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Appraisal of Energy Transition: International Maritime Organisation's Forecast in Shipping Industry

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ABSTRACT

This paper examined the proposed transition of energy from the use of fossil fuel to alternative energies in the maritime industry. This is with a view to appraise all options of alternative energies available with their impacts on climate, environment and cost effectiveness. Master Mariners and Chief engineers in Nigeria with their association comprising about 103 in population were reduced to 44 in sample using Yamane formula and designed questionnaire distributed through random sampling techniques. The responses were retrieved via the google form. The result from the analysis showed different levels of strength, weaknesses, opportunity and weaknesses with hybrid and electric being the least to impact climate but somehow costly in the areas where the electricity is unstable, while biogas is available and cheap production is difficult and may affect agriculture, landuse, e.t.c. All other kinds of fuel were explained according to their SWOT explanations. Attempt should be made to increase the use of electric energy and hybrid from ships though it will be limited in power, biogas and other renewable energies can be worked on to have a better environment and good climate with cost effectiveness in the long run. Considering all the aforementioned issues, it is imperative for IMO to consider this SWOT analysis and observe all areas of interest with a view to formulate polices and encourage sustainable ship building and fuel that is to be used to achieve the vision of 2050.

1. INTRODUCTION

The general definition of energy is ability to do work. In life, without energy no man can possibly survive. The makeup of earth and man surprisingly requires coolant and heat to be habitable and survive respectively. Ocean, seas and other waters are naturally available for man to tap and sunlight has naturally been provided to generate heat. Today, our emphasis is on energy. With energy we power generator, boil water to drink, propel ships and move our cars. One of the major ways we do all these is through the use of combustive engine that uses refine petroleum products. The refine petroleum products are derivatives of crude oil refinement. The reliance on crude oil and its resultant demand necessitated tanker shipping with concomitant economic realities of countries endowed with it. Shipping is the major driver of the world economy and responsible for 80% of international trade (Shutterstock, 2023). According to Clarksons, (2022a) noted that, 64% of oil produced globally is moved by ships. Four major factors are responsible for energy transition. The ***first*** is the price of crude oil in global market. The price of petroleum product especially in Nigeria after the removal of fuel subsidy has forced

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middle class citizen to become poor and the poor become poorer. In order to get away out of seemingly uncontrollable increasing in price of this essential commodity, it is either we make it more surplus that its supply will be more than demand or will seek for alternative fuel (Adepoju et al, 2023). Secondly, is the effect of pollution arising from the use of refined petroleum product or carriage of crude oil on a voyage. According to the report by Tyndall Centre for Climate Change Research, University of Manchester, efforts to reduce global pollution is to limit global energy to 1.5^0C because of its effect on climate change.

The **third** factor is the concept of zero-carbon or decarbonization is or has brought a paradigm shift in today's shipping industry. According to Gerdes (2023) the new IMO rule states that all ships are mandated from 1 January, 2020 to stop using high sulphur fuels. Of major contaminates that are driving this transition are Sulpur, cabon dioxide, Nitrogen oxide with their contributions to environment per annum at the rate of 13%, 3% and 15% respectively (IMO, 2018). In order to limit the emissions by ship and to reduce energy consumption both by 75% in years to come, IMO came up with retrofitting concept and energy saving technologies (Gao, 2022). The aim of IMO is to replace all the existing ships with "eco-ships" by year 2050.

The last ***(fourth)*** is the change and requirements in shipping transition moving from fossil fuel to what was referred to as heavy fuel oil (HFO) and diesel oil or marine gas (MDO/MGO)) to biofuel (Ramsay et al,2022). According to IMO (2022) this will require seafarers to be trained on how to handle liquid cargo like ammonia, hydrogen and other biofuels. In all, we are attempting to reduce the impact of emission against global warming and also use alternative fuel without considering how it will also affect Sustainable Development Goals of food security.

1.1 Review of IMO and underpinning literatures

Having it more in surplus is constrained by certain factors by the fact that crude oil shipment contaminates seas and ocean, has a significant negative effect on marine habitat and constantly needed to be replaced with renewable energy.

