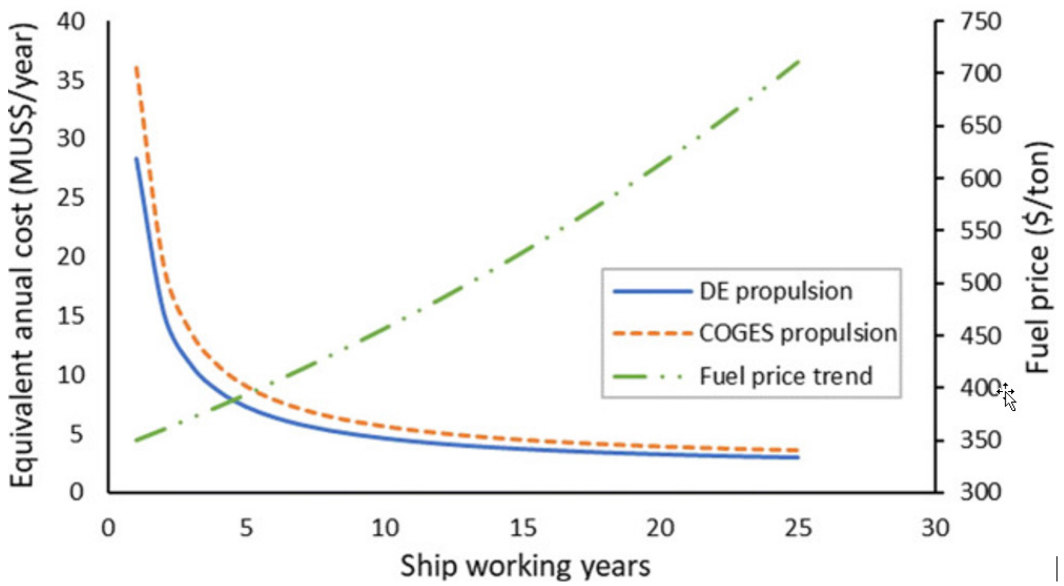


Figure 6.4 Equivalent annual costs per year on a cruise ship depending on the type of propulsion and FO pricesfor a sister ship for the Holland America line passenger vessels designed with a total gross tonnage of 82,897 (source Evaluation of the environmental and economic impacts of diesel electric propulsion on board ships: a case study passenger vessel)

6.3 EU Monitoring Recording and Verification and IMO Data Collection Systems

Having a figure of the CO_2 emitted by ships was then needed. This was useful to develop good proxies for the "transport work" (distance multiplied by the actual cargo carried) and fuel used to develop measures for existing ships. This would also allow in the future to implement a market-based measure (levy or emission trading scheme where for each ton of CO_2 emitted a price would be paid). Therefore, the discussions started developing a data collection system which quickly lead to two different systems. Firstly, the IMO system which is called data collection systems (IMO DCS), to start measuring from 2018 and have a first data collection available in 2019 and secondly the EU MRV, adopted in 2016 and measuring from 2017. Both require annual reporting, apply to ships from 5000 GT and this includes most cruise ships. They need accredited verifiers.

But why two different systems? Why an EU MRV and an IMO DCS? The answer is in European Commission's 2011 White Paper on transport which suggested that the EU's CO_2 emissions from maritime transport should be cut by at least 40% of 2005 levels by 2050, and if feasible by 50%. In June 2013 the European Commission set out a phased strategy for progressively integrating maritime emissions into the EU's policy for reducing its domestic GHG emissions. The strategy consisted of three consecutive steps: (1) monitoring, reporting and verification of CO_2 emissions from large ships using EU ports; (2) GHG reduction targets for the maritime transport sector; and (3) the development of further measures in the medium to long term. IMO did not have this goal around 2013 and EU required a system with more data such as the MRV. The EU scheme was aiming at publicly made emissions available to provide transparency and bring the focus to the sector to encourage further measures. On the contrary the IMO DCS is confidential, the amount of data to be provided is limited and was mainly design for data collection on fuel consumption and distance to estimate fuel consumed for a soft "transport work" (not actual

6.3 EU Monitoring Recording and Verification and IMO Data Collection Systems

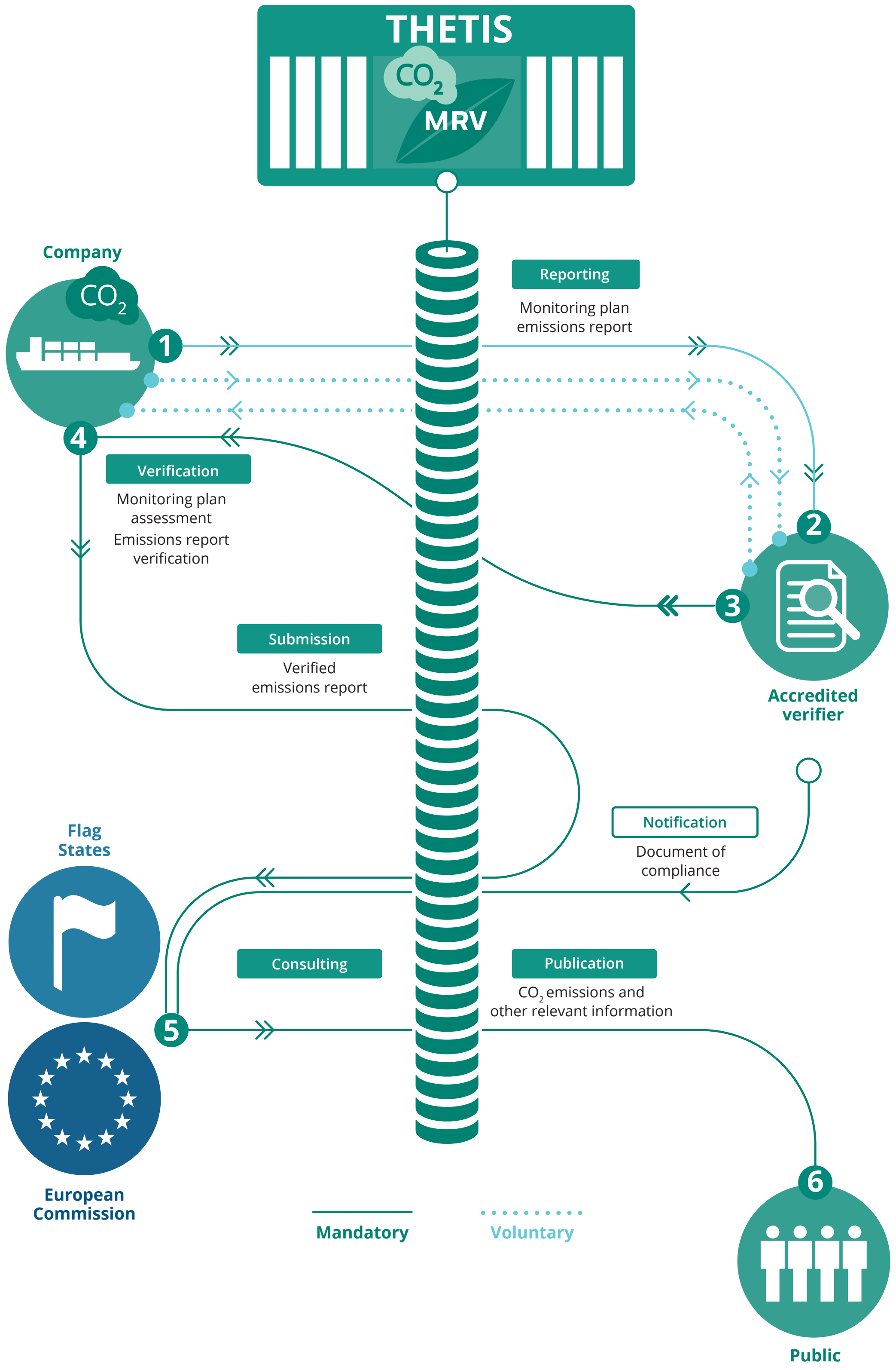


Figure 6.5 EU MRV data collection system (source EMTER)

6.4 IMO GHG studies and IMO Strategy

cargo carried).
The first IMO Study on Greenhouse Gas Emissions from Ships was completed in 2000, soon after the adoption of MARPOL Annex VI in 1997, using data from 1996. It estimated that ships emitted about 420 million tonnes of CO_2 and thereby contributing to about 1.8% of the world's total anthropogenic CO_2 emissions that year.

Since then IMO has prepared GHG studies. However, the initial figures were very rough and coupled with the seaborn trade estimated by UNCTAD (growing trade means growing emissions). The first emissions that are considered consistent enough are those from 2012 onwards, which considered also a bottom up approach. 2012 is the reference value used at IMO, that needed to be extrapolated to 2008, which is the year taken as a reference for the databases to measure efficiency. In 2012 the emissions were 962 million tonnes of CO_2 and in the latest, in 2020, 1056. It was also estimated that the demand of energy would peak around 2030 and oil fuels needs to be phased out.

For the first time in 2020 the study included estimates of carbon intensity. Overall carbon intensity has improved between 2012 and 2018 for international shipping, as well as for most ship types. The overall carbon intensity, as an average across international shipping, was between 21 and 29% better than in 2008. The figures are more accurate now, although there are some slight differences when considering actual cargo carried (demand based) versus available tonnage or weight in the fleet (supply approach) and considering tons per nautical mile. Indexes such as EEOI (demand based-see figure 6.1) allowed to considered actual cargo carried but others such as AER (supply based- CO_2 per transport work) consider deadweight or tonnage, meaning that an empty ship accounts for emissions as if it was loaded.

In 2018 the Initial IMO Strategy on reduction of GHG emissions was adopted with the following objectives:

6.4 IMO GHG studies and IMO Strategy

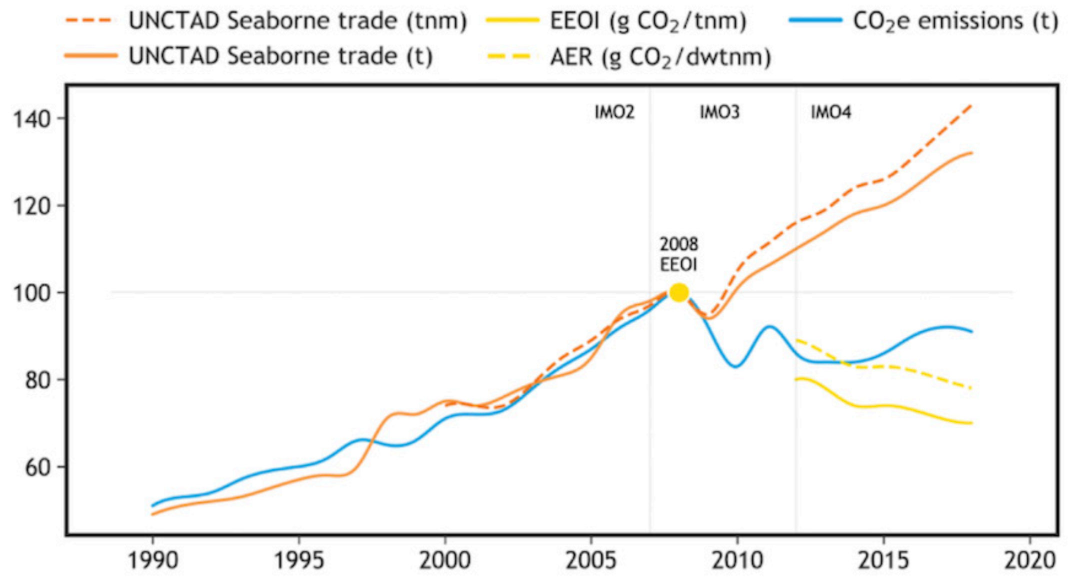


Figure 6.6 International shipping emissions and trade metrics indexed in 2008 for the period 1990-2018 according to voyage-based allocations (source IMO GHG 2020)

- Reduction of CO_2 emissions per transport work (carbon intensity), as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008; and
- A reduction of the total annual GHG emissions from international shipping by at least 50% by 2050 compared to 2008, while, at the same time, pursuing efforts towards phasing them out as called for in the vision, for achieving CO_2 emissions reduction consistent with the Paris Agreement goals.

