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Navigating Towards Net-Zero: Exploring Alternative Fuels and Propulsion Systems for Decarbonising Maritime Transport

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Abstract

Decarbonising maritime transport is required to be the main goal of the global stakeholders as around 90% of the global trade practices is carried through this mode. To accelerate the decarbonising process nations around the world have pledged and set their net-zero targets by the end of the year 2050 under the UN's 13th SDGs. This research aims to understand net-zero's relevance in decarbonising the maritime transport industry along with the exploration of alternative fuels and propulsions. The method that has been used here for the collection of data is secondary data while its analysis has been carried out with the help of thematic analysis. The findings of this research article have revealed that net zero is important for maritime operations due to heavy maritime fossil fuel emissions. The alternative fuels that can be taken in use include methanol-based fuel, ammonia-based fuel, and hydrogen-based fuels. When it comes to the propulsion system the best propulsion system could be the nuclear-powered propulsion. Finally, the implementation of these practices comes with several challenges which include political challenges, challenges regarding geopolitical tensions, and challenges due to lack of investments.

Keywords: Fuels, Propulsion, Maritime, Decarbonise.

1. Introduction

In simpler terms, net zero can be defined as the process by which the greenhouse gas emission is reduced to closest to zero. Net zero has become a very important part of the discussion on climate change after the year 2015 when the Paris Agreement was signed. The Paris Agreement aims to limit the global temperature of Earth to 1.5 degrees centigrade and reduce carbon emissions by 45% by the end of the year 2030 (Meinshausen *et al.* 2022). Carbon emissions can be witnessed across the sections of land usage, industrial usage, agricultural waste burning, energy production, transportation, and others. Transportation is one of the largest sources of carbon emission and this is done through maritime transportation, road transportation, and air transportation. The share of population growth worldwide is mainly due to transportation trading and electricity.

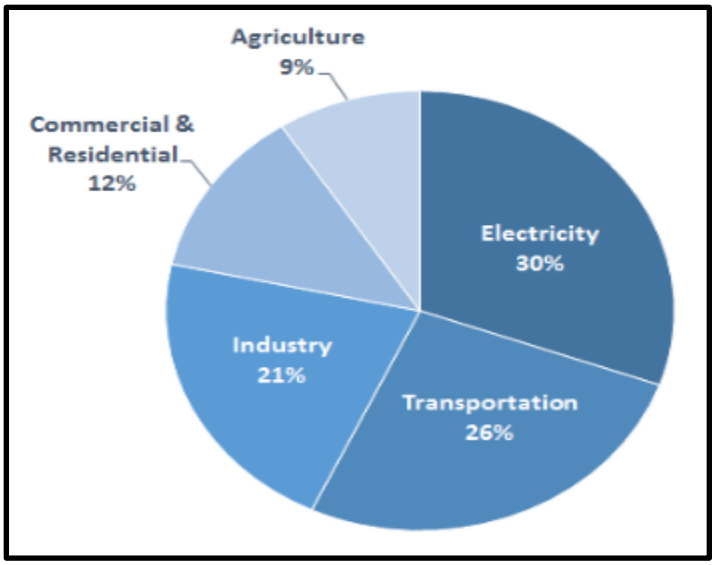

Figure 1: Greenhouse gas emission in the US sector-wise

(Source: Government of the US, 2024)

Over 90 percent of the world trade practices are carried out through the regions of the ocean with over 90,000 maritime vessels. Most of these vessels are operated by fossil fuels which produce huge amounts of CO2 which grave the climate situation and acidification (Oceana, 2023). In 2007, the International Maritime Organization calculated that around 1.12 billion metric tonnes of CO2 were released through ocean vessels in the same year (Oceana, 2023). The main pollutants of greenhouse emission include the NO2, N2O, and the Black carbon content (Oceana, 2023). These constituents are directly responsible for heat trapping in the atmosphere which reduces the rise of average carbon emission. The total shipping emission was around 501 million metric tonnes in the year 2000 which had become 661.4 million metric tonnes in the year 2010. The total emission however decreased in the year 2020 due to the global pandemic but it started to reach a new hike in the year 2022 by reaching the mark of 709.7 million metric tonnes of CO2.