IMO summon a general Assembly in Talona 2018 to deliberate on issues of greenhouse emissions emanating from ships and how to curb this by December, 2023. Some of the gases that are responsible for GHG include Carbon dioxide (CO_2), Nitrox Oxide (N_2O) and methane (CH_4)(IMO, 2018). Part of the resolution was to

1. Regulate energy efficiency of ships through technical and operational measures from MARPOL annex VI. Up to date, about 2700 new ships have been certified to meet energy efficient requirements (Energy Efficiency Design Index) (IMO, 2021)
2. That Marine Environmental Committee of IMO promotes technical cooperation and transfer of technology on issues relating to energy efficiency and providing technical assistance to developing countries and member states through IMO's various projects.
3. Device a means for data collection on fuel consumption of ships and mandate ships to record and report their respective oil and fuel consumptions.
4. All matters relating to pollution in UNCLOS- United Nations Convention on the Law of the Sea (pollution from seabed activities, pollution by dumbing, pollution by atmosphere and pollution by vessels)
5. United Nations Sustainable Development Goals Agenda of 2030

By implication, according to IMO; ships will now have to estimate their energy efficiency using Existing Energy Efficiency Index (EEXI) and also estimate annual operational carbon intensity indicator (CII) rating. According to European Commission (2015) that stated that, retrofitting is concerned with the willingness of the ship-owners to install on their ships latest technology, innovative components or systems so as to meet up with the new emission and energy regulatory standards. Traditional retrofitting methods are hull modifications and propeller modifications. Advanced technology has also made it possible for Advanced Power Management Systems. This allows ship energy to be optimized from onboard control system.

Three major measures of achieving environmentally friendly ships are: 1) operational measures (2) technical measures and (3) management measures

Operational measures include- ships speed reduction or optimization of ship, cleaning of hull, polishing the surface of propeller, routing of weathers (Wartsila, 2008).

a) Optimization of ship: Most ships are designed to carry a designated amount of cargo at a certain speed for certain fuel consumption. This implies the specification of set trim conditions. Loaded or unloaded, trim has a significant influence on the resistance of the ship through the water and optimizing trim can deliver significant fuel savings. For any given draft there is a trim condition that gives minimum resistance. In some ships, it is possible to assess optimum trim conditions for fuel efficiency continuously throughout the voyage. Design or safety factors may preclude full use of trim optimization.

b) Weather routing: Weather routing is the practice of using weather forecasts to optimize a ship’s route so as to minimize exposure to bad weather and/or to allow it to benefit from favourable wind and current directions or weather conditions. Weather routing is typically offered as a service.

Technical measure mainly is about energy saving measures with the introduction of technologies into the existing ships. The last one which is the ship management system is about the overall management system of ship performance. Out of about 55,000 world vessels, only about 4000 are fitted with energy saving technology (Clarksons Research, 2020 and Statista, 2021). The major five areas of Energy Saving Technology EST and the coreesponding number of ships fitted can be seen in Table 1 adopted from Gao (2022) citing Clarksons Research, 2020).

Table 1: Ship Energy Saving Technologies

Group	Key Technologies	Examole Project	Fuel Saving	vessel equipped
propeller	propeller duct	Becker Mewis Duct	3-8%	>1161
	Rudder Bulb	Rolls-Royce Promas	3-5%	>268
Hull	Bow enhancement	Ulstein X-Bow	4-10%	>252
	Air lubrications system	Silver-Stream	5-10%	>71
Engine room	Waste heat recovery system	Calnetix Hydro current	3-8%	>38
	Exhaust gas economiser	Alfa Laval, Warsila	4-6%	>1515
Wind	Fletner rotors	Norspower roto sail	7-10%	>8
	Wind kite	Airseas seawing	up to 20%	>0
Solar	Solar Sail	Eco-marine energysail	Up to 20%	>0