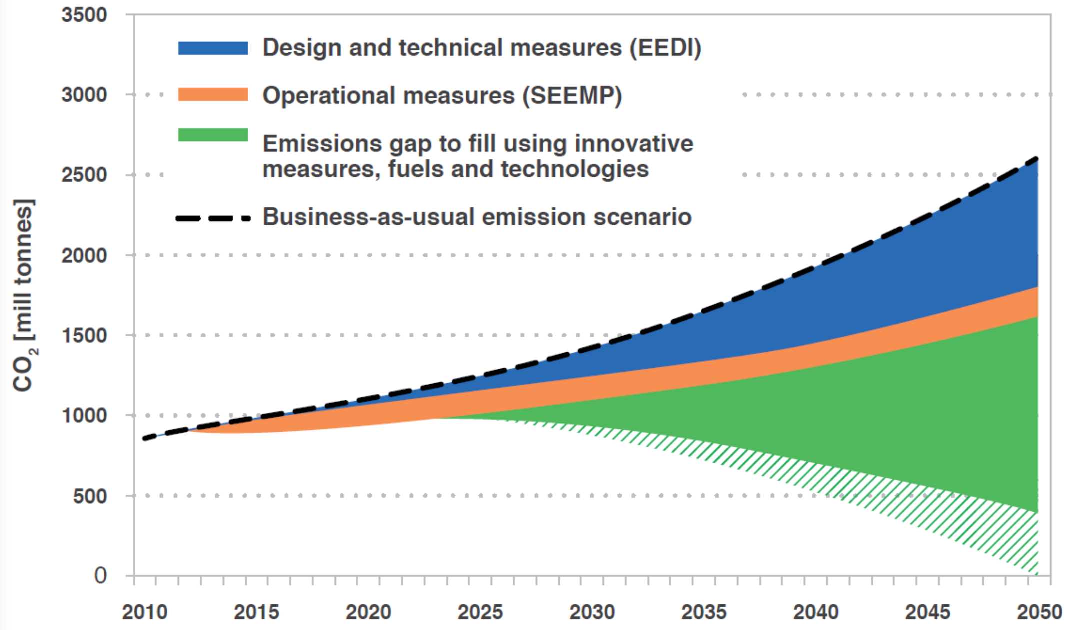


Figure 6.7 IMO projected scenarios for the 2018 Strategy (source IMO)

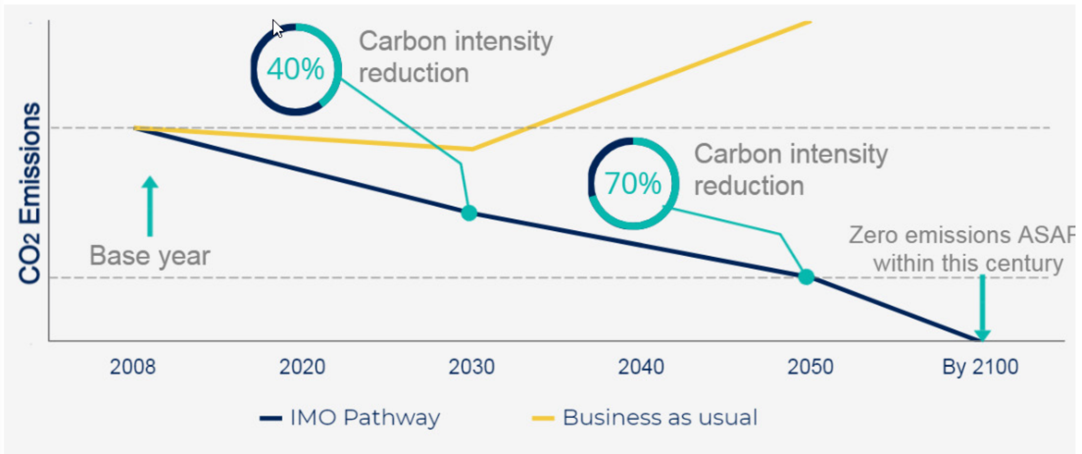
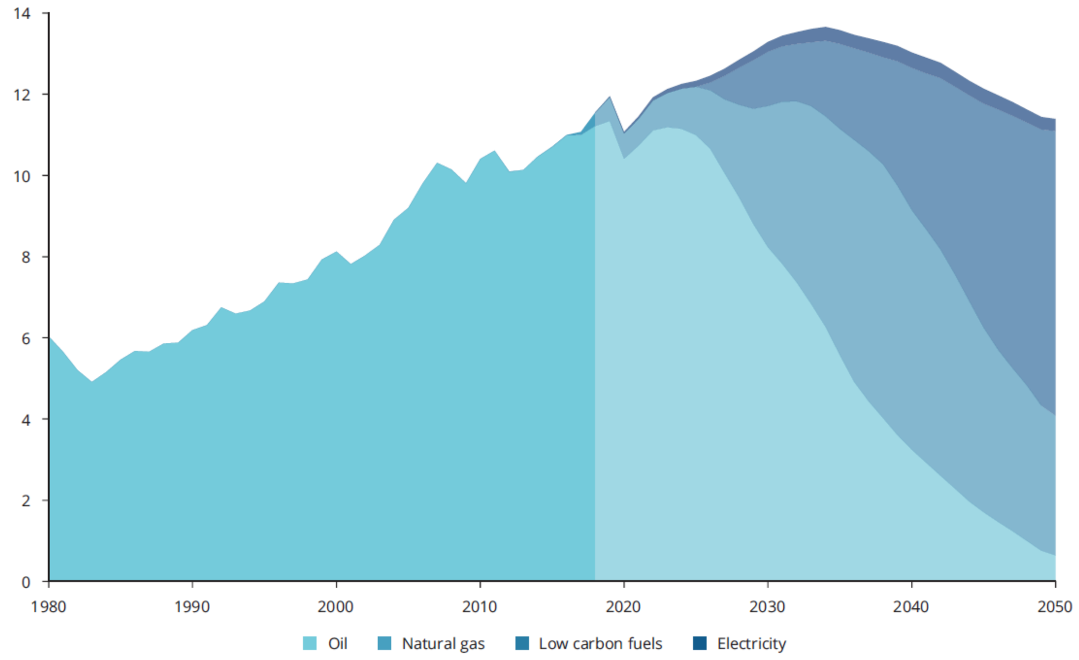


Figure 6.8 CO_2 emissions in the IMO 2018 pathway (source DNV)



Note: For this Figure natural gas includes liquefied natural gas (LNG) and liquefied petroleum gas (LPG). Low carbon fuels include ammonia, hydrogen and synthetic fuels.

Source: DNV GL (2020b).

Figure 6.9 World maritime subsector energy demand by energy carrier 1980-2050 (source DNV)

This degree of ambitions is not enough to meet the Paris 2015 goals. Terminology such as "pursues efforts"is vague and, in addition the ambition is set at 50% reductions "by" 2050.

In the meantime, the cruise line sector was under pressure due to its visibility and its emissions per person and km in comparison to other transport modes. Cruise ships double as floating hotels, not only a transport system so it's fair to also consider emissions from hotel stays for those who fly. As an example, according to a 2021 tool from Cornell it has been indicated that a *1 night stay in a 4-star hotel in the United States results in about 30 kilograms of carbon dioxide equivalent emissions (kgCO_2e) per room per night. Assuming that there are two people per room, emissions can be cut by half. So, if one person goes on a 5-night cruise that covers 2,000 km, at 250 gCO_2/pax-km (the most efficient cruise ship line) that*

passenger is responsible for 500 kgCO_2. The same person flying by jet would emit 160 kgCO_2 on an average airline. Adding in the hotel emissions means an extra 15 kgCO_2 per night, so 75 kgCO_2, and the total is 235 kgCO_2. In this example, even accounting for emissions from an equivalent-night hotel stay at a 4-star U.S. hotel, a passenger on a cruise ship would lead to twice more CO_2 than someone who flies and stays in a hotel .

As an attempt to become environmentally more sustainable CLIA indicated that cruise lines were the first in the maritime sector to publicly commit to reducing the rate of carbon emissions 40 per cent by 2030. And at COP26 in 2021, Carnival was one of 500 organisations to sign the Glasgow Declaration on Climate Action in Tourism, committing to halving its emissions by 2030 and achieving net-zero by 2050.

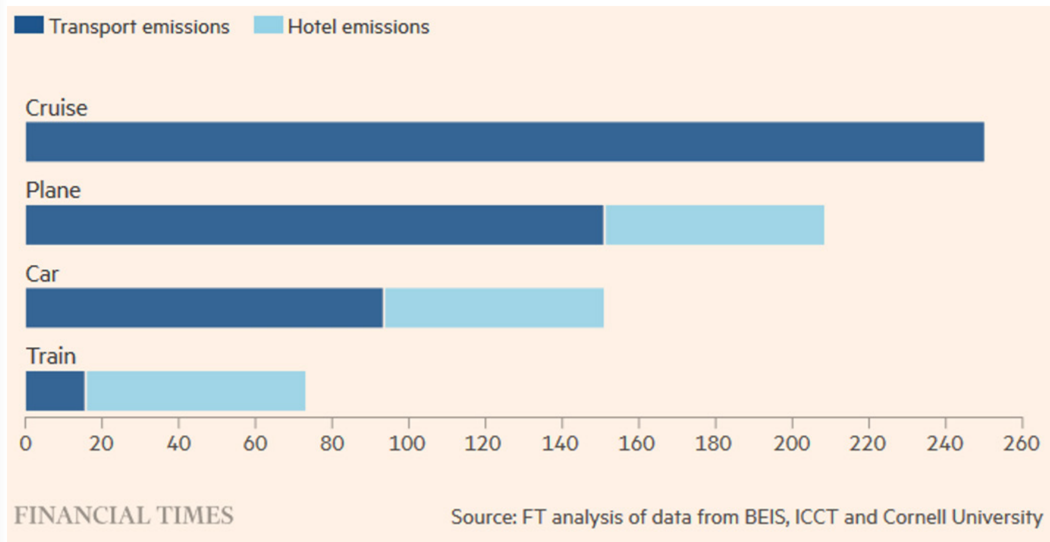


Figure 6.10 Transport emissions (source Financial Times)

6.5 Port Infrastructure to reduce GHG atmospheric pollution. On shore Power Supply

Cruise ships are made of steel, which is an extremely bad insulating material that demands a large amount of energy for air conditioning or heating. Multiple indoorspaces without natural light need illumination, refrigeration, pumps, communications and other critical on-board equipment are needed to maintain essential function and safety of the ship. When a ship is hotelling, the main propulsion engine(s) is/are turned off while the auxiliary engines and boilers continue to operate.

In this regard, on top of the services indicated in Chapter 3 ports need to provide infrastructures to support decarbonization and reduce environmental pollution from shipping. Facilities are needed to collect residues from the EGCS', ozone depleting substances but due to the pressure to stop emitting gases at port are leading towards the implementation of "cold ironing" or onshore power supply (OPS), mainly oriented to particular ship type such as cruise ships, that would have a high electricity demand.

The use of OPS does eliminate the need to run the auxiliary engines and eliminates air emissions associated with the burning of marine fuels at berth.

The actual emissions reduced by OPS' depend on the type of engine and engine technology, and the type of fuel that is being burned. It should be noted that the use of shore-power does not eliminate all of them, like fired boilers.

Depending on the type and size of the ship and the length of the call, hotelling time can range from several hours to several days. Since the specific consumption of fuel for power generation at the European cruise terminals is available the fuel consumption per hour and the KW requirement for the port operations can be calculated. These figures vary significantly at sea where all sources are driven by shipboard power as indicated in Chapter 1.

Figure 6.11 Onshore power supply for a cruise ship (source Stemmann-Technik)

For an OPS the shore-side electrical system consists of cables and a substation to transfer electricity from the local grid; voltage transformers to step down the voltage from local power grid to 6.6 kV or 11 kV to adapt to cruise ship voltage and frequency; and, a specially designed dock-side gantry cable system for connection to accommodate tidal fluctuations. Suitable cables need to be used for electrical connection.

