Sustainable Shipping-Assurance of Safe Environment

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Abstract

Humans have always had a close relationship with the aquatic environment, including the early use of the sea for food harvesting and communication. Shipping is one of the least environmentally damaging forms of commercial transport. Where it competes directly with other means of transport, shipping remains by far the most energy efficient. But the environmental performance of shipping is not perfect. Shipping causes a wide range of effects on the marine environment. Most of the harmful emissions come from the daily release of various substances. Oil, chemical cargo residues, garbage and cleaning agents, anti-fouling paints, exhaust and other air emissions, and invasive species from ballast water have ongoing adverse effects on life in the world's seas. Quality shipping or sustainable shipping can be seen as a response to the environmental challenges the shipping industry is facing. Sustainability and related concepts, such as ecosystem services, planetary boundaries, newest technologies and resilience thinking, Ocean governance with IMO POLAR CODE could be used as guidance in addressing these challenges.

Keywords: Shipping, Industrial revolution, Resilience thinking, sustainable development, Green technology, IMO POLAR Code.

Introduction

In planet earth 70% of the surface is covered by ocean and 90% of human habitation is beside river or water source. Therefore, humans have always had a close relationship with the aquatic environment, including the early use of the sea for food harvesting and communication. Increased trade and the population growth in Europe launched global explorations and led to "discovery" of the New World and new communication routes to Asia. A romantic view of nature in the 19th century evoked a new interest in the sea in art and in recreation. Much of this interest was related to the sea in terms of something to look at and enjoy. In the mid-20th century, science made discoveries below the surface of the sea and public interest in diving and

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learning about the sea's ecosystem developed. These developments also led to additional observations of adverse effects on the environment and an increased awareness of the marine environment. Today the sea is an important component of the transportation system, with large amounts of cargo and passengers. Ship's transportation has increased tremendously since the industrial revolution, which has resulted in increased emissions due to shipping and increased stresses on the environment (Rozwadowski 2008).

The increased use of oil for propulsion and increased global transportation of oil during the 20th century led to discharges of oil that were highly visible and produced demands for safer and less damaging shipping. The formation of what later became the International Maritime Organization (IMO) was a result of the need to enact international regulations for safety at sea and to prevent accidental oil discharges. The belief that the sea is greatly resilient and is a suitable place for discharging waste has survived for a long time. Organized dumping of waste at sea was a common practice around the world, including Europe, until the 1970s. The amount of waste ammunition and chemicals dumped into the sea after World War II is still a potential problem for fishing and installations at sea. Even today, large amounts of waste end up in the oceans on purpose or from uncontrolled sources. Recently, problems related to "micro-plastics" and "ghost fishing nets" have garnered more attention. In shipping and in other maritime activities, the sea remains close to working people, and the relationship between activities and environmental impacts is sometimes highly visible, although some shipping impacts occur far from the source of emissions or activity (Kuliukas and Morgan 2011). This paper focuses on the interaction between shipping and the natural environment and discusses how the use of the oceans through shipping is affecting the environment. The study is carried out to propose few eco-friendly options for more sustainable shipping in the environment.

Ships and Shipping

To discuss the relation among shipping, the environment, and sustainable development, it is useful to define certain terminology. The main focus of shipping is on commercial ships, although many of the emissions, impacts and measures are common to other sectors, such as leisure, research, and fishing. The different regulations also require definitions of a ship. Different definitions exist, although according to the glossary of the US Navy, a "boat" usually refers to small vessels that are often open, whereas "ships" are vessels of considerable size that are intended for deep-water navigation. A ship can also be defined by its size: vessels longer than 12 m and wider than 4 m are referred to as ships and smaller vessels are known as boats (Ford 1972). Common ship types can be identified according to their type of use:

> **Container ships**: These vessels carry most of the world's manufactured goods and products in standardized containers that also can be transported by rail and truck. These ships are usually scheduled liner services.
>
> **Bulk carriers**: These vessels transport unpacked cargo in large volumes. The cargo might be grain, products such as concrete, or raw materials like iron ore, limestone and coal.
>
> **Tankers**: The vessels transport liquids, such as crude oil, chemicals and petroleum products.
>
> **Ferries**: Ferries usually perform short journeys that carry mixtures of passengers, cars and commercial vehicles. Most of these ships are RoRo (roll on–roll off) ferries, in which vehicles can drive straight on and off. Ferries that combine passengers and RoRo transport are often referred to as RoPax.
>
> **Cruise ships**: Cruise ships have different sizes, and several thousand passengers and crew are common on these vessels. These ships combine transport with the role of 'floating hotels'.

