ALTERNATIVE MARINE FUELS: A GREEN APPROACH TOWARDS ACHIEVING CARBON NEUTRALITY

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Abstract: In recent times to cope with the ever-increasing demand the fisheries sector is growing at a much faster rate. Fuel consumption is a factor that heavily depends on various factors, among which type of fishing method employed is predominant. Many authors studied and reported the effect on the environment by capturing fisheries using the life cycle assessment method. A study reported annual fuel use of about 50 million m3, 1.2% of global oil consumption. With marine fish and invertebrate landings at 80.4 million tonnes, the global average fuel-use intensity was 620 litres (527 kg) per live weight tonne or about 1.9 tonnes of catch per tonne of fuel. Fishing vessels released 134 million kilograms of carbon dioxide (CO2) into the atmosphere at an average of 1.7 kg of CO2 per tonne of live-weight landings. In India alone mechanized and motorized boats emitted 1.18 t CO2/t and 0.59 t CO2/t of fish caught. Among the mechanized craft, the trawlers emitted higher CO2 (1.43 t CO2/t of fish) than the gillnetters, baguettes, seiners, liners and do letters (0.56–1.07 t CO2/t of fish). The use of alternative fuels and energy in the context of carbon neutrality focuses on reducing carbon emissions from the shipping sector. The maritime industry is urgently searching for clean, reliable and affordable alternative fuels and. Therefore, alternative fuels and energy are essential for decarbonization in international. Many countries have focused on alternative marine fuels, such as Japan , Europe, Australia, China, Poland , Norway. This piece explores potential solutions by ten such fuels that might be feasible with respect to special marine alternative-fuel-powered ships in the future. With increasing commitments to achieving carbon neutrality, transitioning to alternative fuels and energy sources has become a realistic choice for many shipping companies in the era of carbon neutrality.

Keywords: Alternate Fuel, Green Technology, Carbon Neutrality, Environmental Sustainability

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Introduction

Fisheries is a sunrise sector that provides the most affordable source of protein to the masses and is also recognized as the primary means of alleviating malnutrition and food scarcity globally. In recent times to cope with the ever-increasing demand the fisheries sector is growing at a much faster rate. India stands fourth in capture fisheries after China, Indonesia and Peru, with a 5.49% contribution of the total global capture fisheries production (96.4 million t) in 2018 (FAO, 2020). During 2017-18, the marine fish production was 3.69 million t which contributed around 29.35% of the total fish production of India and supported nearly 3.79 million fisher population (CMFRI, 2018; HBFS, 2019;). The northwest coast of India alone constituted around 28.57% of the entire coastline and contributed 32.14% (2017-18) of the total landing. Thereby justifying its position as one of the leading contributors of fisheries in the national as well world scenario.

Globally, fisheries production faces concerns in the form of sustainability issues, increased fuel consumption, and resultant burdens contributing to worsening the scenario. All specified problems are most prominent in the trawling industry, which is the most common and dominating worldwide. As India depends deeply on fisheries for employment and food security, the energy cost concerns seafood consumers, seafood traders and fishing communities.