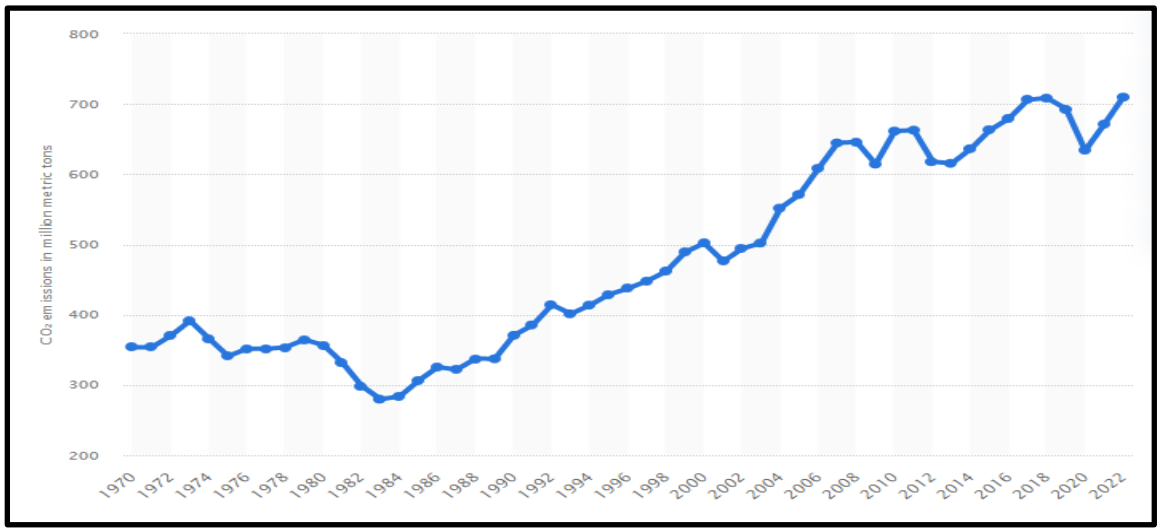

Figure 2: Global international shipping emissions up to the year 2022

(Source: Tiseo, 2023)

Global targets for the reduction of carbon emissions have been set to the year 2040 to reduce 70% of the total emission and if possible need to push towards an 80% emission target (Tiseo, 2023). This could only be achieved with the help of investing more money and resources towards alternative fossil fuels and proportions options. This will help to decarbonise the process which will decarbonise maritime transportation which is the aim of this research study.

2. Methodology

The data collection method for this research study was a secondary way of collecting data. Secondary data included collecting data from authentic websites, government websites, and websites of intergovernmental organizations. Data was collected from books published by famous authors, journals published by authors, and peer-reviewed journals from scholarly sources (Johhson & Sylvia, 2018). The gathered data will undergo in-depth analysis through thematic analysis, incorporating four distinct themes. These themes will be formulated in alignment with the aims and objectives of the research study.

3. Findings

3.1 Significance of navigating towards net zero for maritime transportation

Ocean shipping or maritime shipping is an instrumental part of the global supply chain making it a backbone of various industries. From the year 1990 to the year 2021 maritime transportation had almost doubled in its volume and reached nearly 11 billion tonnes of cargo annually (IEA, 2024). China is perceived as the shipping powerhouse of the world which has some of the busiest cargo ships. As of the year 2022, the total number of container ships docked in China was around 5600 which is huge (IEA, 2024). The items that are mostly transported around the world include Crude oils, raw steel and manufactured goods. During the COVID pandemic of the year 2019 global trade had somehow affected the global ports & shipping industry facing the problems of shortage of labour, closures of ports, and blank sailing (Notteboom *et al.* 2021). Through understanding the trade volume it can be said that almost all the nations around the world are directly or indirectly dependent on maritime transportation for trade practices.

Historically, the energy demands of international shipping have been filled up by oil products. In the year 2022, bio fuels were introduced in the international market of shipping but they had met less than 0.5% of the demand of the shipping industry (IEA, 2024). The maritime which is currently run by fossil fuels cannot be replaced directly by renewable sources of energy (IEA, 2024). Meanwhile, using the low emission alternative fuels the carbon emissions can be reduced somehow. The low-carbon emitting fuels include bio fuels, methanol, hydrogen, electricity, and ammonia (IEA, 2024). To meet the net zero (NZE) scenarios it is very important to reduce at least 15% of the total emissions by the end of the year 2030 (IEA, 2024).