Many other types of ships operate regionally or locally. One size limit is up to 500 passenger vessels, which includes road ferries and public transport/shuttle ferries. Vessels might be intended for special purposes, such as pilot boats, fishing vessels, icebreakers and military vessels. Different ships are also adapted for transport on inland waterways in areas with rivers and canals.

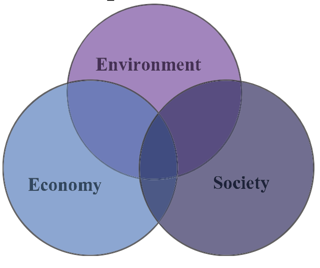
Sustainable Development and Sustainable Shipping

The most common international definition of sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", which was presented in the 1987 Brundtland Report (Douvere 2008). Four primary characteristics of sustainable development also have been derived from the Brundtland Report:

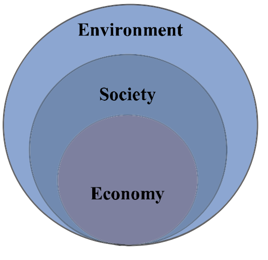
(1) Safeguarding long-term ecological sustainability
(2) Satisfying basic human needs
(3) Promoting intra-generational equity, and
(4) Promoting inter-generational equity.

Several secondary characteristics are also important for sustainable development, preserving nature's intrinsic value, endorsing long-term effects, promoting public participation, and satisfying aspirations for an improved quality of life. The importance of safeguarding long-term ecological sustainability is expressed in the Brundtland report, through such statements as, "At a minimum, sustainable development must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings" and "There is still time to save species and their ecosystems. It is an indispensable prerequisite for sustainable development". This characteristic has its origin in ecology and represents the conditions that must be present for the world's ecosystems to sustain themselves over long periods of time (Brundtland 1987).

Sustainable development is commonly represented as three pillars: economic, social and environmental aspect or three 'P' commonly known as people, profit and planet. Hence, sustainable shipping depicts marine economic transportation activities prioritizing environmental safety.



View 1: Most common view on sustainable development interception of 3 pillars



View 2: Environment sets the outer limit where ecologically sustainable condition assures sustainable development

Ships and Their Environmental Impacts

A ship is a vessel for use at sea that has a hull and can be steered by a rudder. A ship's mission can vary substantially depending on the ship, such as the transportation of passengers or goods through international waters, servicing of other vessels, exploiting the sea in the form of fishing, or building underwater pipelines. The different systems on a ship must be able to perform the functions that are necessary to fulfill its mission. Even if absolute generality can rarely be obtained, it is reasonable to state that every ship must be able to provide mobility. This basic function is provided by the propulsion system and by several additional systems related to the functions of steering, navigation, and anchoring.

Because a ship is assumed to perform a specific mission, this capacity will often require specific operational functions related to the specific mission. This functionality involves the need for given systems that are largely dependent on the mission, for example, container cranes for small container ships, cargo pumps for tankers, equipment for handling fishing gear for trawlers, and kitchens and sanitary systems for cruise ships. Even if the large variety of possible operational functions does not tallow us to specifically address each and every of them, these functions are often associated with a large consumption of heat or electric power and, sometimes, with the handling of hazardous material. Every ship has several on-board operations that must be directly performed by humans. Therefore, the crew must be provided with hotel facilities that fulfill the basic needs of accommodation, food, and services (Engel and Schaefer 2013). Finally, several general support functions must be performed, such as providing electric and hydraulic supplies, fuelling and lubrication, and heating and cooling. All these technical actions directly or indirectly are affecting our environment as described below on a pictorial view (figure 1):