Mechanized fishing contributes 82% of India's marine landing (Handbook on Fisheries Statistics 2022). It is an energy-intensive method of fish catching that consumes 15-20 times more energy than it produces (Endal, 1989). It is exclusively depending on fossil fuel which is limited and non-renewable. Most of humankind's environmental concerns can be connected to energy use, especially fossil fuels, in one way or another. Fossil fuel release carbon dioxide and other greenhouse gases into the atmosphere, leading to the 'greenhouse gas effect' and its attendant impacts, causing climate changes, sea level rise and global warming. Fossil fuels are also responsible for production of pollutants such as suspended particulate matter, photochemical smog particulates, ozone-depleting substances like CFCs and gaseous emissions such as Sulphur dioxide (SO_2), carbon monoxide (CO) and oxides of nitrogen, which are injurious to the environment and human health (TERI, 1999; Pelletier et al. 2007; Avadi & Freon, 2013 and Parker & Tyedmers, 2015). Because of all the specified concerns, fuel use can be the key to determining the environmental sustainability of fishery activity. Carbon emission from fisheries is based on two aspects primarily as a waste of fossil fuel combustion and secondarily as the provision of craft, gear, engine, fuel, ice and other necessities (Ziegler et al., 2003; Hospido & Tyedmers, 2005 & Thrane, 2006). Fuel consumption is a factor that heavily depends on various factors, among which type of fishing method employed is predominant (Boopendranath, 2008; Thrane, 2004; Tyedmers et al., 2005; FAO, 2007; Schau et al., 2009; Cheilari et al., 2013; Parker & Tyedmers, 2015; Parker et al. 2015; Wiviott & Mathews, 1975; Leach, 1976; Edwardson, 1976; Lorentzen, 1978; Rawitscher, 1978; Nomura, 1980; Hopper, 1982; Watanabe & Okubo, 1989 and Tyedmers, 2001). Purse seining and trawling are the most common fishing methods (Sainsbury, 1971), among which trawling is 15 times more energy intensive than purse seining. Not only in comparison with purse seining, trawling is more energy intensive when compared to any other fishing method, whether it is active or passive (Wiviott & Mathews, 1975; Leach, 1976; Edwardson, 1976; Lorentzen, 1978; Rawitscher, 1978; Nomura, 1980; Hopper, 1982; Watanabe & Okubo, 1989 and Tyedmers, 2001). In addition to the type of fishing method employed, the amount of fuel consumption may vary depending on the size and design of the vessel and engine, weather conditions, type and size of fishing gears, location, skill and knowledge of the crew, among which vessel size have a major role (Wiviott& Mathews, 1975; Rochereau, 1976; Edwardson, 1976; Lorentzen, 1978; Watanabe & Okubo, 1989).

Fuel consumption of a given fishery, even within a local area, can change as the abundance of fisheries resources changes, fleets expand, the average size of vessels increases, vessels travel further to fish and become more technologically advanced. Moreover, rising fuel prices associated with the future scarcity of fossil fuels and increased environmental hazards have raised awareness of the fuel efficiency of the fishery sector.

Energy Inputs to Fisheries

A few studies have been conducted in the Indian context for energy analysis of fishing systems and operations (Edwin & Hridayanathan, 1997; Boopendranath, 2000; Boopendranath & Hameed, 2009; Boopendranath & Hameed, 2010; Vivekanandan, 2013; Ghosh et al., 2014). In Indian marine fisheries, the boosted fishing effort and efficiency in the last five decades led to a considerable increase in fuel consumption, equivalent to CO_2 emission of 0.30 million tons (mt) in 1961 to 3.60 MMT in 2010. The CO_2 emission has increased from 0.50 to 1.02 t for every ton of fish caught during the period. The authors also reported large differences in CO_2 emission depending on craft types and age. In 2010, the larger mechanized boats (with inboard engines) emitted 1.18 t CO_2/t of fish caught, and the smaller motorized boats (with outboard motors) 0.59 t CO_2/t of fish caught. The author reported that among mechanized craft, trawlers emitted more CO_2 (1.43 t CO_2/t of fish) than the gillnetters, baguettes, seiners, liners and do letters (0.56–1.07 t CO_2/t of fish). (Vivekanandan, 2013). Many authors studied and reported the effect on the environment by capturing fisheries using the life cycle assessment method. Tyedmers (2001), Ziegler et al. (2003), Thrane (2004, 2006), Ellingsen & Aanondsen (2006), Ziegler & Valentinsson (2008), Vázquez-Rowe et al. (2010a and 2010b), Ramos et al. (2011) and Svanes et al. (2011). The study revealed that the technical efficiency of the different types of ring seines using lesser horsepower engines performed well regarding the catch per adjusted horsepower (Edwin & Hridayanathan, 1997). Energy requirements have been used to evaluate the performance of food production systems for over a hundred years in terms of energy input and carbon footprint.

Current estimates of fuel use and cost

Tyedmers et al. (2005) reported annual fuel use of about 50 million m3, 1.2% of global oil consumption. With marine fish and invertebrate landings at 80.4 million tonnes, the global average fuel-use intensity was 620 litres (527 kg) per live weight tonne or about 1.9 tonnes of catch per tonne of fuel. Fishing vessels released 134 million kilograms of carbon dioxide (CO_2) into the atmosphere at an average of 1.7 kg of CO_2 per tonne of live-weight landings. They further noted that these were likely to be serious underestimates, as they did not account for freshwater fisheries or substantial IUU catches. Global fisheries were estimated to use 12.5 times the amount of fuel energy as their edible-protein energy output, which, although significantly inefficient, compared well with several other animal-protein production systems.