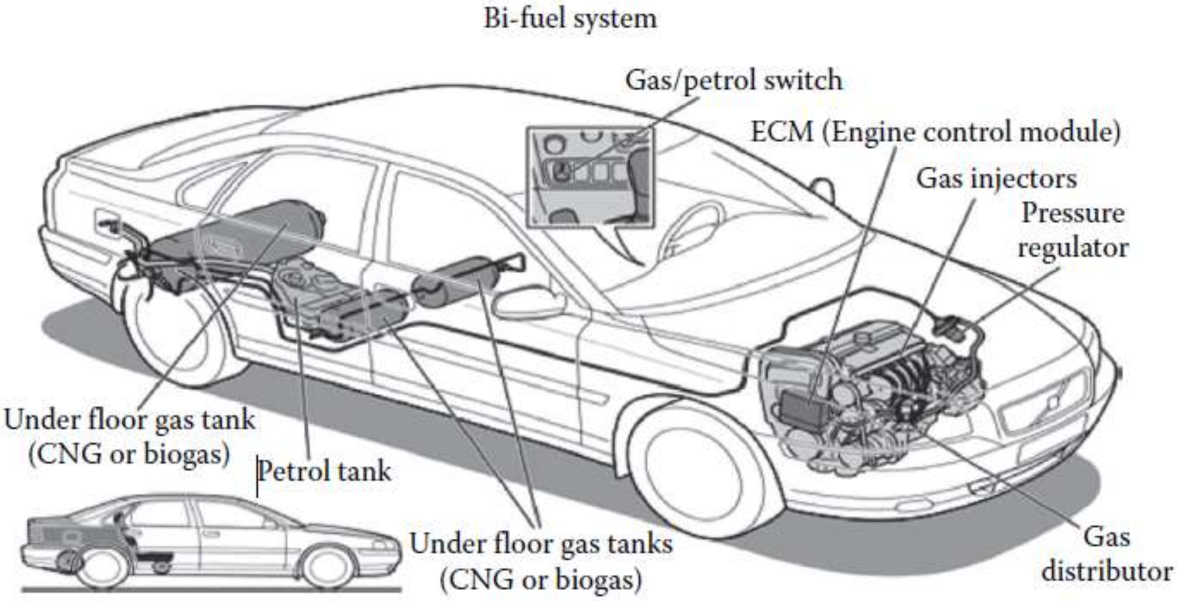
Sources: Clarksons Research (2020) and Gao (2022)

Crude oil, which is the major energy source and of course the possessor of larger share in international shipment requires refinement before it can be used. Many products that are useful for human endeavor are produced during refining process. Distilling crude oil will produce the following petroleum products at different temperature: Liquefied Petroleum Product (LPG) gas, aviation gas, jet fuels, kerosene, distillate fuel oil, lubricants, creases, waxes and bitumen (Adepoju, 2023)