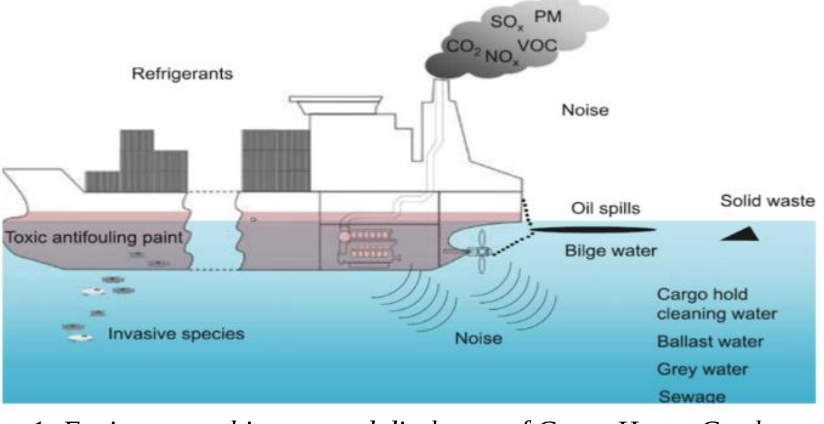


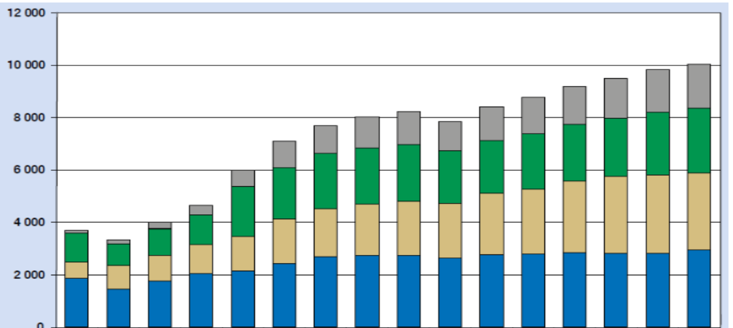
Figure 1: Environmental impact and discharge of Green House Gas by marine transportation

A Ship's Life Cycle

Similar to all products, ships pass through different stages in their life cycles, including the design, construction, operation with maintenance, refurbishments and scrap phases. The design and construction phases allow for a large range of options for technical solutions and offer a large opportunity to influence environmental impacts and energy usage. It is also important in these stages to allow for refurbishment and technical improvements during the long operation time of a ship often 30 years or more. Operation is the main phase of the life cycle and is the time during which most energy usage occurs. Additionally, the possibility of scrapping a ship in an organized manner that allows for its components and materials to be recycled is largely determined in the design phase (Beaudoin and Pendleton 2012). Ship recycling causes colossal environment hazard which is usually processed in developing the third world countries where economic benefits achieve priority over environmental concern.

The Hull and Ship Structure

The main function of a ship is to safely carry its cargo, crew and passengers. Therefore, a ship must be a safe and trustworthy vehicle that can handle various sea states and reduce damage in the case of accidents. The main structure of a ship is the hull, which provides a carrying platform and protection against the environment. The hull must be resistant to loads of different types and intensity over its entire lifetime and to possible collisions. These requirements translate into different solutions and technologies depending on the ship type and its trade. The figure-2 below shows the rising volume of international sea trade;



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Containers	102	152	234	371	598	1 001	1 076	1 193	1 249	1 127	1 280	1 393	1 464	1 544	1640	1687
Dry cargo other than main bulk commodities	1 123	819	1 031	1 125	1 928	1 975	2 112	2 141	2 173	2 004	2 022	2 112	2 150	2 218	2393	2463
Main bulk commodities	608	900	988	1 105	1 295	1 711	1 814	1 953	2 065	2 085	2 335	2 486	2 742	2 923	2985	2951
Oil and gas	1 871	1 459	1 755	2 050	2 163	2 422	2 698	2 747	2 742	2 642	2 772	2 794	2 841	2 829	2 825	2 947

Figure 2: International Seaborne trade 5th yearly (Millions of tons loaded); Source-UNCTAD 2016

Ships sailing on international routes, particularly in the North Atlantic Ocean, tend to be especially loaded as a consequence of frequent heavy seas, and they must meet higher requirements in terms of hull structure resistance compared with ships sailing in inland waterways or in less harsh seas. The possible consequences of accidents also influence the selection of hull structure, shape and materials. The extensive consequences of accidents with large oil tankers (e.g., the Exxon Valdez, the Amoco Cadiz and the Prestige) led to stricter regulations for these vessels; including requirements for double-hull construction to limit the consequences of such accidents. However, ferries and passenger ships have also experienced several accidents (e.g., the Estonia and the Costa Concordia) that have led to increased standards in safety requirements (Anderson Karlin 2016).