In the context of Indian marine capture fisheries, the substantial increase in fossil fuel was noticed due to increased fishing effort and efficiency during the last five decades. This resulted in the equivalent CO_2 emission of 0.30 million tonnes (mt) in 1961 to 3.60 mt in 2010. Roughly for every tonne of fish caught, the CO_2 emission has increased from 0.50 to 1.02 t above said period. There are large differences in CO_2 emission among the types of craft made of different materials. In 2010, mechanized and motorized boats emitted 1.18 t CO_2/t and 0.59 t CO_2/t of fish caught.

Among the mechanized craft, the trawlers emitted higher CO2 (1.43 t CO2/t of fish) than the gillnetters, baguettes, seiners, liners and do letters (0.56–1.07 t CO2/t of fish). (Vivekanandan, 2013).

Green Technology

Technology usually refers to applying various techniques, skills, methods and processes for all practical purposes or to achieve certain objectives such as scientific investigation or research. A technology that is environmentally friendly in its production, supply chain or usage is called Green Technology or Green Tech.

Green tech is an umbrella term that continuously develops products, systems or equipment that are less taxing to the natural environment and its resources, limiting and diminishing the negative effect of human exercises.

The world we live in has a limited amount of natural resources, referred to as Non-Renewable resources or resources which can be depleted over time. Human activities have caused many to already perish from the face of the Earth.

According to the estimated Global Footprint Network in 2018, humans are consuming natural resources 1.7% faster than the Earth can replenish. Therefore, the need of the hour is that we as a society should invest in Green Tech as they are:

a) Less taxing to the natural environment, thus reducing the depletion of the resource.

b) Emission of greenhouse gases (GHG) (CO_2, CH_4, N_2O) is considerably less or zero.

c) Usage of renewable resources (wind, solar) is encouraged.

Understanding Green Tech

The main goal of producing Green Tech is to control climate change, protect the natural environment, reduce our dependence on Non-Renewable resources such as fossil fuels, and heal the damage done to the environment.

The market for Green Tech is relatively in its starting stage, but the investment capital is already blooming. While it is true that green tech has gotten progressively mainstream in the modern age, components of these business policies have been being used since the 18th and 19th centuries when the Industrial Revolution was at its peak.

Manufacturers were trying to minimize their negative environmental externalities in the early 19th century by modifying manufacturing practices to create less soot or waste by-products. In any case, green innovation as a perceived business division didn't generally create until the 1990s.

The global cumulative investment in renewable forms of energy and green technology processes exceeded $200 billion in the year 2017, according to a United Nations study published in 2018. $2.9 trillion has also been invested in sources such as solar and wind power since 2004. The U.N. also reported that China was the world's largest investor in the field, with about $126 billion invested in 2017.

Advantages of Green Tech and Hurdles to Cross

● Helps in recycling and managing waste materials.

● It is environmentally friendly. As a result, it emits zero or less harmful materials into the environment

● Maintaining Green Tech is very cost-efficient.

● Green Tech helps conserve energy

● It is also helping in rejuvenating the health of our ecosystem.

While there are many advantages to the use of Green Tech, there are many hurdles in the way of Green Tech that first need to be cleared. We as a civilization grew largely depending on fossil fuel as our main energy source.

Statistics show that around 90% of our energy needs are fulfilled by burning fossil fuels. The shift from using cheap, energy-dense and abundantly available fossil fuel towards environmentally friendly green tech will surely be a major hurdle to cross.

Widespread usage of wind and sun energy would help us move away from relying on fossil fuels. Still, expanding wind and solar technologies will prove difficult because the sun does not always shine, and the wind does not always blow. This unreliability can be solved by storing and using the energy generated when needed.

Few of these green technologies also cannot be anywhere, such as tidal energy can only be utilized during high tides, and geothermal energy can only be used in a geologically unstable place.

We will also require new transmission lines to shuttle existing energy around the electricity grid and bring wind and solar energy generated in the prairies and deserts to cities and towns where needed. Although there are a few hurdles in the way of Green technology, in the long run, the usage of green tech will be worth the extra mile we will put into it.