On the shipside, cables are connected using male/female plug-and-socket system for easy handling, which need to be standardized. On-board power management software needs to be used to automatically synchronize, combine and transfer. While synchronization of the ship with shore-power is mandatory for passenger ships, any disruption of power to passenger services should not be acceptable.

6.5 Port Infrastructure to reduce GHG atmospheric pollution. On shore Power Supply

Condition	KWh at Port	KWh at Sea	Avg. Fuel Usage
Cruise Vessels (up to 200 meters)	943	2403	0.15 / 0.20
Cruise Vessels (above 200 meters)	1111	3833	0.20 / 0.31

Table 6.12 Cruise ship energy demand at port vs at sea (source Cruise Market Watch)

Therefore, the necessary investments to provide onshore power are not low both on ship side and shore side with some challenges: shore side infrastructure requirements, electrical requirements and cable management with a large capital investment.

In one example the overall cost of a program was estimated high, including 2.5 million US$ for construction and equipment ashore which (could be in the range of 1.5 to 3.0 million US$). Shore side infrastructure capital costs with an approximate range of 500,000 US$ to 1.5 million US$ for on-pier electrical supply fixed costs, and 500,000 -700,000 US$ to convert each ship, however, the retrofit cost would be reduced proportionally according to the number of ports where it used shore-side power.

For an average length of a call of 12 hours and daily power usage on-board could go around 100,000 kilowatts and an average power cost of$4,000 to $5,000 per day for power in a cruise ship, which is slightly higher than diesel fuel cost of $3,500 per day if auxiliary engines were used while in port.

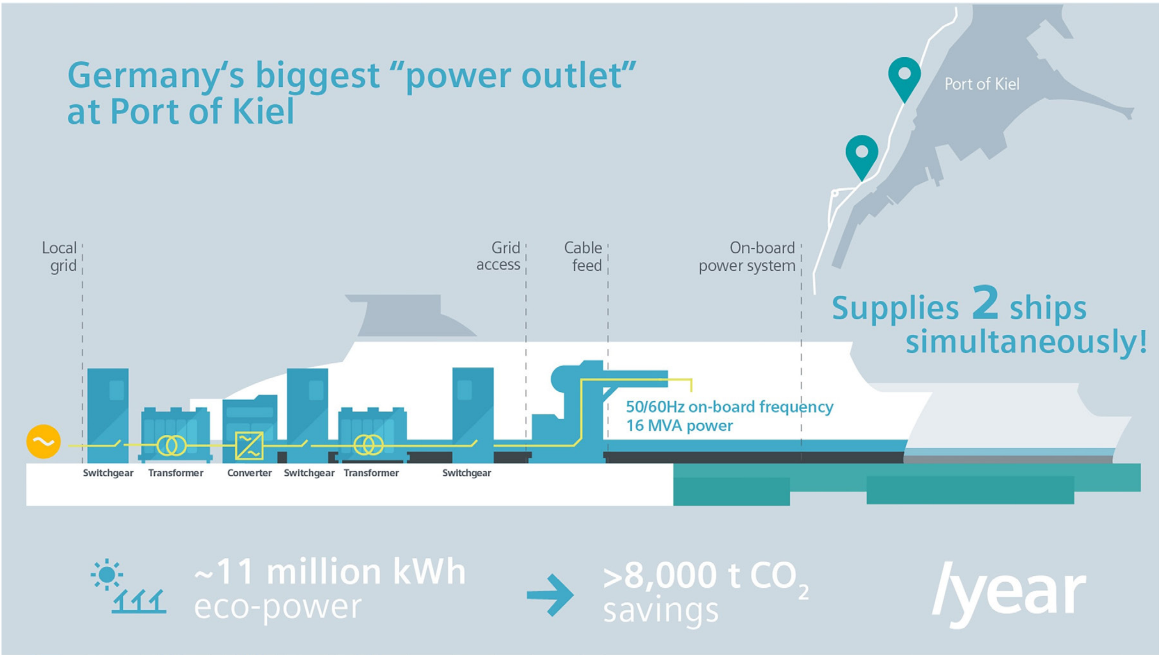


Figure 6.13 OPS Schematic Power diagram and figures (source Port of Kiel)

However, this depends on the rates kWh. Overall time required for cable connection and power synchronization and transfer could be 40 minutes, and the disconnection time approximately 30 minutes.

The industry has vowed to power its boats, when in port, using electricity from 2030. Cruise ships are the most advanced one in terms of installation and preinstallation of onshore power supply in comparison with other ship types, but only a third of global cruise ships have the technology to support it and, currently, there are only seven berths across Europe's 350 cruise ports equipped to accommodate it. The effort to be made in the sector is enormous.

Catalising the maritime sector. Reduction of intensity and efficiency for existing ships globally

This chapter will lead through measures aiming to help stakeholders develop a mindset of ongoing improvement, where modifications both small and large can ultimately drive down onboard carbon emissions and will also discuss lifecycle analysis and future fuels

7.1 Carbon Intensity Indicator

When the IMO agreed on a global strategy it was indicated that there would be short and mid term measures. Since the initial strategy would be revised in 2023 there was a very strong momentum to set the base for some operational and technical measures, that could be used for the implementation of midterm measures (levy, market-based measures, etc).

Once the IMO had set a reduction target for 2030 there was a need to identify whether the Organization was in a good path as well as setting an operational measure to ensure this. At a very fast speed the carbon intensity indicator, otherwise known as CII, was developed for cargo and passenger ships from 5000 DWT/GT which are the ones already included in the data collection system as a new generation of measures with high impact.

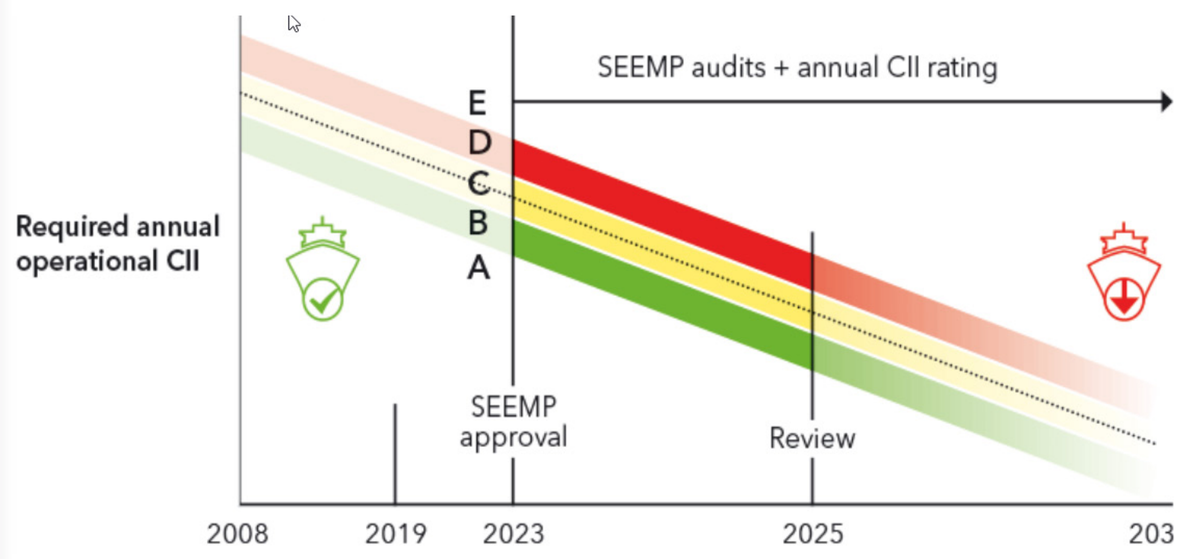


Figure 7.1 Carbon intensity indicator (CII) bands of compliance and implementation calendar

7.1 Carbon Intensity Indicator

With this index ships are categorized either as A,B,C,D,E depending on the distance to average values. This indicator measures the CO_2 emitted per nautical mile and per ship's capacity, to measure CO_2 for a transport work. Ships obtaining an A, B or C rating would be fine, however ships that achieve a D rating for three consecutive years or an E rating in a single year, a corrective action plan needs to be developed and approved.

This measure has an impact because it requires to continuously engage in reduction emissions, either saving fuel, low steaming or implementing efficiency measures, while at the same time affects the dynamics between shipowners and charterers, raising questions about who will control them and what effect they will have on every shipping sector.

However, there are limitations in this index due to the inherent and previous negotiations: transport work is not defined with accuracy at IMO and the IMO data collection system does not include actual cargo carried. For some ships deadweight is used as a measure, while for others such as cruise ships tonnage, expressed in GT, will be used. As it can be seen in figure 7.1, as time goes by reductions are needed and this is to be done on an annual basis, With this the IMO should ensure a 40% intensity reduction by 2030.

Equation 7.1 AER is the index used as a reference for CII which was heavily used in IMO GHG studies

$$AER = \frac{Annual\ CO_2\ emissions}{Deadweight \times Distance\ sailed} = \frac{\sum_j FC_j \times C_{Fj}}{DWT \times D} = \frac{g_{CO_2}}{DWT\ mile}$$

There are interesting things in the application of this parameter. Ships undergoing longer voyages would benefit from the measure while others staying at port for a long period would not, because the fuel accounted is all the fuel emitted, not only that used for travelling purposes. It is expected that most ships would be average, but it is not that simple and there are multiple scenarios of operation. As an example, a cruise ship crossing the Atlantic would continuously benefit of a long distance travelled, therefore it would be easier to obtain an "A" or "B". However a cruise ship stopping every 8 hours with 12 hours at port would have travelled a short distance and can easily be categorized worse than "C" even if the ship is highly efficient in terms of emissions.

It was expected that suitable correction factors had been developed at the IMO. The cruise industry proposed to discount time ashore as a port correction factor, asking for a reduction, however even if the proposal deserved future consideration, it was considered that there was a perverse incentive that could potentially increase the emissions at port and cruise ships would, in this regard, have a special treatment versus other ship types. Although a threshold was proposed, it was considered that there was not enough evidence to assess this. Further discussions will be needed to agree on a factor. This discussion stresses the need to provide the cruise industry with OPS'.

There are other problems in the use of the CII index: the low ambition agreed at the IMO for the periods 2023 to 2026, the limitations in the indicator from the above-mentioned lack of definition and its potential towards decarbonization and Paris Agreement ambitions.

7.2 Energy Efficiency Index for existing ships

In Chapter 6 it was indicated that an efficiency index for existing ships was not agreed at the IMO. This was due to the lack of appetite in the conventions to develop legislation for existing ships. The conventions mostly apply to new ships, therefore developing new requirements is not something the sector would always support.

However in 2020 it was agreed to develop a measure for existing ships similar to the EEDI, hence applying to the same ship types from 400 GT. This would be the energy efficiency index for existing ships (EEXI) and would be referenced at EEDI phase 2 curve, which was the required ambition for new ships built from 2020. If the attained EEXI is below the curve setting the required EEXI the ship is compliant. If not, the ship will have to introduce immediate measures.

The EEXI works in the reduction of the CO_2 and the implementation of technical and operational measures. Due to the fuel high prices, an excess in the operating fleet and COVID pandemic "slow steaming" had become an option for some shipowners. Slow steaming reduces consumption and therefore emissions. Ships may use power limitation devices either as Shaft Power limitations or Engine Power limitations which limit the ship power (with a maximum limit of 83%MCRlim) and the speed. In most cases, existing ships need to register less power in the EEXI calculation than new ships, which results in a lower attained value that makes it easier for them to meet the requirement. It is calculated only once in the life of the ship and therefore is it's a one-off measure to apply from January 2023 because new ships will have to comply with EEDI.