A stronger and thicker hull comes at a cost. Additional material is required for construction, which impacts both the investment cost and the life cycle demand of materials. In addition, a heavier hull requires a higher lightweight which results in reduced cargo carrying capacity for a given ship size and shape. This trade-off can pose a challenge for tankers and bulk carriers, for which weight is the limiting factor. Modern ship hulls are almost always constructed from steel. Lighter materials, such as aluminum and composite materials, are currently being investigated and have been used in highly specific applications. The choice of materials used in ship manufacturing has an impact on the emissions associated with shipping.

The Propulsion System

Several methods are available to generate the thrust required for a ship to move through water. However, nearly all of the world's commercial fleet is currently based on the concept of converting the chemical energy contained in fuel to mechanical energy, which in turn is converted into ship thrust. The pictorial view below depicts the historical changes in marine propulsion (Corbett 2004).

Ship Resistance

Antifouling paints are applied to hulls to prevent the growth of fouling organisms, such as barnacles, mussels, bryozoans and algae. Antifouling systems are required when unwanted biological growth occurs, and the need to protect ship hulls from fouling is as old as the use of ships (Almeida, Diamantino and Sousa 2007). However, the release of biocides from antifouling into the water can result in a harmful impact on the marine environment.

Auxiliary Systems

Ballast water is needed to ensure vessel stability during operation without cargo and to balance the weight when the cargo is not evenly distributed. In port, the ballast water might be pumped into specially designed tanks to compensate for changes in the weight distribution as cargo is removed and subsequently released when cargo is loaded. It is estimated that at any given time, approximately 10,000 different species are transported between geographic regions in the ballast tanks alone (Bax, et al. 2003).