Emissions arising from maritime transport continue to significantly contribute to air pollution (IMO, 2021). *Introducing several alternative marine fuels is considered an important strategy for maritime decarbonization. These alternative marine fuels include liquefied natural gas (LNG), liquefied biogas (LBG), hydrogen, ammonia, methanol, ethanol, hydrotreated vegetable oil (HVO), etc. In some studies, nuclear power and electricity are also included in the scope of alternative fuels for merchant ships.*

Especially after the International Maritime Organization (IMO) adopted its initial strategy for reducing the emissions of greenhouse gas (GHG) from ships, transitioning to the use of alternative fuels and energy sources has become a realistic need for many shipping companies (IMO, 2018).

These cleaner alternative marine fuels and energy include liquefied natural gas (LNG), liquefied biogas (LBG), hydrogen, ammonia, methanol, ethanol, hydrotreated vegetable oil (HVO), fuel cells, nuclear power, wind power, solar power, electricity (ITF, 2018; Wang and Wright, 2021; Al-Enazi et al., 2021; Santos et al., 2022) (Figure 1).

The use of alternative fuels and energy in the context of carbon neutrality focuses on reducing carbon emissions from the shipping sector.

The maritime industry is urgently searching for clean, reliable and affordable alternative fuels and energy (Al Enazi et al., 2021).

Therefore, alternative fuels and energy are essential for decarbonization in international shipping (Wang and Wright, 2021). Many countries have focused on alternative marine fuels, such as the USA (Bicer et al., 2016), Japan (Tanaka, 2013), Europe (Prussi et al., 2021), Australia (Paul et al., 2018), China (Yang et al., 2019), Poland (Miętkiewicz, 2021), Norway (Laribi and Guy, 2020), etc.

This piece explores potential solutions by ten such fuels that might be feasible with respect to special marine alternative-fuel-powered ships in the future.

Liquefied Natural Gas (LNG)

Liquefied natural gas (LNG) is natural gas that has been cooled to the point that it condenses to a liquid, which occurs at a temperature of approximately -256oF (161oC) and at atmospheric pressure. Liquefaction reduces the volume by around 600 times, thus making it more economical to transport between continents in specially designed ocean vessels. In contrast, traditional pipeline transportation systems would be less economically attractive and could be technically or politically infeasible. Thus, LNG technology makes natural gas available throughout the world. To make LNG available for use in a country like the U.S., energy companies must invest in a number of different operations that are highly linked and dependent upon one another. The major stages of the LNG value chain, excluding pipeline operations between the locations, consist of the following.

 Exploration to find natural gas in the earth's crust and production of the gas for delivery to gas users. Most of the time, natural gas is discovered during the search for oil.

 Liquefaction to convert natural gas into a liquid state so that it can be transported in ships.

 Shipping the LNG in special-purpose vessels.

 Storage and Regasification, to convert the LNG stored in specially made storage tanks from the liquefied phase to the gaseous phase, ready to be moved to the final destination through the natural gas pipeline system.

Liquefaction also provides the opportunity to store natural gas for use during high-demand periods in areas where geologic conditions are not suitable for developing underground storage facilities. In the northeastern part of the U.S., a region lacking in underground storage, LNG is a critical part of the region's supply during cold snaps. In regions where pipeline capacity from supply areas can be very expensive and use is highly seasonal, Liquefaction and storage of LNG occurs during off-peak periods to reduce pricey pipeline capacity commitments during peak periods.

Ammonia

Another zero-carbon fuel option being considered is ammonia. Similar to hydrogen, most ammonia is currently made using natural gas. Ammonia can be used as the energy source for fuel cells or as part of the fuel source for an internal combustion engine. Notably, "green" ammonia offers the dual potential towards zero-emission shipping in both "well-to-wake" and "tank-to-wake." Scalability of production and availability remain obstacles, as are novel engine technology designs, safety considerations and concerns about the supply chain. Moreover, there are regulatory and technical barriers to the use of toxic fuels.

While there are many competing fuel options across several scenarios, notably, in a recent "Maritime Forecast to 2050 Energy Transition Outlook 2021", DNV predicts that ammonia is one of the most promising carbon-neutral fuels. However, for ammonia to be a viable future option, it must be manufactured through low-carbon processes.