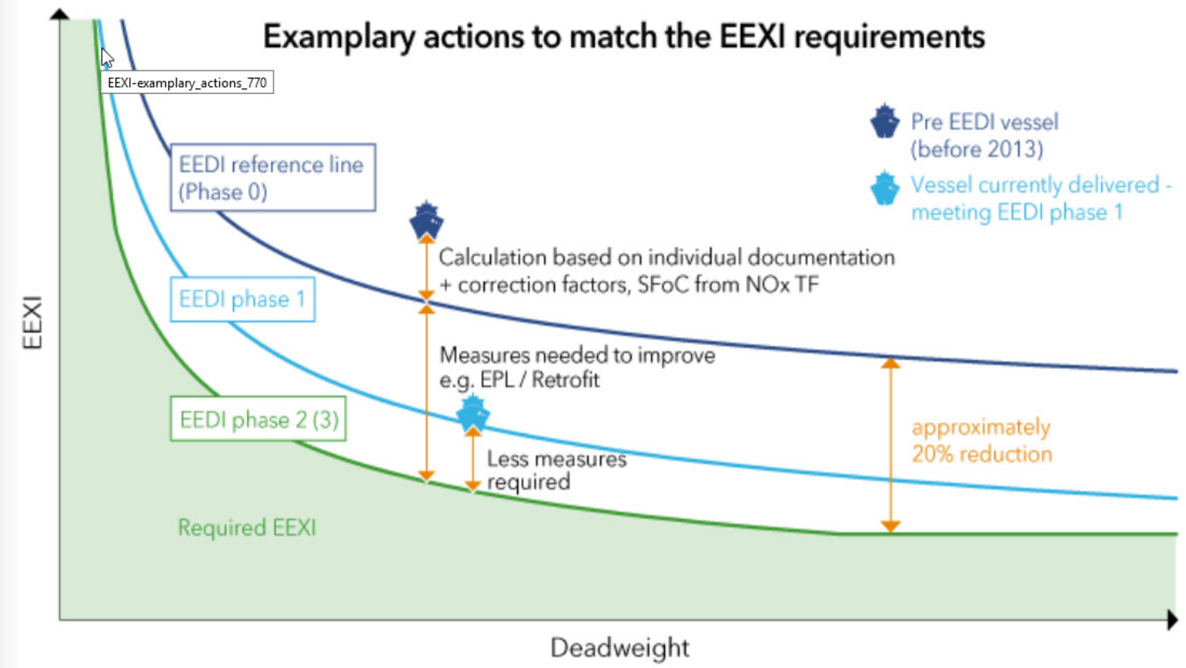


Figure 7.2 EEXI for existing ships how it compares with EEDI (source DNV)

$$EEXI = \frac{ME\ and\ AE\ emissions - Energy\ savings}{Deadweight\ x\ Speed}$$

Equation 7.2 EEXI formula where ME stands for main engine and AE for auxiliary engines

7.3 Ship Energy Efficiency Management Plans

The above measures, in particular the CII are based on the idea of continuous improvement. The SEEMP that was referred to in Chapter 6 was considered the document where all data had to be reflected. EEXI, IMO DCS data to calculate CII, the CII calculations and the results.

From 2024, the CII must be calculated and reported to the IMO DCS verifier together with the aggregated DCS data for the previous year, including any correction factors and voyage adjustments. The CII will be verified together with the aggregated DCS data. From 2024, the attained CII and the environmental rating (A to E) will be noted on the DCS SoC and it will be required to keep the SoC on board for five years. This is why SEEMP is a very relevant document.

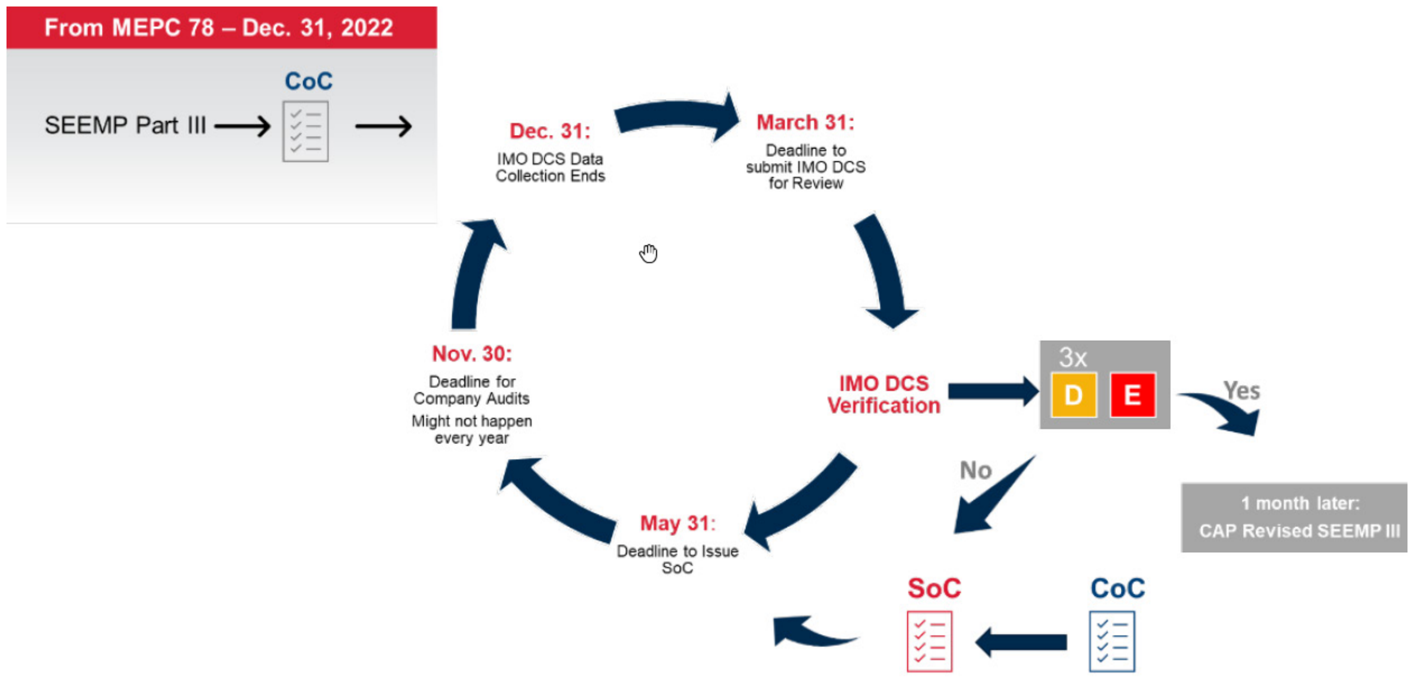


Figure 7.3 IMO Data collection system and CII integrated sequence (source ABS)

7.4 Sustainability and life cycle assessment

Shipping has to reach full decarbonisation[12] as soon as possible to support the temperature objectives set by the Paris Agreement. However, IMO has always considered downstream emissions - related to fuel combustion – but not the emissions related to feedstock extraction and process. This is not sufficient to assess and compare the GHG emissions induced by the use of different fuels and technologies in the shipping sector. For example, a engine burning hydrogen (H_2) will not emit CO_2, however it is important to take into account the CO_2 emitted to produce and carry to the ship all the H_2 needed to have a complete picture of sustainability.

In order to do so a comprehensive methodology to account for the sector's emissions on full life-cycle basis must be introduced. The IPCC methodology for mobile transport is applicable to ships and ensures that several principles (such as completeness, consistency and transparency) are fulfilled, however not all the elements are fully applicable.

This is why a Life Cycle[13] Assessment (LCA), retaining all relevant features and principles as the IPCC methodology, but particular for shipping, needs to be applied to offer a holistic examination for the product/ service/system from "cradle to grave" based on data in relation to the specific activity and it is relevant for the purpose of the assessment of the GHG impact from shipping, as it is being done in the aviation sector to prepare for an effective uptake of alternative fuels[14], either low-carbon and zero-carbon fuels.

[12] Decarbonisation is an overarching term that describes acts, pathways, or processes, by which countries, individuals or other entities aim to reduce and ultimately eliminate greenhouse gas (GHG) emissions from human activities.
[13] A life cycle describes consecutive and interlinked stages of an activity from raw material acquisition or generation from natural resources through to final disposal of any products. A life cycle analysis (also called a life cycle assessment) provides a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system or activity throughout its life cycle.
[14] Alternative fuels are fuels which serve, at least partly, as a substitute for traditionally used fossil fuels in the energy supply and which have the potential to contribute to decarbonisation.

7.4 Sustainability and life cycle assessment

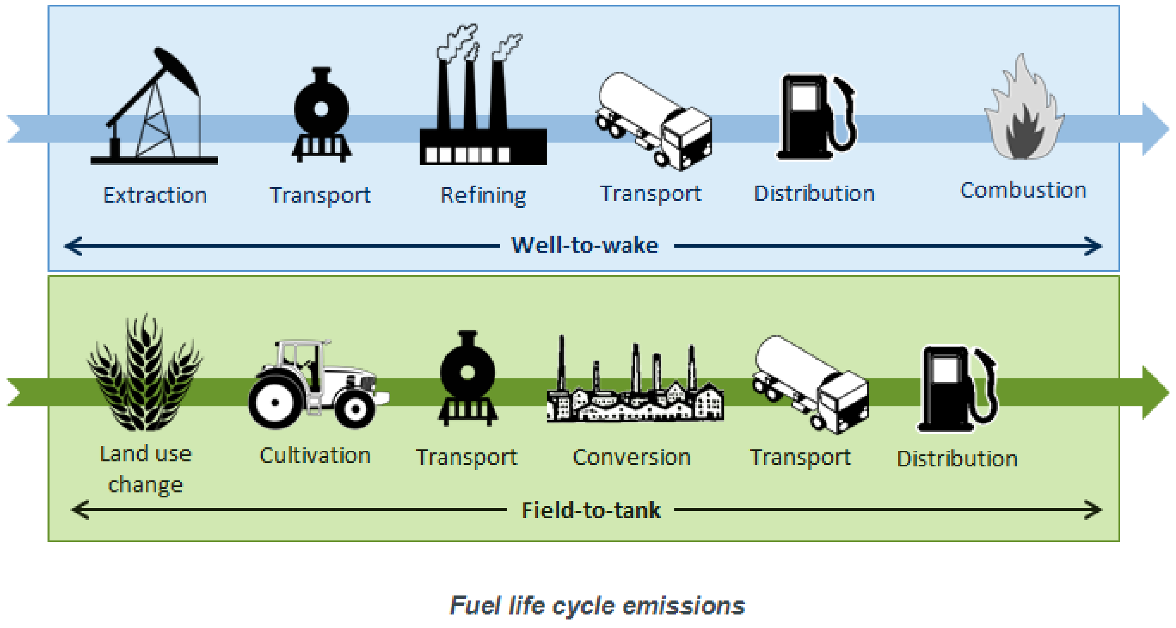


Figure 7.4 Fuel cycle emissions (source IMO)

In accordance with the life cycle all GHG emissions needs to be considered. This should follow Well-to-Tank (WtT) and Tank-to-Wake (TtW) approach. Well-to-Tank (WtT) aims to assess the total emissions of grow or extracting raw materials, producing, and transporting the fuel to the point of use. Tank-to-Wake (TtW), instead, represents the total emissions from combustion (including leakage) or from the use of other energy carriers for the propulsion of the ship.

The combination of the two parts (WtT and TtW) named Well-to-Wake (WtW) allows estimating the total life cycle GHG emissions. The determination of the GHG emissions for the WtT and for the TtW requires to apply the most appropriate path within the methodology for the estimations of the GHG emissions.

For example, let's compare the range of WtT GHG emissions for H_2 and for Synthetic Diesel[15].

[15] Synthetic fuel is a generic term applied to any manufactured fuel with the approximate composition and comparable specific energy of a natural fuel. It is primarily used to refer to carbon-based liquid or gaseous fuels manufactured, via chemical conversion processes, from a carbon source such as coal, *carbon dioxide (CO_2)*, natural gas, biogas, or biomass. This includes using established conventional fossil-based processes.