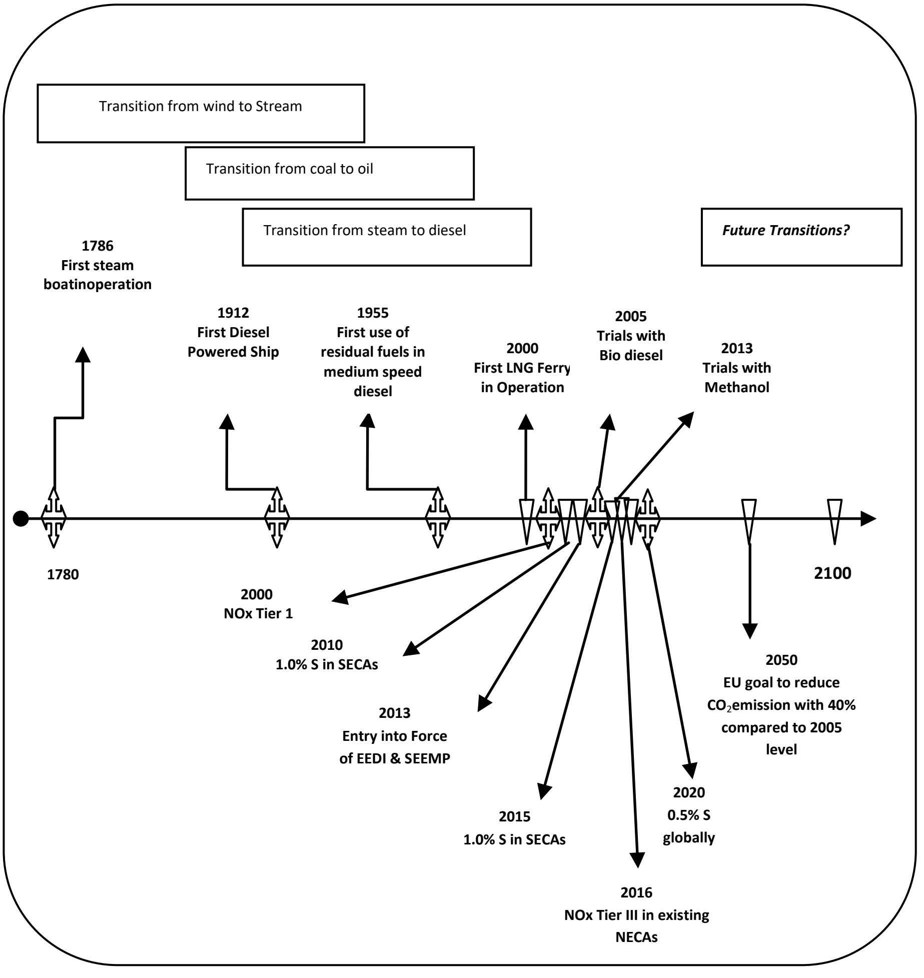


Figure 3: Historical timeline for transition of marine fuels from 1780 to 2100

Although many alien species become integrated components of the background flora and fauna, others are invasive and will eventually take over and dominate the native flora and fauna. This may have associated economic impacts such as a decrease in economic production by fisheries, aquaculture, tourism and marine infrastructure. Human health can also be affected. For example, the Asian strain of the bacterium responsible for cholera was probably introduced into Latin America via the discharge of ballast water.

Oil Spills

Accidental oil spills from tanker vessels have decreased since the 1970s, although numerous small spills still occur in ecologically sensitive locations. The release of oil to the environment from shipping originates from the transportation of fuels in tanker vessels and from fuel used for propulsion. The portion that originates from fuel used for propulsion is affected by the choice of fuel for marine transportation. Only approximately 7 % of oil spills originated from non-tank vessels during the period 1990–1999. Operational oil pollution also originates from various sources, such as bilge water and propeller shaft bearings (Council 2003).

Interpretation of Sustainability

Sustainability is becoming increasingly important in every aspect of today's society, because of exponential human population growth, enhanced technical skills, and consequently a much larger pressure on the environment. Sustainable use implies that a business is economically viable, has low ecological impact, and is socially acceptable. Pro-Sea considers sustainability to be a balance between these three P's: Profit, Planet, and People. In this world where economic value is often seen as very important, sustainable thinking requires the recognition of the value of environment and people. There is no 'fixed recipe' for sustainable development. Balancing economic prosperity, environmental quality and social equity can be carried out in different ways, by different choices. Thus, a practical application of 'sustainability' is open to many interpretations. Sustainability can be achieved by technical innovations and environmental regulations. However, the effectiveness of innovations and regulations always depend on the professionalism and competence of seafarers: the human element. Therefore, an increased awareness of the (marine) environment will contribute to sustainable use of the environment and oceans by maritime professionals.

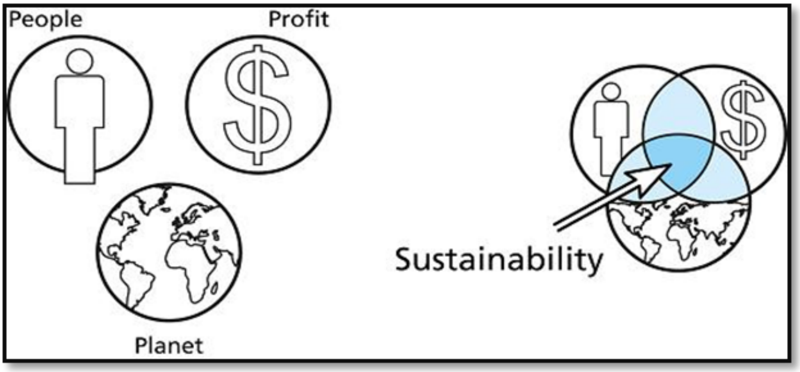


Figure 4: Concept of 3P on Sustainability assessment

Emission Control and Green Shipping Concept

Sustainable or green shipping is generally defined as logistics and transport operations that strive to limit the company's Green House Gas (GHG) emissions. A company's GHG output is often referred to as its carbon foot-print, meaning the amount of carbon dioxide and other greenhouse gases it uses. In 2015 the requirements within the Emission Control Areas (ECA) call for a reduction of sulphur content in the fuel to 0.1 % or alternatively the equivalent level measured in the exhaust gas. Similarly in 2020, the global requirements will be a reduction of sulphur content in the fuel to 0.5 % or alternatively the equivalent level measured in the exhaust gas. A scenario with a global sulphur cap entering in 2025 has also been considered (Klimt and N 2012).