Biofuels

It is most commonly produced from soybean oil, rapeseed oil, sunflower oil, corn oil and olive oil, and some wastes, such as used waste frying oils,26 which appear attractive candidates for biodiesel production. Biodiesel is a renewable fuel compatible with the current engines; its use would reduce dependence on fossil fuels and reduce air pollution and related public health risks. The disadvantages of biodiesel are cold weather starting, some storage instability and a slight increase in NOx emissions (+2:+5%); this increase is due to the higher oxygen content of the fuel. However, some reductions in NOx emissions can be attained by retarding the timing of ignition and slowing the burn rate of the fuel in the combustion chamber. Despite its presence as an environmentally friendly source, its availability is limited.

Nuclear

Nuclear and marine propulsion work started in the 1940s, and the first test reactor started in the USA in 1953. The first nuclear-powered submarine, USS Nautilus, was put to sea in 1955, marking the transition of submarines from slow underwater vessels to warships capable of sustaining 20-25 knots, submerged for weeks on end. Nautilus led to the parallel development of further Skate-class submarines powered by single pressurized water reactors (PWRs) and an aircraft carrier, USS Enterprise, powered by eight PWR units in 1960. A cruiser, USS Long Beach, followed in 1961 and was powered by two of these early units. Remarkably, the Enterprise remains in service.
Nuclear power is particularly suitable for vessels at sea for long periods without refuelling or for powerful submarine propulsion.

The use of nuclear-powered ships and offshore nuclear-powered platforms may lead to marine radioactive contamination in the absence of adequate nuclear safety measures. Particularly in exceptional circumstances, such as extreme weather, collisions, external threats, or operational errors, nuclear-powered ships and offshore nuclear-powered platforms may leak sources of radioactivity, leading to serious marine pollution incidents. When a reactor melts down and the main containment is breached, nuclear fuel may leak from the core into the surrounding environment, and widespread marine pollution is likely to result. "Radioactive wastes are not biodegradable, nor is there any possibility of removing them from the sea once they have entered it. These substances vary in effect, but in general, they are absorbed by marine organisms, often becoming concentrated as they move up the food chain, affecting the growth, reproduction and mortality of marine life" (Churchill et al., 2022).

Hydrogen

It is considered a renewable energy source and has been considered the fuel of the future for decades. The scientific research concerning the use of hydrogen in transportation began shortly after the first oil crisis. Many car manufacturers started development programs to produce a car running on hydrogen fuel in internal combustion engines. The beginning was in Germany and Japan, and the United States followed them. Nowadays, the United States has national programs for the development of hydrogen systems, especially for fuel cell applications, to overcome any combustion-related problems. GHG emissions from hydrogen fuel depend largely on the energy source of hydrogen, with the majority of emissions coming from steam methane reforming and liquefaction processes (Hwang et al., 2020). At present, the use of fossil fuels is the main method of producing hydrogen energy, such as coal gasification and steam methane reforming (Hwang et al., 2020; Van Hoecke et al., 2021), which lead to a large amount of GHG emissions during the process of producing harmless hydrogen fuel.

Safety is also worth considering when bunkering, storing and using hydrogen fuel on board. The explosive and diffusible nature of hydrogen may affect the hull's integrity and the crew's safety. Hydrogen molecules are so small that they can easily leak through pipes or storage joints and cracks. Although hydrogen is nontoxic, it may reach flammable concentrations (between 4% and 75% in air) and ignition temperatures and then burn, or it may cause asphyxiation by displacing oxygen from the perspective when leaking into a closed environment (Hydrogen Tools, 2022). The energy required to burn hydrogen is so small that even the sparks from a crew member’s cigarette may ignite it (Hydrogen Tools, 2022). When a ship collides, the pressurized storage system for hydrogen may leak. Once hydrogen explodes and burns, even in an open environment, hydrogen flames can severely damage the objects touched, including the hull, cargo, personnel, etc.