H_2 derived from natural gas needs nearly 500 gCO_{2eq}/MJ while if derived from certain biogas pathways its emissions are negative (-140 gCO_{2eq}/MJ). Synthetic Diesel if derived from Coal hits 130 gCO_{2eq}/MJ while if derived from wood feedstock is negative (-105 gCO_{2eq}/MJ). The figures are very different meaning that if hydrogen was considered as fuel on a TtW basis the emissions would be zero, hence a clean ship, however all the WtT would not have been considered and this may increase overall emissions in the atmosphere, depending on the path. It is not the same having zero emissions on a TtW basis, which is the traditional IMO approach, than a WtW basis.

Hence a fuel pathway is identified for each fuel type and could include:

- Feedstock extraction
- Feedstock (early) processing/ transformation at source
- Feedstock transport
- Feedstock conversion to product fuel
- Product fuel transport
- Product fuel storage
- Local delivery
- Retail storage and dispensing

IMO is developing these guidelines that will be used to determine the CO_{2eq} needed to manufacture a fuel, combined with the CO_{2eq} produced for its combustion and therefore calculate the WTW GHG emissions of different fuels used on board ships and the criteria to assess their sustainability.

With all the above the scenario to be carbon neutral[16] may be set.

[16] For carbon neutral ship operations, the *carbon dioxide (CO_2)* produced by, or as a result of human activities, is balanced by removals of CO_2. Carbon neutral ship operations means the operations may rely on supplementary use of carbon *offsets* and/or *insets* that lead to carbon reductions or efficiencies.

7.5 Low and Zero Carbon fuels. Alternatives in the cruise sector

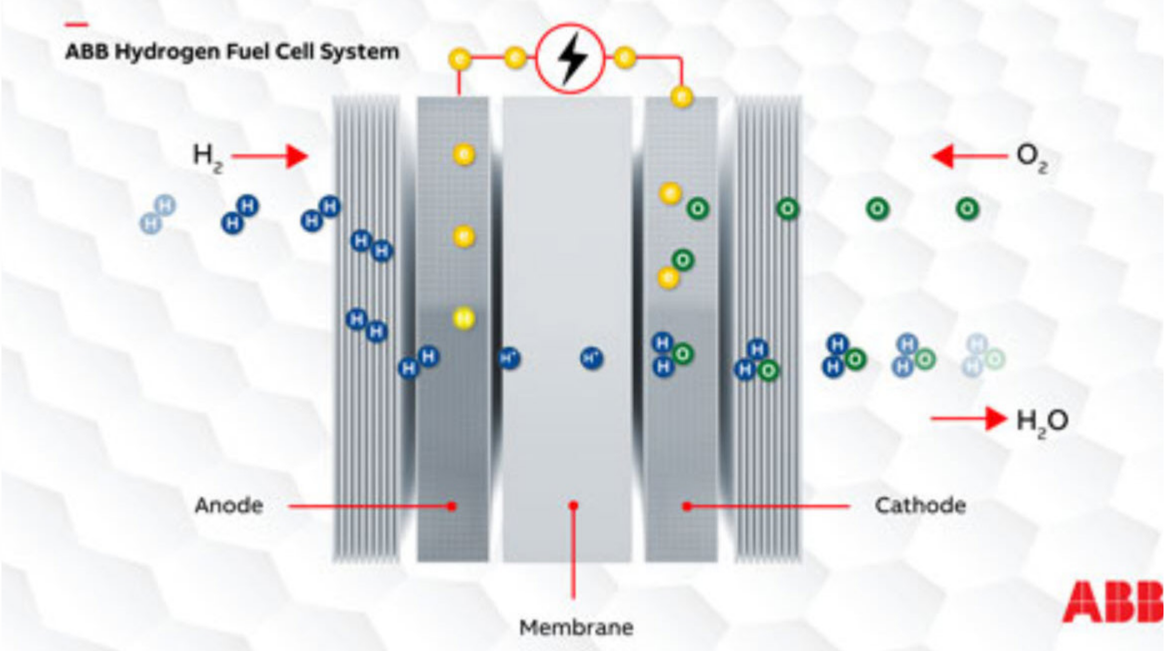
Traditionally ships have been using heavy oils while other parts of the oil cracking have been used for other transport modes. The large demand of fuel to move a large number of tons of cargo combined with the higher prices paid by other transport makes the sustainable conversion to other fuels difficult.

For years cruise ships used conventional propulsion with engines and turbines burning fuel oil. The advent of diesel electric propulsion led to changes due to its flexibility and capability to manoeuvre the ships. The availability of other fuels is leading to the installation of dual-fuel engines that allow the use of two types of fuels, which is a smart strategy to derisk the acquisition of a ship. Nowadays most of the fleet is still using liquid fuels, either fossil or mixtures with biofuels or LNG. However, a revolution is taking place with alternative fuels. We will refer to the most common ones noting that the future should be linked to fuels generated from the use of renewable electricity or sustainable biofuels, including biomass and biogas.

With this radical changes we also need to understand that other energy storage or converters will play a role in the cruise sector, notably fuel cells and batteries that for the time being are able to produce and store limited quantities of energy.

Fuel cells are an energy conversion system, transforming the electrochemical potential energy of H_2, which is the primary consumer, into electrical energy, which is then either consumed directly or, as in most cases, indirectly stored in batteries. Before consuming H_2 in the cell several technical arrangements may exist whereby different fuels are directly fed into the fuel cells, such as LNG or methanol, which are used as chemical carriers/sources of the H2 when oxidized. It is important to note that cruise ships will also use fuel cells when they deliver substantial power. Similarly, cruise ships may also use batteries in a limited manner to directly store electricity either generated or charged at OPS stations. In a WtW analysis, the reduction in GHG emissions of

Fig 7.5 Fuel Cell in a Royal Caribbean cruise ship (source ABB)



batteries will depend on the WtT emissions created by generating electricity. In order to be emission free, batterypowered vessels are dependent on the electricity being sourced from renewable energy. Several studies have investigated and compared the CO_{2eq} emissions from a life cycle perspective for a conventional combustion system and a battery system in the automotive industry.

For maritime applications, very few life cycle assessments have been undertaken for onboard battery systems.

The key issue for the deployment of fuels are the technological maturity to be used on board, the prices to produce them as they should come from renewable sources. These fuels may be green fuels[17] depending on the way they are produced.

[17] Green fuels are those where the production employs electrolysis—the separation of hydrogen and oxygen molecules by applying electrical energy to water. To be a green fuel, renewable sources such as wind and solar power are used to generate the electricity for the separation process. When applied to fuels such a methanol, it normally means that the hydrogen is produced in this way and the carbon dioxide (CO_2) used has been captured from the air. For ammonia, it means the hydrogen has been produced in this way and the nitrogen used has been separated from air using renewable energy. As an alternative.
Blue fuels are those which use hydrogen produced from traditional fossil fuels but where the carbon dioxide (CO_2) from steam reforming is captured and stored- using carbon capture and storage (CCS). Blue ammonia therefore means that the carbon generated in the production of hydrogen has been captured and stored using industrial CCS. The term blue is also used when the gases used to generate the fuel have been recycled or are reused from another industrial purpose eg blue methanol.
Grey/Black and Brown fuels are generated from traditional fossil fuels sources with the shades normally referring to the fossil fuel feedstock which is used in the process (eg brown/black for coal and grey for natural gas). The carbon dioxide (CO_2) and any carbon monoxide (CO) generated during the process of fuel production are not recaptured

7.6 Natural Gas / Biogas / Synthetic methane

Due to the pressure to reduce SOx, PM and NOx emissions the end of the 2000s a large momentum took place to develop and install dual diesel engines burning both conventional liquid fuels and natural gas, which was bunkered as fossil LNG, which is well known across the industry. Natural Gas (mostly methane -CH_4 -) is clean, emits 15-20% less CO_2 than oil fired engines, 80% less NOx and 90% less SOx. With such an advantage and a good LNG price, some cruise shipowners decided to carry out investments in this technology. This was also supported by regional policies such as those of the EU, and the deployment of this technology took place.

However, some engines, mainly four stroke engines, which are the typical choice in cruise ships have a problem of carbon slip[18]. Although carbon slip is being fastly reduced by by manufacturers and the issue is nearly solved in two stroke engines this is one of the reasons why there is substantial pressure against LNG as fuel in the sector. The other reason is that the deployment of LNG as fuel is recent and it could hinder the scale up of other fuels with lower emissions. However, the use of LNG as a fuel could represent a transitional alternative, in dual-fuel engines for specific routes in combination with creating the related LNG bunkering infrastructure, which is now in the full process of development. But methane by itself may also be highly sustainable if biogas or liquified synthetic gas from renewable sources is provided since LNG ready cruise ships can also use liquefied biogas or liquefied synthetic gas as fuels. These alternatives and a combination with fossil LNG would have the advantage that the technology and infrastructure is already available. Cruise ship could take advantage of these possibilities.

[18] This is the fuel injected in the combustion chamber that is not burnt. Due to the GWP of CH⁴ being ²⁷ times that of CO_2 a small slip and fugitive emissions for LNG handling may make the CO_{2eq} emissions similar to a ship using very low sulphur fuel oil

7.7 Biofuels

Biofuels are fuels that are derived from feedstock resources such as oil and sugar crops, forest or agricultural residues or algae (i.e. biomass). These feedstocks undergo several processes before being converted into a biofuel. Of the various biofuels, biodiesel can be used as a substitute for MGOs, marine diesel oils and other marine fuel oils in low- to medium-speed diesel engines without substantial or any modifications in the engine room. However, they are currently more commonly used as a fuel additive and are poured directly (drop-in) into blended fuels. The use of biodiesels (i.e. fatty acid methyl ester or FAME) in diesel engines has been shown to reduce SOx, carbon monoxide and unburned PM emissions. Second-generation biofuels, such as hydrotreated vegetable oils (HVOs), are growing in importance in the maritime fuel mix.

For this type of fuels it is important to understand that a key factor to assess its sustainability is the feedstock resource to be used categorizing them in generations as follows:

The first-generation refers to biofuels mostly produced from food and sugar crop-based resources, meaning biomass dedicated to this use which led to additional agriculture processes for feedstock.

The second generation was produced from biomass resources such as wood and organic waste.

Third generation biofuels could be produced from sustainably cultivated organic materials such as algae, though to date there is no commercial algae plant for biofuel production in use. Future fourth generation biofuels could involve a combination of biomass with carbon dioxide capture and storage techniques. As biomass is a renewable fuel source, biofuels produced from it could in theory be considered carbon neutral.

This line of reasoning derives from the fact that CO_2 is considered to have been first absorbed during plant growth, resulting in no net change in atmospheric carbon. However, on a WtW analysis, biofuel's actual GHG contribution depends very much on the type of plant or waste from which it is made and even on the use of land to grow the plants. The advantage of these fuels is that up to certain mixtures with fossil diesel fuels there is no problem. The only problems that this fuel have is economy, since these could be demanded by aviation and road transport which could be willing to pay higher prices. Safety issues could arise if the percentages of the mixtures were too high.

7.8 Ethyl and methyl alcohols

For methanol a reduction in SOx emissions of up to 99% and in NOx emissions of 60% and very low PM emissions during combustion is achieved. This this led to the introduction of this fuel in the maritime sector, in particular in the passenger ship sector. These are liquid fuels that can be used in existing internal combustion engines, subject to some modifications and the technical and safety requirements are easy to comply with.

Methanol can be produced from many different feedstocks, such as fossil natural gas, coal, farmed wood, wood waste and even CO_2 combined with electricity from renewables.

Ethanol, on the other hand, is mainly produced through the fermentation and distillation of biomass. Depending on the source of could be a sustainable solution e.g when ethanol is produced from biomass, it could in theory be considered a carbon-neutral fuel, Ethanol (and methanol) produced using hydrogen combined with biogenic or atmospheric CO_2 and using renewable energy have the potential to be almost carbon neutral but when derived from fossil LNG, which is the main stream, it would not. Methanol is relatively easy to store and handle, and it is already being produced on a commercial scale from natural gas.