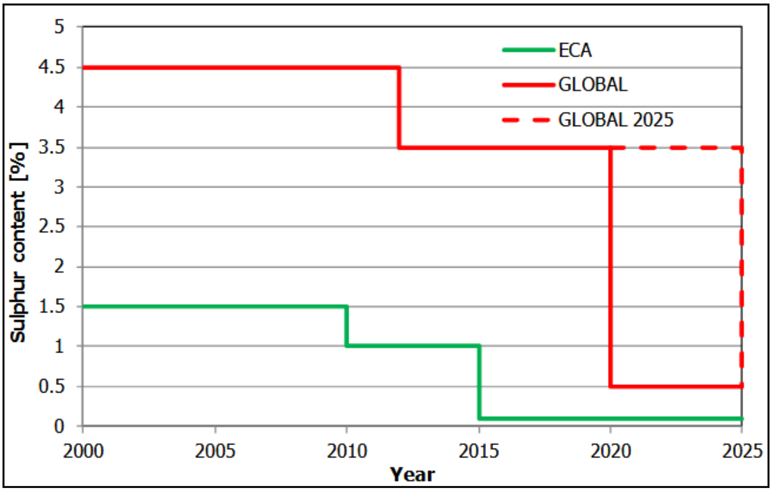


Figure 5: IMO Regulation of SO_X levels on every 5^{th} year plan

At present study evaluates technical and economic feasibility of retrofit conversion or modification into few operational modes in order to meet the future IMO SOx regulations:

Low sulphur fuel (MGO) – Base case

The base case is defined as the reference tanker in original as-built condition; in case of operation in Emission Control Area (ECA), the vessel will shift to low sulphur fuel (MGO) in order to comply with the prevailing emission requirements. Low sulphur fuel referred to in this study comprises fuel with not more than 0.1% sulphur in the case of ECA operation as of 2015. In addition, it comprises fuel that will satisfy the global sulphur cap of 0.5% as of 2020 (or 2025). For simplicity reasons, all of these low sulphur fuels are referred to as 'MGO' (marine grade oil, i.e. distillates). The expectation is that the price difference between 0.1% and 0.5% sulphur fuel will be limited.

Scrubber technology

The exhaust gas scrubber system removes sulphur oxides and particulates from the exhaust gas. The scrubber system is a hybrid system being capable of operation both on fresh water and on sea water. During the operation of the scrubber in fresh water mode the water cleaning system will generate sludge. This sludge can be treated as other normal sludge from ships 'engine rooms; however it is not allowed to incinerate it on board the vessel. If the 'normal' sludge is not incinerated onboard, the sludge from the scrubber water cleaning system can be mixed with this sludge and treated in the same manner meaning delivered to the port waste reception facilities. The amount of sludge from the scrubber water cleaning system will amount to 2.5 liters/MWh engine output, which is around 10 % of the "normal" sludge. The sludge from the scrubber water will be 20% solid and 80% water.

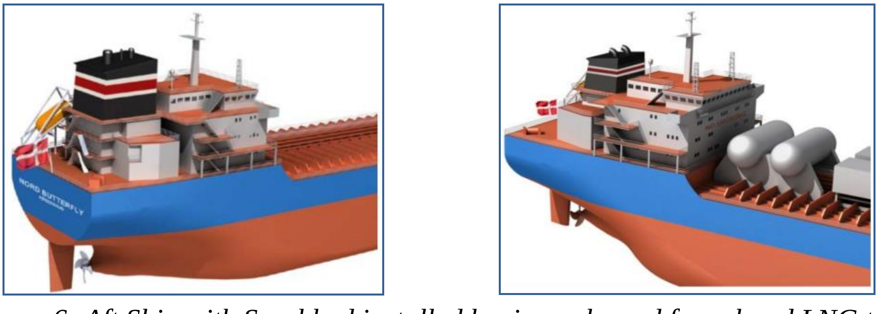


Figure 6: Aft Ship with Scrubbed installed having enlarged funnel and LNG tank on main deck

LNG Conversion

Conversion of the existing 6S50MC-C engine to ME-GI dual fuel engine requires that the MC engine is first converted to a ME-B type engine with electronically controlled fuel injection. This requires installation of hydraulic equipment for the electronically controlled fuel injection system and replacement of the camshaft for the exhaust gas valve actuation. A further benefit of converting the MC-C engine to ME-B type engine includes improved specific fuel consumption during Tier II mode operation. During conversion of the MC-C to ME-B engine, the additional GI conversion can also take place simultaneously. This requires installation of new cylinder covers with gas valves and gas control block pipes to supply the engine with gas. Additional control systems and instrumentation are also required to fully convert the engine to ME-B-GI type engine.