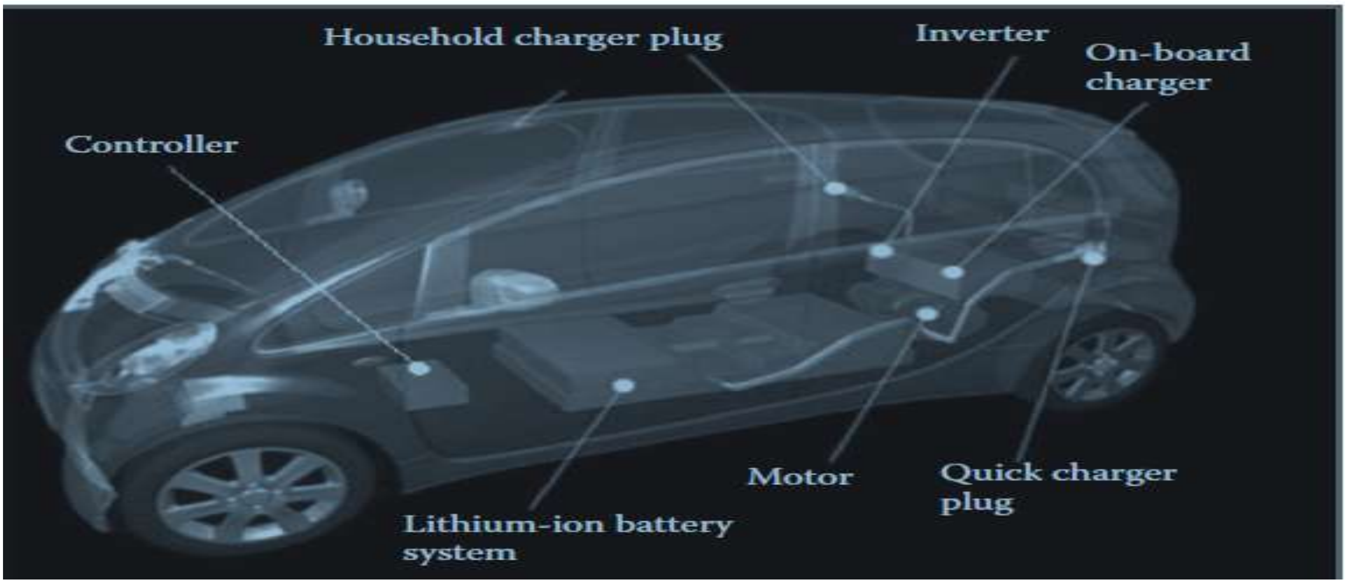
Almost all the countries of the world are seeking for solution arising from the aforementioned factors and necessity to reduce impact of carbon on climate change to make use of alternative fuel. So, the new world system in maritime transport is to either seek for energy efficiency through alternative fuel or improve the fuel efficiency of the existing ships (American Planning Association, 2010). The following are currently sources of energy aside the use of fossil fuel and are so called alternative fuel or energy.

Biogas: Biogas can be described as gases extracted from the fermentation process or enclosed system of producing renewable energy in the absence of oxygen when micro-organism broken down organic matter. Biogas is made up of methane and carbon dioxide. It can be produced with dung and urine from goat, sheep, cattle; aquatic plant like algae, water hyacinth, forest residue like leaves, bark and solid materials like paper and domestic waste. Because of hike in fossil fuel price, United States initiated bio-fuel through the use of ethanol. The ethanol can be produced from corn, cassava and other cereals. If follows a process of fermentation of sugarcane, corn or sugar beet. However, the challenge has always been the production capacity (Adepoju, 2023). Babatunde (2022) expressed that, there is limitation in developing countries on how to diversify from the use of fossil fuel because of lack of industrial capacity and latest technology. DOE (2020) explained that 40% of corn produced in United States is converted to ethanol. According to Adepoju (2023) ethanol has been found to also be produced from high content starch items like sorghum, barley, sugarcane and recently from sawdust, rice straw, grasses and wood chips. Brazil has been said to be the highest producer of corn and a country that makes use of biofuel in this regard than any other countries of world as of now. As noted by Babatunde (2022) United States investment on Bio-refinery and ethanol production in the last twenty years has increased to the tune of 130MMT as of year 2015. Consequently, there has been steady increase corn yield per hectare and chemical per hectare in the United States. This big question is, what it the assurance of its sustainability? How many hectares will be required to produce certain litres of ethanol required to propel millions of vehicles per time? Limitations with the use of biogas as experimented can be in form of drag, low speed, storage problem, corrosiveness, efficiency and large quantities. The cost of products used for fuel will be very high as there will be demand continuously. The examples of sugarcane plant in Hawaii in Figure 1 and bi-fuel car in Figure 2.

Source:



Electric Vehicles: Electronic Vehicle (EV) is the game changer. Electric Vehicle was initiated in 1832 (mmmmm). Interest on Electric Vehicle increased because of factors mentioned earlier (price and pollution). Battery is powered through electricity and this provides the vehicle propulsion with the battery being recharged through mostly the photovoltaic panels set up by recharging centres. This produces no noise and no pollution. However, unlike internal combustible engines, it relies on batteries, have low density and low energy. It is easier to produce but has lesser power and requires 4-8 hours to charge.