7.9 Hydrogen

Hydrogen (H_2) is considered the holy grail of alternative fuels, mainly because it is the alternative to store produced electricity particularly from renewable sources and is taking momentum to “green” the industry. As an alternative fuel it can be used on board ships using two separate energy conversion technologies: fuel cells or in internal combustion engines. In fuel cells, no air pollutant emissions are formed during this process. In an internal combustion engine, H_2 can be burnt in the presence of air in the same way as traditional fuel oils or natural gas, but in this case the combustion will produce NOx as one part of the exhaust gas stream and at least 8% of the fuel would be liquid fuel to have a pilot flame. H_2 can be produced from natural gas and from coal through charcoal and sustainable H2 can be produced through electrolysis. If a renewable source of electricity is used, electrolysis is an almost carbon-free process. However, electrolysis is very energy demanding, which renders the production of green H_2 an inefficient and costly process.

Water splitting is potential techniques for producing H_2 in future, which can make use of renewable energy sources.

There are challenges for its use in shipping. H_2 is a very light gas with 1 kg occupying 5.4 m3 at standard temperature and pressure. Therefore, it results in a very low energy density. A large amount of storage space would be needed for gaseous H_2. Liquid H2 (LH2) reduces the storage space needed but requires extremely low temperatures (-253 °C) and pressures, still resulting in a relatively low energy density. Therefore, the high energy content of H_2 by mass is penalised by its low volumetric energy density and it is not expected to be used as fuel in the maritime sector also due to additional safety problems which could make it extremely dangerous. Alternatives are being develop to mix it with other fuels such as LNG however, the maritime industry is not mature enough to consider this fuel in pure form and its energy density turns this into a challenge.

7.10 Ammonia

NH_3 is a compound of nitrogen and hydrogen, a colourless gas in ambient conditions with a characteristic pungent smell. It has higher energy density by volume than hydrogen and can be liquefied at low pressures (860 kPa) and at ambient temperature, which makes it easy to store on board a ship. However, it is commonly stored at 17 bar (1 700 kPa) to keep it in a liquid state even when surrounding ambient temperature increases. Although NH_3 is common in nature and widely used, it can be toxic in concentrated form. As H_2 this fuel does not produce CO_2 when burnt or oxidized and has the advantage to carry hydrogen as a component. Its use as fuel does not result in SOx or PM emissions. However, the combustion of NH_3 may result in NOx formation which can be controlled.

Hence ammonia (NH_3) has the potential to be used as an alternative fuel on ships. Its widespread use in industrial and agricultural processes may also facilitate its distribution using the existing infrastructure and supply chains. On board ships, NH_3 can be used in combination with internal combustion engines and fuel cells. In combination with internal combustion engines, its expected performance is similar to that of conventional fuels in relation to power density and load response. Its GHG WtW emissions are basically those of WtT, hence if produced from renewable sources it could be a zero-carbon fuel. However, due to its toxicity and more stringent storage and handling requirements, NH_3 engines are still at the development stage and further development of fuel cells may render them the main application for NH3 on board ships. The toxicity in case of leakage is so high that it is unlikely that this fuel is used on cruise ships in the short term.

7.11 Deployment of alternative fuels

The transition in the maritime sector is complex. As indicated in Chapter 4 emissions in shipping are hard to abate. The climate urgency does not allow for a soft transition in shipping and therefore there is a need to find the funding, the resources and the technology to achieve the maximum possible reduction of GHG emissions. At the level of the IMO the measures adopted before the CII might be considered “soft measures” that, like the EEDI, are easy to achieve in new ships but they are not sufficient to trigger a quick transition.

Since emissions need to be curved down there is no other choice than using other fuels.

The selection of a fuel will be associated with its costs; its carbon footprint[19], in particular if the associated WtW emissions are selected; the cost of the technology to install machinery and equipment in a ship and the cost of training the crew for fuels that will not be “as safe as” conventional oil fuels. Unlike aviation there are so many pathways open for the shipping sector that not all of them will be the final choice.

However shipping is a conservative sector where shipowners have an aversion to risk. A limited number of shipowners have large fleets and there are many different types and subtypes of ships.

[19] A carbon footprint is a general term used to represent the total volume of *greenhouse gases (GHGs)* resulting from everyday economic and human activity. It can be considered a misnomer as it covers all GHG emissions, including *carbon dioxide (CO_2)*, and is normally measured in mass units of CO_2 and using *CO_2-equivalents ($CO_{2\text{-}eq}$)* for other GHGs. It is expressed as “per person or activity” and is most often used to compare sectors, products, and countries eg, per capita CO_2 emissions are used to compare country A to country B.

7.11 Deployment of alternative fuels

Pioneers who install new technologies usually are companies which can bear the risk of trying machinery or equipment because they may afford to fail. Therefore, in the race towards decarbonization there may be a disadvantage for small companies.

In the last few years the cruise industry has tried to go one step forward as demonstrated by policies like those of CLIA. However for the cruise industry the exposure is higher because of the business itself, which is carrying persons, which is very different to carrying goods and probably because cruise ships are highly visible due to the places they call in.

One way to “derisk” could be public investment and another to use two technologies at the same time, such as dual fuels, and to develop partnerships. With this available, shipowners may be willing to install them, but sufficient sustainable fuel may not be available. In order to stimulate the sector, there is a need to set taxes or penalties for the use of fossil fuels or fuels with a large carbon footprint to bridge the gap in the costs. While the IMO is discussing levels of ambition some regions such as the EU are taking measures applicable to ships to create suitable revenues.

7.12 Carbon Capture and storage

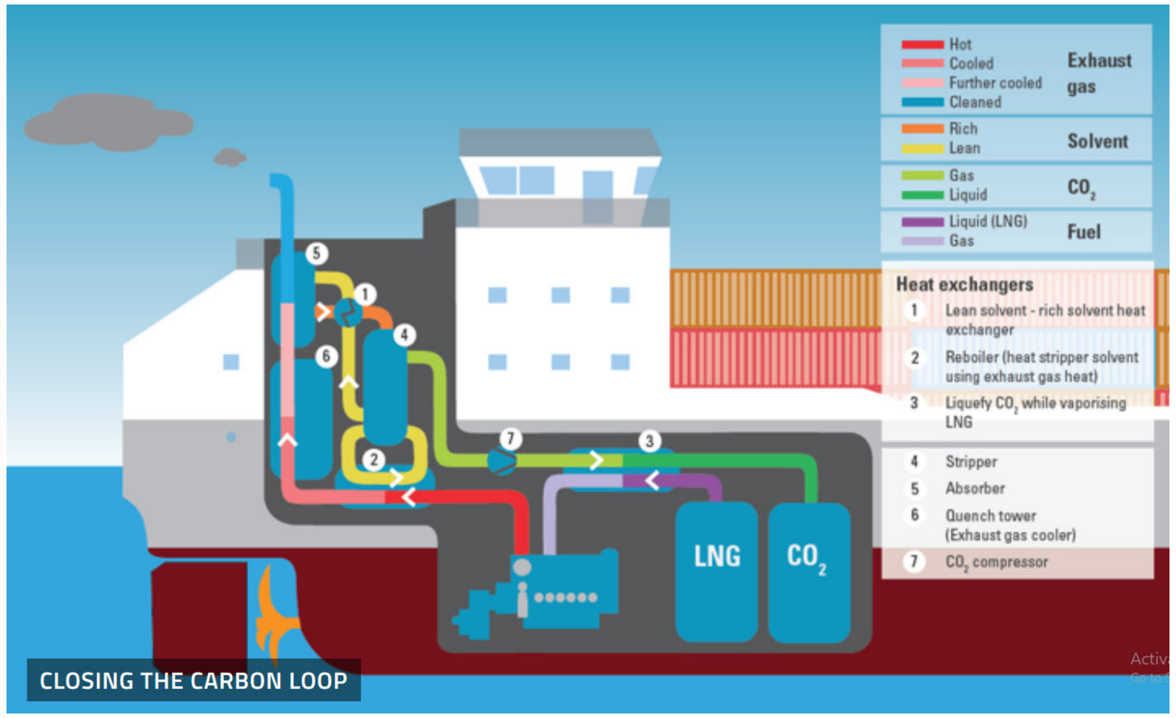


Figure 7.6 Carbon capture on a ship (source CONOSHIP)

Carbon capture and storage is the process of first capturing CO_2 emissions generated by industrial and energy-related sources, such as the combustion of carbon-based fuels, and thereafter transporting and permanently storing the captured CO_2 subsea in geological formations.

As an alternative to storing the captured CO_2, it can be utilized as an input or feedstock to create products and services. This is often referred to as carbon capture and utilization (CCU).

There are currently several initiatives to investigate and develop carbon capture technology for implementation on ships to convert an existing CO_2 capture system for onshore power plants to a marine environment demonstrating the feasibility of capturing CO_2 from the flue gas of marine engines on board ships.

For carbon capture technology to become a viable option for shipping, a value chain for carbon dioxide needs to be developed. Transport networks enabling ships to deliver the captured CO_2 to a terminal for onward transport and permanent storage could act as green corridors that could facilitate a more rapid uptake of CCS. Different infrastructure projects for CCS are under development.

Regional measures. Financing the deployment

This chapter will deal with the measures included in the EUs "Fitfor55" package addressing the maritime sector within the Green Deal which will be into force by 2023 or 2024. As indicated in the previous section, the EU had higher ambition, had implemented a system to monitor emissions, the MRV, had a cap and trade system in place for the land industry and it as the time to implement measures giving a signal on carbon pricing, taxes and deployment of non-fossil fuels.

8

8.1 EU Green Deal

In December 2019, the European Commission published the communication on the European Green Deal. It addresses the climate and environmental challenges that Europe and the world are facing and provides an initial roadmap of the key policies and measures needed. This includes the maritime sector. Reducing emissions of GHGs by 2050 with a climate neutrality objective by 2050 therefore would require an an 80-82% reduction in emissions by the EU's international seagoing maritime transport sector by 2050 relative to 1990 (i.e. equivalent to an 88-89% emission reduction relative to 2008). Therefore the union would act unilaterally while expecting to catalyse measures and ambitious targets at the IMO.

Among others, the Green Deal, through the 2030 Climate Target Plan, specifically mentions the possible extension of the EU Emissions Trading System (ETS) to the maritime sector. It formulates the ambition to ramp up the production and deployment of sustainable alternative fuels and the need to have cleaner transport, including requiring the use of onshore power supply at berth and potentially limiting the access of the most polluting ships.

This ambition was turned into a five measures that affect the cruise sector: the emission trading scheme; the deployment of OPS and low and zero carbon fuels in ships via a new regulation called FUEL EU Maritime; the revamping of the directive of alternative infrastructures into a regulation; a directive on fuel taxation and the amendment to the overarching Renewal Energy Directive (RED II) into a new RED III.

8.2 Emission trading Scheme

This scheme, also known as ETS, has been in place since 2003 for the land industry. The EU ETS works on the “cap and trade” principle. This means that greenhouse gas allowances in terms of CO_2, not CO_{2eq}, are treated as a commodity or product that can be traded on the EU carbon market.

The overall volume of greenhouse gases that can be emitted by all the companies covered by the ETS is subject to a cap (or limit), which is set at EU level. The EU also decides how much and how quickly the total emissions should decrease. The cap or limit moves downwards each year to meet this emissions reduction target. Companies regulated by the EU ETS must acquire carbon allowances.

Companies can buy these on the carbon market or through the EU ETS auctions. Some companies, regulated by the EU ETS, receive a certain amount of allowances for free, but the maritime sector contrary to aviation will not.