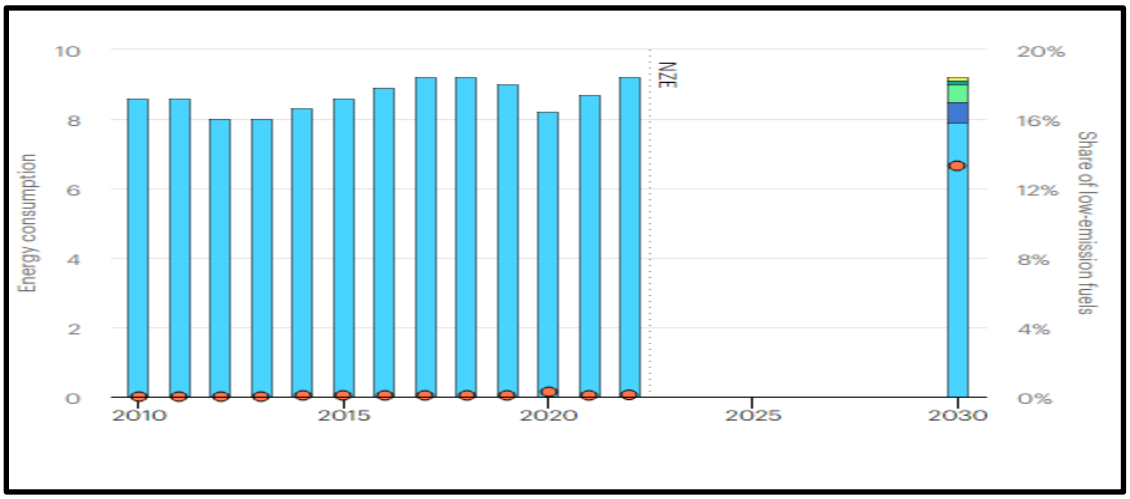

Figure 3: Energy Consumption in international shipping

(Source: IEA, 2024)

In the figure above, energy consumption in international shipping has been provided by it can easily be understood that from the year 2010 to the year 2022 fuels used by maritime transportation are usually fossil fuels. As of the year 2030, the share of low-carbon fuels in the maritime industry is expected to reach 13.3% (IEA, 2024). Various initiatives have been taken by various entities from around the world for developing projects to build up vessels that are focused on zero-emission. In May 2023 around 200 pilot projects which are focused on zero-emission vessel technologies were identified (IEA, 2024). Around 50 of them were ammonia-based, battery-based, and hydrogen fuel-based propulsion technologies (IEA, 2024). Around 30 of them focused on methanol fueling and 15 of them were hydrogen combustion (IEA, 2024). In the year 2023, China's Classification Society furnished guidelines for Shipping with the help of Ammonia-based fuel. From the above analysis, it could be understood that achieving net zero is very important for saving the Earth's ecosystem and limiting the Earth's temperature to 1.5 degrees centigrade.

3.2 Exploration of Alternative Fuel and Propulsion System for Maritime Transportation

The alternative fuel and propulsion systems provided in the above section include "Biofuels, Ammonia, Hydrogen, Methanol, and Electricity". Using these new fuels in the process of transportation activities is a long process as it needs to draw an infrastructure development, and design of the vessels to run with the help of alternative fuels like bio fuels and ammonia (Mansoori *et al.* 2021). Among all of the alternative fuel segments, the segment that grabbed the highest attention was the methanol-based fleet. The world's biggest shipping company A.P. Moller-Maersk announced recently that it has been ordering 19 methanol-based fleets and it is to be delivered between the years 2023 and 2025 (Wang *et al.* 2023). After the step taken by Maesrk other companies started showing interest in it which comprises companies like "CMA CGM, Cargill, and Cosco".