1. Hybrid vehicles: This is in form of use of both the international combustive engines and electric vehicle together. The working situation is that, the battery starts the car, when accelerator is pressed; the vehicle converts shaft's power into electricity and stores it. When the vehicle driver wishes to switch to Ev
2. Solar Energy Driven vehicle technology: The technology here makes use of ***photovoltaic*** and ***concentrating solar power*** to generate electricity. With the photovoltaic technology, conducting properties of silicon with the aid of photo-electric effect can be used to generate electricity. On the other hand, Concentrating Solar Power (CSP) uses a reflector to face sunlight and generate steam that powers electric plant.
3. Hydrogen Vehicle: In this case, hydrogen is produced through electrolysis through the extraction of hydrocarbon. Secondly, it requires compressing hydrogen into liquid form and storing it onboard a vehicle. Fuel cell is used to generate electricity on demand and propel a vehicle. Hydrogen is usually wasted in production and other problems. Hydrogen car is not cost effective because it requires 2 to 3 times energy for operation than electric cars. Hydrogen is also said to be very low in density which requires very high-pressure storage tank which adds to the weight of the vehicle and low temperature. However, liquid hydrogen fuel can be a good alternative fuel for aircraft and vessel propulsion.
4. Synthetic Natural Gas: Chandel and Williams (2009) expressed that the gas is produced from Biomass or coal and it is also referred to as Subtle Natural Gas.
5. CNG:
6. Ammonia: Nitrogen and hydrogen are the composition of Ammonia (Machaj et al, 2022). It is a fuel that has reduced CO_2 among alternative fuels but has problem of storage and the use of ammonia in plastic, pharmaceutical and explosive manufacturing industry may further reduce the quantity available for fuel production.
7. Battery Energy Storage System (BESS): This has to do with storing energy in the battery to propel ship

1.2 Energy Transition- use of renewable energy and transport same (Challenge and Opportunity)

According to Smith et al (2021) the likely phases of energy transition in shipping can be summarized as:

1. Emergence Phase: the use of the alternative fuel will be slow and research will continue to be developed to increase its progress. There will be little difference in price between fossil fuel and alternative fuel. The cost of production will be higher here for alternative fuel. While observing progress, adjustments will be made to regularize disparities.
2. Diffusion stage: Cost of new technology will be lowered because of economies of scale and technological improvements. The lowered cost will initiate more investment in shipping by the investors. The policy makers will be more interested with policies on taxes and subsidies.
3. Reconfiguration phase: the use of fossil fuel will be phased out. There will be standard regulations and incentives to compete transition to alternative fuel.

Energy changes are consistent based on the following scenarios:

a) There will be reduction in global energy consumption because of energy efficiency
b) There will be electrification of many sectors of the global economy
c) Coal and gas replacement in energy sector with electricity, wind and solar energy
d) Reduction in the use of coal, gases and oil
e) Growth in the use of hydrogen, bioenergy and other lower carbon fuels

According to Jones et al (2022), the trend of demand for fuel between 2020 and 2050 can be depicted in the Figure 1 below.