Energy Sail and Aquarius Marine Solar Power

Like every aspect of modern life, shipping is focusing increasingly on a green image. Innovations are made each day that reduce the environmental footprint of ships. Improvements to the engines, better propeller performance and high-tech coatings, as well as friction-reducing air cushions and even skysails are reducing carbon and sulphur emissions**.** Eco Marine Power is at the forefront of developing and supplying innovative marine renewable energy technologies for shipping which harness the power of the sun and wind. These solutions include our Aquarius MRE System, Energy Sail and Aquarius Marine Solar Power which reduce fuel consumption, lower noxious gas emissions and deliver cost benefits (Unveiled: the clean queen of the sea 2017).

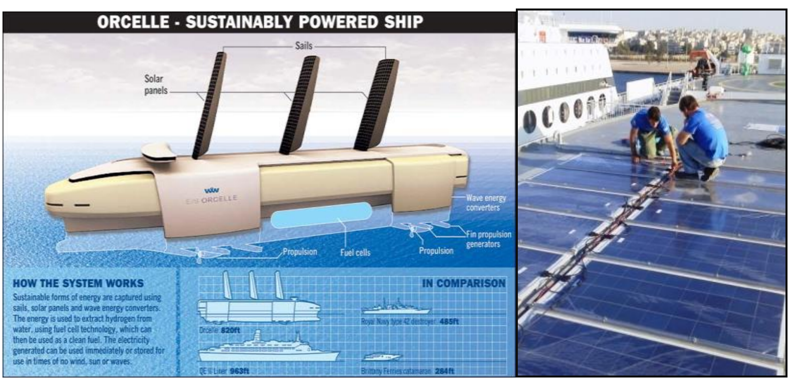


Figure 7: Sustainably powered ship and solar panel on cargo deck.
(Source- http://www.rense.com/general63/sea.htm)

Slow steaming Concept

British economist and the father of Maritime economy Dr. Martin Stopford developed this concept of slow steaming to enhance sustainable shipping. The International Maritime Organization (IMO) has set a goal to reduce greenhouse gas (GHG) emissions from existing vessels by 20–50% by 2050 and develop the Energy Efficiency Operational Indicator (EEOI) as a measure for energy efficiency. To achieve this goal, IMO has suggested three basic approaches: the enlargement of vessel size, the reduction of voyage speed, and the application of new technologies. In recent times, liners have adopted slow steaming and decelerated the voyage speed to 15–18 knots on major routes. This is because slow steaming (Woo and Moon 2013) is helpful in reducing operating costs and GHG emissions. However, it also creates negative effects that influence the operating costs and the amount of GHG emissions at the same time.

Sustainability Challenges for the Maritime Industry

Many problems remain to be formulated and solved before the shipping industry can be deemed sustainable, e.g., the combustion of fuel in ship engines impacts global warming, acidification, eutrophication and human health; invasive species spread via ship ballast water; the scrapping of old ships on beaches causes heavy metal contamination; and seafarer working conditions vary depending on the flag state. Another question that arises is related to how shipping can contribute to sustainable development. IMO has developed the concept of a Sustainable Maritime Transportation System for the "safe, secure, efficient and reliable transport of goods across the world, while minimizing pollution, maximizing energy efficiency and ensuring resource conservation" (IMO 2013). This concept is divided into the following areas with specific goals and actions for each area:

- Safety culture and environmental stewardship
- Education and training in maritime professions and support for seafarers
- Energy efficiency and ship-port interfaces like slow steaming concept
- Energy supply for ships like green/ renewable energy
- Maritime traffic support and advisory systems

- Maritime security
- Technical cooperation like solar and wind energy incorporation
- New technology and innovation like low sulphur or scrubber concept
- Finance, liability and insurance mechanisms
- Ocean governance ensuring implementation of IMO Polar code (10th Arctic Shipping Summit report on safe shipping 2017).