A recent report published by the Clasksons has revealed that, as of the year 2022 around 90 newly built ammonia vessels with the 11% tonnage capacity and 43 vessels were designed and ready for methanol-based fuels (IEA, 2024). Research and innovation are being carried out by many organizations and it has been carried out mostly by the shipping organizations. In the year 2023, the final trial of a hydrogen-fuelled-based ferry ended successfully and after its successful trial in every aspect, it will be operationalized. When it comes to developing the infrastructure announcements have been ammonia-based bunker designing (IEA, 2024). The created bunker is expected to be a unique one as it will be the world's first floating terminal bunker of ammonia. The Parliament of Europe and the Council of Europe have reached an agreement in the year 2023 on Alternative Fuel Infrastructure Regulations. Bunkering infrastructure development will help to enhance the entire supply chain, production, distribution, and storage facilities.

The research and development towards renewable and sustainable fuels have brought two different alternatives to existing fossil fuels. This includes drop-in fuels and emerging marine fuels. Drop-in fuels are those fuels that can be used in the current mechanism without any discrepancies or any major modification (Kargbo *et al.* 2021). These fuels will reduce emissions comparatively to that of fossil fuels which will offer little time to support the full modification towards sustainability by the shipping industry. The popularly known drop-in fuels include renewable diesel, biodiesel, bio-oils, hydrotreated oils, bio-crude oils, and vegetable oils. All of the above-mentioned fuel alternatives can be used to immediately bring down the emission situation to a large extent. The emerging fuel in the market which will surely replace the existing fuels includes existing fuels "Bio-methanol, Lignin-alcohol mixes, bio-based natural gas others". All of these are at an emerging stage and it will take years to completely replace the existing vessels' fuels as this will require a lot of work (Edeh, 2021). There are other ways as well for the reduction of fossil fuels impact by implication of emission control machinery for the machinery. The existing petroleum fuels that are used for combustion have a higher content of sulphur and these sulphur contents release harmful gasses like SO2, NO2, and particle pollution.

3.3 Steps to Decarbonise Maritime Transportation through Propulsion System Development

When it comes to the development of a propulsion system the best and most effective propulsion system that can be implied will be nuclear propulsion. The IMO is responsible for reducing the GHG from all types of international shipping under the treaty of "MARPOL", "EEDI" and "SEEMP". IMO has taken up this initiative to meet goal 17 of the UN's SDGs which is to combat the impact of climate (Forbes, 2020). Various technologies have been described above as the source of alternative options against carbon emissions. Reduction in carbon emissions with the help of nuclear power propulsion is best described by the US Navy (Furfari & Mund, 2022). As of now, the US Navy has 100 nuclear reactors which propel its 86 submarines, and all its Aircraft carriers (Forbes, 2020).

Figure 4: USS John F Keneddy

(Source: Forbes, 2020)

Nuclear power saves a lot of fuel and with the help of Nuclear propulsion ships can even move 50% faster (Yu, 2020). This would help the shipping industry to increase the total number of runs per year which will help increase the profitability of the company, and create less pollution. Work towards nuclear marine propulsion was stationed during the 1940s and it was first implemented on the USS Nautilia which is a submarine (Forbes, 2020). Many reports have suggested that the nuclear propulsion system could help the shipping industry to another level but it can be used in larger vessels as the size Aircraft carriers of the US Navy (Bigornia, 2021) Hence, from the above analysis, it can be said that by accepting alternative fuels for decarbonisation, nuclear propulsion can easily be used by the shipping industry to keep the best energy propulsion with less environmental impact.

Figure 5: Dwight Eisenhower

(Source: Forbes, 2020)

3.4 Challenges Faced by Maritime Transportation for Reducing Carbon Emissions or Decarbonising Maritime Transportation

The maritime industry around the world has been facing several challenges as well which is acting as a barrier to achieving the net zero target. Some of the most common challenges include creating a lack of seriousness, implementing and choosing the right technology, changing geopolitical scenarios, cooperating with political leadership, and investing more time and energy towards research and innovation.

3.4.1 Lack of seriousness

Most of the heads of government around the world have pledged to achieve net zero by the end of the year 2050. For an annual review of each other's progress, an annual meeting is hosted by UNDP which is popularly known as COP (Conference of Party) meeting. In the year 2023, UAE hosted the COP 26 meeting and the meeting was not attended by either the US president, the Chinese President, or the Russian president (Business-Standard, 2021). Both the US and China are the two largest economies and largest carbon emitters in the world. If these two nations are not attending a meeting their commitments cannot be called upon. India, speaking on behalf of the BASIC group, has warned that a lack of seriousness in the approach to climate finance will surely jeopardize the climate ambitions and net zero pledges (Business-Standard, 2021). In the later statement, the Indian delegation emphasized setting clear milestones and timelines so that climate reduction can be carried out successfully. The BASIC groups collectively have warned that a serious approach is required to deal with the climate threat otherwise the large nations would somehow survive but the small island nation would not be able to survive (Business-Standard, 2021). The climate approach needs to be clear-cut and well-funded, especially for those nations that are poor and need assistance.