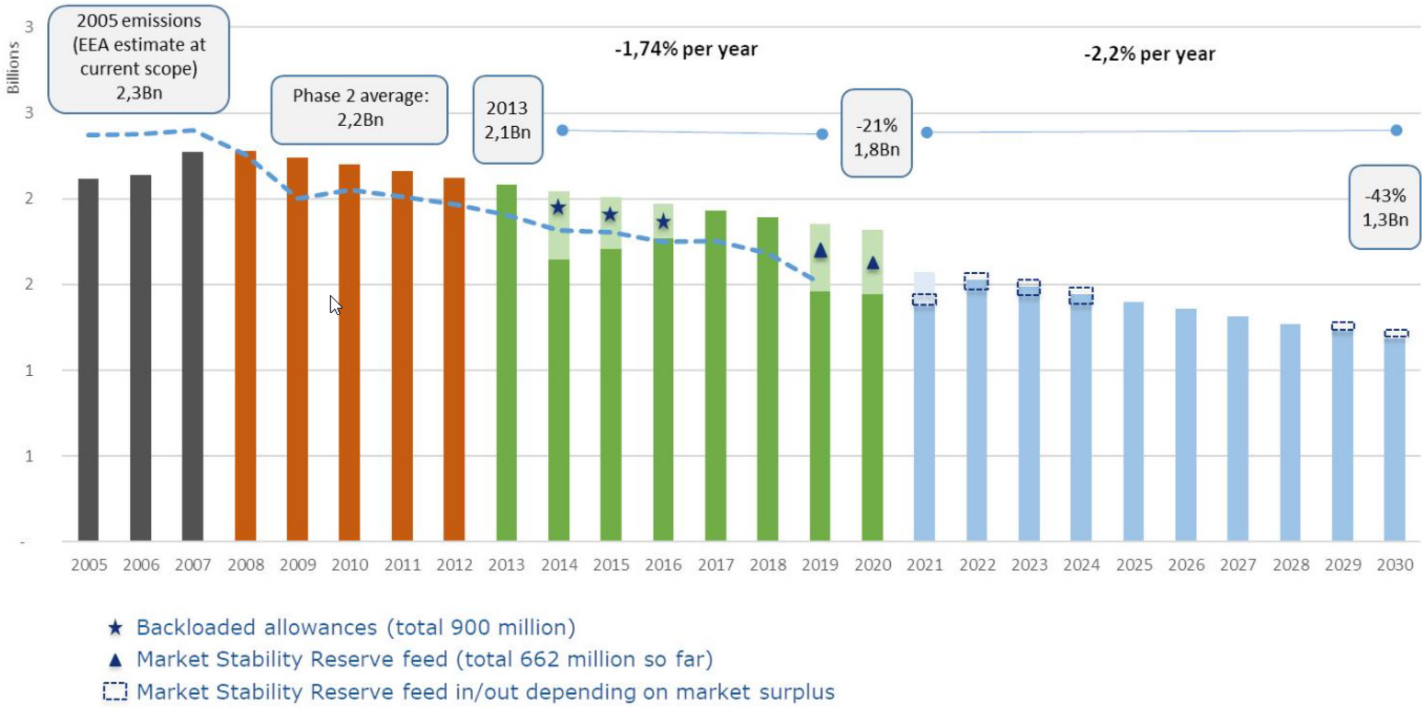


Figure 8.1 Decreasing CO_2 available in the market (source European Commission)

Sources: Refinitiv, Bloomberg and ECB calculations.
Notes: The EU ETS has undergone numerous changes over the years. Introduced in 2005, the system was designed in trading periods and is now in its fourth trading phase. The latest observation is for February 2022 (ETS spot prices, monthly data).

Figure 8.2 Carbon price per tonne evolution (source European Commission)

These carbon allowances only exist electronically. The companies regulated by the EU ETS must open Union Registry accounts to hold these carbon allowances. The Union Registry is like an online banking system which holds carbon allowances instead of money. Every year, the companies regulated by the EU ETS must surrender enough carbon allowances out of their Union Registry accounts to account for their greenhouse gas emissions. So, like paying a bill with money, these companies account for their emissions using carbon allowances. If these companies do not comply, heavy penalties are imposed.

If a company reduces its emissions, this reduces the amount of carbon allowances the company must surrender every year. The company can then keep the spare carbon allowances for use in the future. Alternatively, it can sell the spare carbon allowances to another company that is short of allowances.

8.2 Emission trading Scheme

When companies trade like this, it creates a market price for the carbon allowances. As the limit or cap decreases each year, the market price increases.

The measure will enter into force for the maritime sector in ships from 5000 GT from 2023 likely from 2024 in incremental steps of 25%-50% per year (steps are not yet decided).

The introduction of the ETS measure for shipping, still under negotiations, was designed for a 50 to 55 Euros per ton of CO_2 scenario in shipping by 2026 but the prices changes on a daily basis and could reach 100 Euros per ton of CO_2 before 2024. Cruise companies will need to develop a strategy to purchase, market and surrender their allowances and the MRV is the database where CO_2 will be declared. All this process will be verified by verifiers accredited by EU member states and monitored by the same member states.

This “cap and trade” approach makes it more economically attractive for companies to invest in emissions reduction technologies and therefore to reduce their greenhouse gas emissions. The moneys collected from surrendering allowances will be invested in measures to curve climate change via the innovation fund. As of today, it is not yet clear whether the innovation fund will have a separate channelling for the maritime sector, or it will be accumulated in a common basket.

8.3 Renewable Energy Directive (RED)

This directive, still under negotiations, also known as RED III is key for the deployment of renewable energies. It establishes a new binding renewable energy target for the EU for 2030 of at least 30% in the overall energy mix by 2030. Member states will need to increase their national contributions set in their integrated national energy and climate plans (NECPs), to be updated in 2023 and 2024, in order to collectively achieve the new target. There are sub targets for the maritime transport and member states are allowed to choose between:

- a binding target of 13% greenhouse gas intensity reduction in transport by 2030. More options will be available for member states to reach this objective, such as a possibility to set a differentiated goal for maritime transport as long as the overall goal is met;
- or a binding target of at least 29% renewable energy within the final consumption of energy in the transport sector by 2030
- A binding sub-target for advanced biofuels in the share of renewable energies supplied to the transport sector will be set at 0.2% in 2022, 1% in 2025 and 4.4% in 2030, integrating the addition of a double counting for these fuels. Regarding renewable fuels of non-biological origin in transport (mostly renewable hydrogen and hydrogen-based synthetic fuels such as e-methanol, e-H2, e-NH3 and e-LNG), an indicative sub-target of 2.6% is agreed, which corresponds to 5.2% also with the addition of a multiplier. This ensures a subquota of certain fuels that need to be provided by the member states.

8.4 Deployment of alternative fuels infrastructure

This regulation, still under negotiations, is a modification from a directive. For the maritime it sector refers to the deployment of alternative fuels and the provision of Onshore Power Supply for ships from 5000 GT. It requires that ports in the trans-European network (TENT core and TENT comprehensive) as indicated the lists established by the EU, with a number of calls of cruise ships above a certain threshold to install OPS (e.g "*average annual number of port calls of ships that are moored at the quayside over the last three years by seagoing passenger ships above 5000 gross tonnes. . is above 25, ...to supply for at least 90% of the total number of port calls"*).

The previous directive was supporting the deployment of LNG with a target, however this directive will only support the deployment of this fuel until 2025and will support the deployment of alternative fuels.

8.5 FUEL EU Maritime

This measure, still under negotiations, aims at decarbonizing shipping using a parameter that will be applicable for each ship. As indicated in chapter 7 the indexes used at the IMO consider an undefined transport work which stems from the decision by the Companies not to share cargo data. With this in mind this measure that will enter into force for the maritime sector in ships from 5000 GT from 2023 to start measuring, considers the CO_{2eq} (CO_2, N_2O and CH_4) emitted on a WtW basis divided per megajoule of energy (MJ) used by an index named green house gas energy index (GHGEI). The measure uses introduces the lifecycle analysis and elements of the RED Directive.

This index is calculated for the world fleet (in CO_2eq/MJ) and each ship needs to reach or improve its index. Every five years the index is reduced by an agreed percentage. Failure to do so implies the payment of a penalty.

Therefore, the companies and in this particular cruise ships companies, need to either pay, use lower carbon or no carbon fuels or increase the efficiency. The measure will apply progressively, hence if the baseline is set at 91.7 gCO_2eq/MJ in the period 2025-2029 the objective will be 89.9 and in the period 2030-2034 86.2 gCO_2eq/MJ. The penalty is set at 0.058€/MJ and reference to the objective for each period.

The CO_{2eq} calculated considers fugitive and carbon slip emissions. All the default values to be used are indicated in tables, however it is acceptable that these are certified by fuel suppliers and manufacturers. Since the regulation needs the WtT values of the fuels these need to appear on the bunker delivery notes.

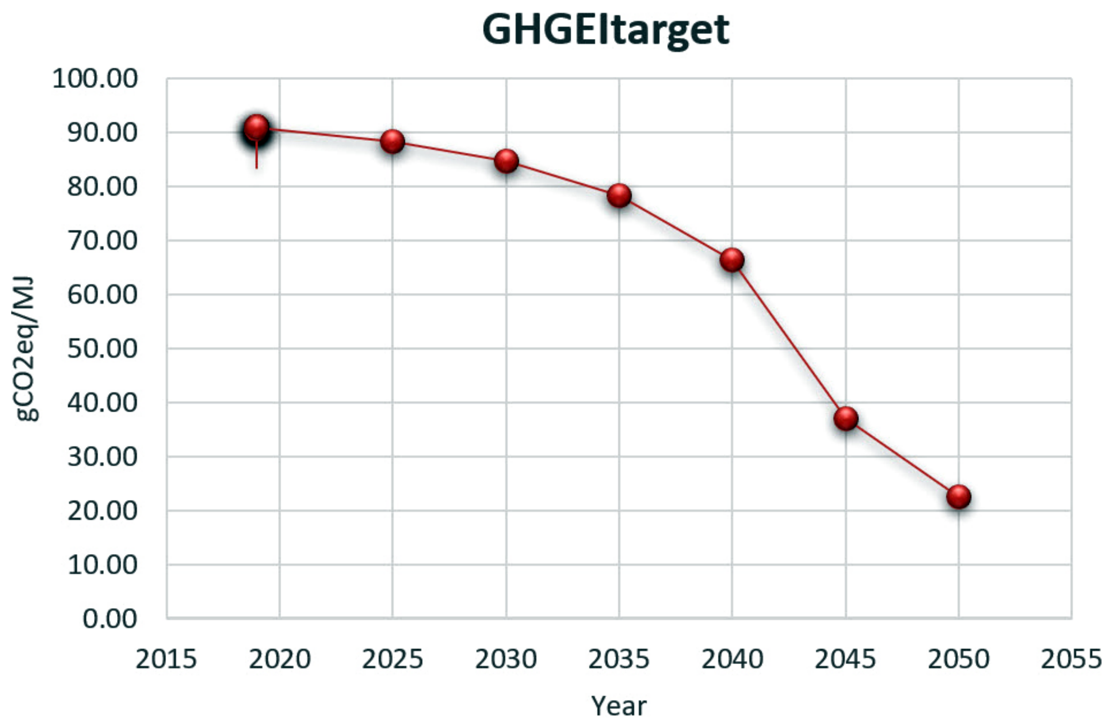


Figure 8.3 Fuel EU Maritime targets (source Miguel Nunez)

In order to reduce the index cruise ships will have to connect to the OPS or use lower carbon fuels. As a transitional advantage, and in order to incentivise the use of electricity, it will be considered that the electricity provided by the ports does not contribute to the emissions. In addition, the regulation allows for pooling among ships meaning that if a ship has an excess in compliance this excess may be borrowed to other ship. This borrowing is acceptable among different ship types and they do not have to belong to the same company.

The achievement of the targets indicated by the RED directive e achievement of those targets should be ensured by obligations on fuel suppliers as well as by other measures included in FUELEU on the use of renewable and low-carbon fuels in maritime transport. This is why additional sub targets may be set tr multipliers may be added in the formulation (so that the MJ are artificially increased and therefore the GHGEI lowered).