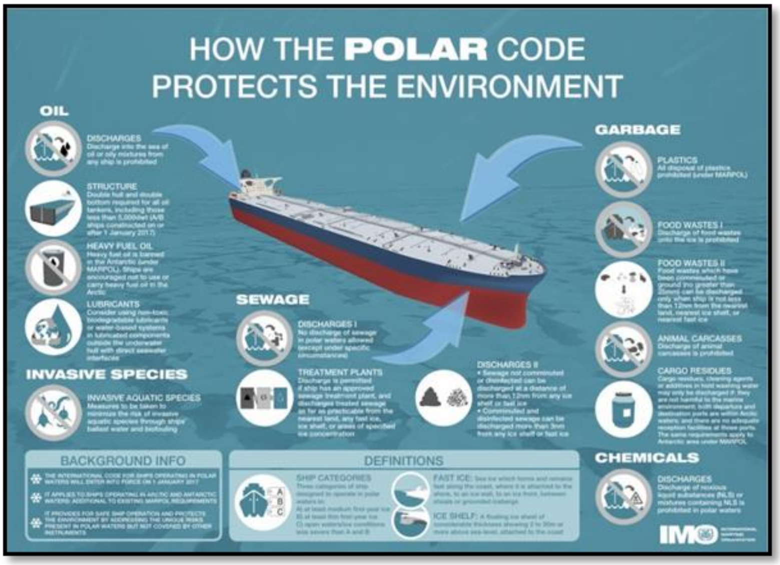


Figure 8: IMO POLAR code of Environmental Protection

Conclusion

The Earth's environment has been relatively stable for the last 10,000 years, making it possible for humans to develop, thrive, settle, and invent agriculture and industrialization. This stable state, which is known as the Holocene, might be threatened due to impacts from human actions. Our environment is severely affected by the activities of humans; some scientists have claimed that we have entered the Anthropogenic, a human-dominated geological epoch. To avoid a shift from this environmentally stable period in Earth's history, a research group has developed the concept of planetary boundaries. Planetary boundaries are boundaries that we cannot cross if we want to sustain the Earth in its current stable state. The boundaries are human-determined values of the control variables set at a “safe” distance from a dangerous level or threshold. A threshold or a tipping point is a point in a system that will cause the system to react in an abrupt and non-linear manner if crossed and will most likely result in irreversible changes (Steffen 2015).

The extent of human activities is increasing with the population, and changes in the natural environment and in the use of resources are also increasing. Humans are a natural component of the environment; thus, human activities should be a natural component of the environment. However, there is an increased concern over the negative effects of human activities in public debate and legislation. The human population has increased by more than a factor of 10 since the industrial revolution, and it is expected to continue to increase to approximately 9 billion people by 2050. The standard of living for most people on Earth has improved during this period due to technical and social innovations, economic growth and international collaboration and trade (Rockstrom 2009). However, approximately one billion people still live in poverty. Several signs have also emerged that humans are not taking care of the Earth and its ecosystem in a sustainable manner. For example, we are consuming and producing an increasing number of products, leading to large energy and material requirements. We are degrading the Earth’s ecosystems and exploiting the Earth’s natural capital, e.g., by burning fossil fuel, which emits carbon dioxide to the atmosphere. The gaps between the richest and the poorest people on Earth are increasing. According to 1987 Brundtland Report marine industry is a component of our society whereby environmental consideration is vital for a sustainable development. Similar to all industry sectors, it contributes to unsustainable patterns in our society. Although this industry is a contributor, it can also act as a component of the solution.

Shipping companies across the world are trying to come up with innovative engineering ideas and green technologies to tackle the stringent regulations about fuel emissions from vessels. A few of them are developing zero emission ships which would utilize a variety of green energy sources for propulsion. Energy Sail & Aquarius Marine Solar Power, low sulphur fuel, CNG propulsion, Scrubber technology and eco-friendly propulsions are the future of sustainable shipping considering the environment factor. It is we who have to decide what we are going to leave behind for our future generation. A safe industrial cash or safe clean environment or may be both? We are at a point of no return to have a tradeoff between environmental loss and Economic benefit. Let the world decide what they are leaving behind for the future generation. Safe environment is the demand for survival of human habitation and safe sea water with healthy living condition of marine lives. For economic necessity, shipping in the environment is indispensable for sustainable development. However, uplifting environmental concern and planned implementation of proposed action is necessary to maintain significant sustainability.

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