3.4.2 Changing Geopolitics and Geo-economics Scenarios

Geopolitics is the branch of study that generally studies politics and international relations around the world across geographical boundaries. Geo-economics on the other hand can be described as the interposition between international economics, strategy, and geopolitics. To understand the actual world order it is important to understand the geopolitics and geo-economics at the same time. In the past few years, the world has witnessed a series of geopolitical events which include the signing of the Abraham Accords by Donald Trump, the Russian invasion of Ukraine, the Hiking of fuel prices by the OPEC plus nations, the expansion of BRICS, and the Israeli military operation in Gaza. All of these developments have out focused the threat of climate change and climate change and this has made the US, China, and Russia less serious about the climate threat. Due to the Russian Invasion, the fuel imports from Russia’s Nord Stream pipeline were cut down to Europe. Instead of offering renewable energy sources and technological assistance, the US started exporting crude oil to Europe.

3.4.3 Research and innovation towards sustainable fuels

Innovation is the instrumentation part of sustainable development in fuel innovation that can be used in achieving carbon neutrality. Utilizing the low carbon hydrogen and hydrogen-based fuels can act as game-changing as Hydrogen can easily be extracted from water (IEA, 2024). It is a long-term process but steps need to be taken today otherwise it will become difficult for countries to meet their carbon neutrality target of the year 2050.

4. Discussion

“Net-Zero” has become one of the most debated topics around the world, especially after the year 2015 when the Paris Agreement was held. The Ocean shipping industry is the major way of trading as around 90% of the global trade is carried through maritime routes. Most of these vessels are propelled with the help of fossil fuels like diesel, petroleum, and other fossil fuels. When it comes to carbon emissions in the world the share of transportation is 26% when it comes to the US. Rising earth temperature will make the earth survive and for this purpose, carbon reduction steps are required to be taken for the maritime sector as well. It will also give rise to CO2 and other harmful gasses that will trap the Earth’s heat. For that purpose, many countries around the world have invested their time and energy

towards finding alternative fuels and propulsion systems. The alternative fuels that have been discovered yet include Hydrogen-based fuels, Ammonia-based fuels, bio fuels, and others. Other than this methanol-based fuels and drip fuels also have been which can be the best alternative to fossil fuels which will possibly reduce the carbon emissions from the process.

Companies like Maserk have set their orders for the development of vessels and the creation of bulk which are run with the help of hydrogen-based fuels whose action was later copied. When it comes to propulsion systems each of the fuels that have been mentioned above requires a definite propulsion system except the vessels that will be driven through the Hybrid fuels. Nuclear propulsion systems have been suggested as the best and most effective alternative to fossil fuels. The nuclear propulsion technology however was successfully implemented and shown by the US naval vessels. A large segment of the US Naval Aircraft carriers and submarines are propelled by Nuclear reactors. These reactors generate a higher amount of energy which helps to propel the vessel at a much faster pace and for a longer period. Thus innovation and development of nuclear propulsion systems will benefit the shipping industry and will help to increase their profit with minimal environmental impact. Implementation of decarbonisation in the maritime transportation industry is slow due to the number of challenges it has been facing. The most common challenges that the company has been facing include geopolitical tension, lack of interest from the political leadership, and lack of R&D towards alternative fuels and propulsion systems.

5. Conclusion

Carbon neutrality or net-zero achievement is crucial for achieving sustainably by the maritime industry. This research aims to explore navigating toward net zero and exploring the maritime industry's alternative fuels and propulsion system exploration. Decarbonisation is a phenomenon that has been practiced by almost all sectors around the world and maritime transportation is no different. The methods that have been taken here are secondary data with the help of thematic data analysis. The thematic analysis has been carried out in the findings part with the help of four themes. After the thematic analysis, the key findings have been discussed with the help of the discussion part before the concluding remarks.

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