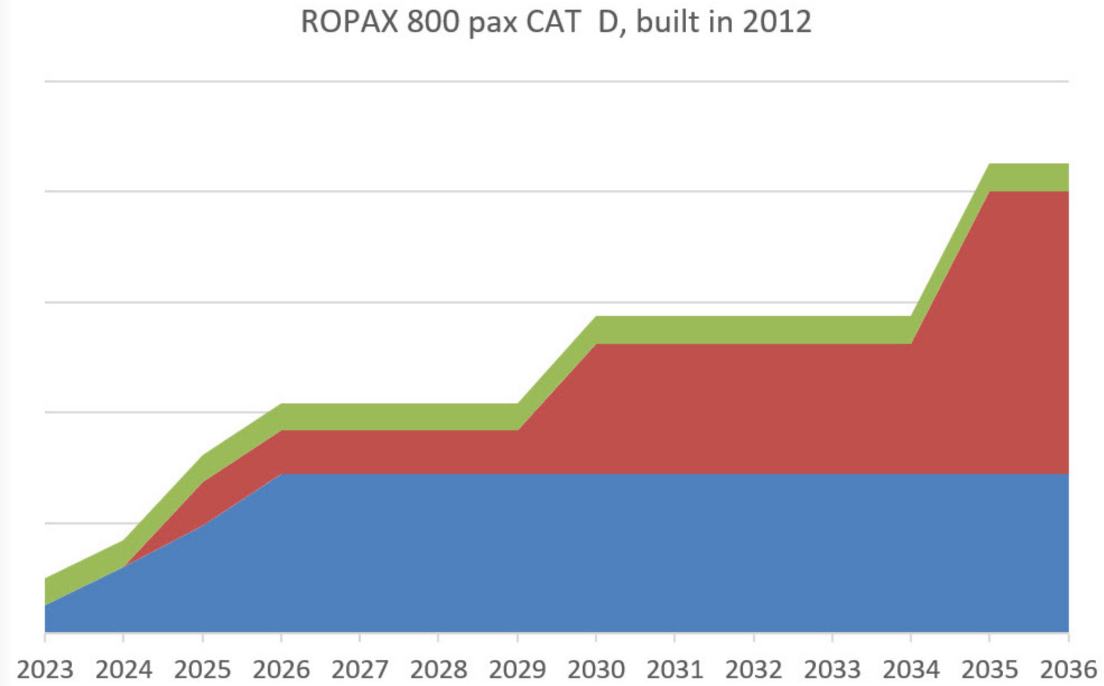


Figure 8.4 Fuel EU Maritime targets, cost structure for a ROPAX in a business as usual scenario (source Miguel Nunez)

Cruise ships burning LNG may have an advantage despite the methane slip, provided the certified values allow for a compensation. In addition, they should connect as much as possible to the OPS and developing this structure is key for them. The introduction of the measure is progressive. This is why during the first 10 years blending with other fuels such as second-generation biofuels is an alternative.

Another element to consider in this regulation are the excess penalties. Although the percentages that will be agreed for the first 10 years are below ETS, in a BAU scenario the penalties from 2035 will be higher. Subquotas for some fuels such as renewable fuels of non biological origin may also be introduce to stimulate their use.

8.4 Fuel Taxation Directive

This directive is applicable to all fuels and all ships.

It eliminates the exemption to tax fuels for the maritime sector and sets a minimum tax of 0,9 €/GJ for conventional fuels (1ton of very low sulphur oil has 41GJ). For LNG it sets a tax of 0,6 €/GJ for 2023 going up to 0.9 €/GJ in 2033.

With regards to other fuels, such as non-advanced biofuels, the taxes are 0,45 €/GJ in 2023 going up to 0,90 €/GJ by 2033. Advanced sustainable biofuels, biogas, renewable fuels of non-biological origin are subject to a very low tax of 0,15 €/GJ by 2023 to reach 0,45 €/GJ by, hence increasing 10% every year. Electricity will be taxed at 0,15 €/GJ.

Global midterm measures

This chapter explains some of the issues driving the current discussions at the IMO with the intention to make understandable how the sector will have regional and global measures at the same time with different degrees of ambition, which could lead to an increase administrative burdens and double payments. Mechanisms to avoid duplicity should be developed.

9

9.1 Global Measures and Revised IMO Strategy

As indicated in the previous chapters it was up to the IMO to develop measures for the maritime sector. Following the strategy adopted in 2018 there is a need to modify this in order to be able to develop measures with a satisfactory level of ambition.

Until 2010 IMO was an agency where adopting conventions was relatively a straightforward process. Before the adoption of the 1997 Protocol and stemming from the discussions in relation to the principle of common but differentiated responsibilities (CBDR) an element of technology transfer was introduced.

The introduction of discussions on greenhouse gases starting from the data collection systems and the IMO GHG studies have turned the debate extremely political. On top of the climate discussions, developing countries are advocating for principles such as common but differentiated responsibilities and respected capabilities[20] (CBDR-RC), not to leave anyone behind[21], just transition[22] and equitable transition[23].

When measures are developed it is difficult to reach a common agreement on the levels of ambition.

[20] *The respective capabilities:* is based on the recognition that not all countries have the same circumstances and opportunities to undergo a transition without help. Therefore, in 1992, the countries were divided into Annex I and Non-Annex countries, where it is the responsibility of developed countries to lead the transition and support the transition in developing countries. The binary division of countries is static thus not taking into account current economic realities, including reflecting changing circumstances, capabilities and thus responsibility. As an example, in Annex-I of the Kyoto Protocol 1992 countries such as Belarus, Greece, Bulgaria and Romania will have to support non-Annex-I countries such as Israel, Qatar, South Korea, China, Saudi Arabia, Singapore and the UAE.

[21] "not to leave anyone behind" is aimed not only at combating poverty, but also; "to combat inequalities within and among countries; to build peaceful, just and inclusive societies'. The 2030 Agenda places great emphasis on equality and leaving no one behind, but inherent in the principle is also a prioritised order of reaching those who are furthest behind first. In the IMO context, it can be translated into an obligation primarily to support the most vulnerable, e.g. SIDS and LDC's.

[22] "Just Transition" discourse is about minimising disruption for workers and communities that rely on unsustainable industries and energy sources, support for the people and countries involved in the shift from fossil fuels, and a focus on labour market equity more generally.

[23] Equitable Transition is a relatively new concept which has emerged as an 'addition' to the 'Just' terminology above in order to extend the relatively narrow focus of fairness beyond the labour market. In this respect, the term also suffers from not being defined, and there are therefore in the IMO and in general many different interpretations of what the term can cover.

The latest discussions on the CII revealed that there would be limitations on the technical side to develop the measure because of its lack of definition, technology availability or high risk. Shipowners advocated that there are real limitations to reach good ratings and measures are adapted, however the way to Paris Agreement becomes steeper as time goes by.

The issue is indeed challenging since even the ambitious measures to be agreed for Fit-for-55 measures agreed for Fitfor55 are not enough to meet the Paris Agreement levels. In order to achieve the goals there would be a need to apply to capture the carbon already emitted into the atmosphere.

With all the above there is a need to increase the levels of ambition but COVID, the conflict in Ukraine, the lack of supplies and goods makes it difficult. The strategy should consider new levels of ambition. Many proposals will be tabled, from the just agreed policy at ICAO, "Net-zero by 2050" to "absolute zero[24]", etc… with or without intermediate targets at 2030 and or 2040, intermediate subquotas such as a minimum percentage of renewable fuels in the market by a certain date with the implementation of a single or a combination of measures.

[24] "Absolute zero". No GHG emissions can occur in any part of the value chain for energy used in shipping. If an absolute zero target was adopted, e.g. for the year 2050, it would not be possible for ships to use e.g. biofuels, methanol or synthetic fuels whereby CO_2 is still emitted but is dealt with by other means elsewhere within the carbon life cycle to achieve net zero emissions (or carbon neutrality) in accordance with IPCC guidelines. The adoption of an absolute zero target would also rule out the use of other potential solutions for decarbonising shipping such as carbon capture and storage (CSS) or CO_2 extraction from the atmosphere whether undertaken on board ships or ashore.

The agreement on a strategy needs to account how midterm measures that will have to be adopted. Depending on the level of ambitions and how the income will be distributed the measures would have to be set at a minimum level, but as a rough reference decarbonizing the shipping industry could cost more than 1 trillion US$. That investment would be required to decarbonize the shipping industry by 2050, according to a report released 21 September 2022 at the Global Maritime Forum during Climate Week in NYC.

There are different possible measures such as:

A GHG tax or levy, that would require ships to regularly pay a fee based on the quantity of GHG emissions by that ship. The tax/levy could either be set directly at a level that renders the use of fossil fuels uneconomical or be gradually increased to that level, so that zero-carbon fuels, over which no taxes need to be paid, become cheaper to use than fossil fuels[25]. The cost-effectiveness of a GHG tax/levy could be increased by using a share of the revenues to support technology development and deployment by subsidizing the use of low-carbon and zero-carbon fuels or ships with a very low carbon intensity. In the latter case, the tax/levy rate could be significantly lower. A GHG tax/levy also creates the opportunity that some share of revenues would be available to address disproportionately negative impacts and fund other supporting measures.

A cap-and-trade scheme for GHG emissions. This is similar to an ETS. Ships would be obliged to annually submit allowances for each unit of GHG emitted, with a limited total amount of allowances becoming annually available for the sector, gradually declining over time. The allowances would be auctioned or could be in part allocated for free off to the ships with the possibility to trade the allowances between them on a secondary market. Ships with low GHG emissions would have to buy fewer allowances or could sell some of their allowances to ships with relatively expensive GHG abatement options[26].

A low-GHG fuel standard. This measure is similar to FUEL EU Maritime. This would set a regulatory limit value for the GHG emissions of a fuel over its life cycle. It could be implemented in a similar way as the current regulations on the sulphur content of the fuel, or be built on the basis of the new regulatory framework on carbon intensity of ships, if adopted. In order to reduce GHG emissions to zero, the limit value would need to follow a trajectory from its current level to zero within an agreed timeframe. Such a standard does not normally generate revenues, and could use exemptions or differentiation, and/or supporting measures in order to address disproportionately negative impacts.

Other possibilities are levies combined to indexes such as the CII, depending on the ratings. It offers a 'feebate' system of charges and rebates[27], which opens the door to carbon offsets.

Due to the issues to economically and legally handle these systems and the need to help developing countries and small island developing states, there will be discussions on how these structures need to be developed and drive, either inside or outside the IMO.

On top of this there are other proposals such as Green Corridors established and ready for operation by ships capable of operating on zero GHG emission solutions (partly or fully). Consequently, a decarbonisation ambition can be established earlier for green corridors than the agreed global decarbonisation for shipping. They would have to be defined in geographical scope of the corridor, list the parties and supporting stakeholders participating, provide a fuel transition towards zero-GHG fuels and indicate which fuels will be introduced in the corridor. Milestones for phasing for fuel availability to identify financial measures and the incentives available in the corridor to encourage the port and fleet investments are also necessary.

[25] Current estimates are that a tax/levy of $250 to 400 per tonne of CO_{2e} ($750 to 1,200 per tonne of petroleum-based fuel) would render low-carbon and zero-carbon fuels competitive with fossil fuels. The tax/levy could be liablae to the flag State, to the IMO or to an organization designated by the IMO to collect the tax/levy and disburse the revenues.

[26] Such systems have the advantage to incentivize ships to reduce their emissions up to the point where reducing them more exceeds the value of the allowance. The value of the allowances can be influenced through the number of allowances made available (i.e. if the number of allowances decreases, their value will increase). In this way, the system can be designed and managed to follow an agreed trajectory of emission reductions while leaving the choice of the most cost-effective investments to the operators. When allowances are valued at $250 to 400 per tonne of CO_{2e} or higher, low-carbon and zero-carbon fuels become competitive with fossil fuels. A cap-and-trade scheme can be revenue neutral, or it can be designed to collect revenue that can subsequently be disbursed to address disproportionately negative impacts and fund other supporting measures, as appropriate.

[27] Is a system under which more efficient ships are offered rebates while less efficient vehicles have fees assessed against them. Ships with low carbon emissions can receive anywhere from $5,000 to $20,000 SGD, while new cars and taxis with high emissions can incur a surcharge with a similar range. Singapore requires clear labeling in order to distinguish low vs. high emission vehicles.

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