Electricity

Electric ships may not have harmful environmental effects during navigation. Still, during the production and disposal of electric energy, they harm acidification, eutrophication of water bodies and toxicity to humans. The main cause is spoil disposal from lignite mining in surface landfills (Bicer and Dincer, 2018). Eutrophication is a process that disrupts the aquatic ecological balance, in which large quantities of nitrogen- and phosphorus-containing compounds are discharged into the water, causing algae and other marine organisms to proliferate and consume too much oxygen in the water, causing fish plankton to die from a lack of oxygen. In turn, their decomposing bodies cause water pollution.

Methanol

GHG emissions from methanol are largely determined by the raw materials used to manufacture it and the conversion process (Martin, 2021). Methanol from natural gas has the same degree of global warming potential as heavy diesel fuels, while methanol and bioethanol have a lower global warming potential. However, bioethanol fuels operating in marine engines also carry the risk of methane slips. Methanol biodegrades rapidly, but it is toxic at higher concentrations. Thus, there may be localised marine environmental impacts before dilution in a collision, grounding, or other ship accident resulting in methanol leakage (Brynolf et al., 2014). Moreover, the eutrophication potential produced by methanol and methanol fuels is approximately twice that of LNG (Brynolf et al., 2014), which may lead to imbalances in marine water ecosystems. Additionally, the low flash point of methanol makes it a risk of fire on ships.

Fischer–Tropsch (F-T) diesel from natural gas and coal

It is a production process that produces diesel fuel from natural gas or coal (gas to liquid (GTL) or coal to liquid (CTL)) via steam reforming, auto-thermal reforming or gasification. Its availability and adaptability will follow the main fuel source (natural gas or coal). F-T diesel fuel has no sulfur, almost no aromatics and high cetane. On the other hand, the F-T process is very energy intense, and its capital investment is large; this makes it a very costly fuel.

Natural Gas

It is a mixture of paraffinic hydrocarbons such as methane, ethane, propane and butane. Natural gas is a low-density and low-sulfur content fuel as compared to petroleum products and is practically free from carbon monoxide emissions. Natural gas is converted to LNG by cooling it down to 2162 ºC, at which it becomes a liquid, and this process reduces its volume by a factor of more than 600. Thus, natural gas has emerged as the most preferred fuel due to its inherently environmentally benignity, greater efficiency and cost-effectiveness.

Alcohols

They are of two types, ethanol (C2H5OH) and methanol (CH3OH), which can be produced from sugarcane waste and many agriculture products (renewable sources). It is not new; it has been used in motor vehicles since 1954. The availability and indigenous sources, ease of handling, low emission and high thermal efficiency obtainable with its use make it a logical alternative in future, especially to hydrogen generation for fuel cells. Recent studies30 showed the possibility of using methanol as an alternative fuel, especially in dual-fuel engines. The problems associated with using methanol or its blends are the emission of aldehyde, phase separation, vapour lock, cold starting and cost-effectiveness.

Conclusion & Future Scope

With increasing commitments to achieving carbon neutrality, transitioning to alternative fuels and energy sources has become a realistic choice for many shipping companies. The use of alternative marine fuels and energy in the era of carbon neutrality focuses on reducing carbon emissions from the shipping sector. Still, such a transition may ignore the other potential risks to the marine environment that these "carbon-clean" alternative fuels and energy might involve.

Consequently, it calls for more cross-disciplinary research to improve further international institutions concerning regulating alternative-fuel-powered ships. Bunkering facility regulation and freedom of navigation, the need for global environmental enforcement standards related to alternative fuels, deficiencies in the liability and compensation system for pollution damage, and inadequate international cooperation in pollution prevention and response.

Nevertheless, although the international law perspective provides a lens through which to reflect the improvement of regulation over alternative-fuel-powered ships, international law alone is not a panacea to address all their special environmental risks, as many international legal instruments per se are struggling with problems such as insufficient contracting parties, lack of legal binding effect or failure to fulfil by the parties. Therefore, formulating a more effective international response mechanism to address alternative-fuel-powered ships' special environmental risks involves multidimensional issues concerning science and technology, political economy and power politics in international relations.

The existing international law framework has many insufficiencies in dealing with these new challenges.

Therefore, further improvement in the existing international legal regime is called for to effectively prevent marine pollution and ensure prompt and adequate compensation for marine environmental damage to ensure the implementation of marine ecological justice in the era of carbon neutrality in maritime transport.

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