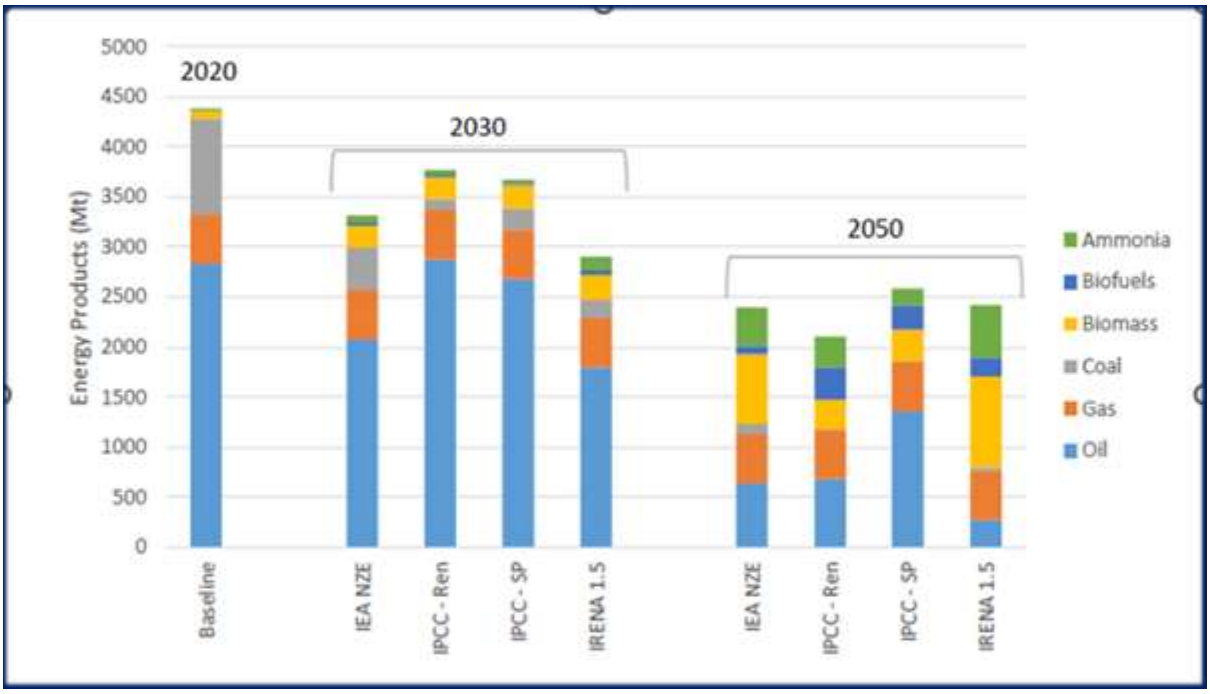


Figure 1: Fuel demand trend forecast to 2050
Source: Jones et al (2022)

As it can be observed in the Figure 1, between now and 2030 the use of oil (blue) colour diminishes, while biomass and ammonia progressively increase and gas seems to be relatively stable across the predicted years.

According to Ramsay et al (2022) who noted that 99.5 world fleet of ships excluding inland waterway vessels, self-propelled vessels and non-merchant vessels are using diesel and heavy fuel oils. Using alternative fuel to propel ships will change shipping industry. Similarly, transporting alternative fuel will bring about changes in requirement for shipping. This means that, the existing ship may be disallowed to ply some routes based on policy in the nearest future. According to a United Nations (2023) Bulletin, to paraphrase it reads "*we are set on a voyage of decarbonization and there is no option of going back"*. Using renewable energy in shipping to achieve the mission of zero-carbon by IMO has been advocated by almost all maritime nations. For example, most African countries are focusing on decarbonization with partnership with developed countries in this regard like Namibian energy transition project. Chile is working on hydro-electricity and Brazil is leading both in the use of ethanol and wind projects for alternative energy. Work Bank has initiated projects in the direction of green Ammonia while United Arab Emirate is considering hydrogen and other renewable energy sources. Majorly, the implication of this will resonate in maritime industry in the following areas (Marine Digital, 2020):

1. Shipbuilding: the construction of vessels and requirements will change. Lighter materials, knowledge of modern technology and incorporation of information and communication systems will be enhanced. Retrofit of vessels to be upgraded to meet new requirements set by the IMO is now the order of the day.
2. Seafarers: There will be need for upgrade of knowledge by the seafarers because the cargo they are used to has changed likewise the vessel. To handle dangerous cargo like hydrogen, ammonia and other renewable energy sources both for propulsion and carriage will require stringent training. Already, IMO has initiated training guide in this direction for seafarers. Increasingly, there will be safety issues like never before and the seafarers must be prepared.

Table 2: Previous research works on alternative fuel for ships

Author (s)	Research focus	Methodology	Findings
Wang et al, (2023)	Decarbonization	Risk assessment and consideration for alternative fuel	Legal framework has not been seen to provide workable implementation to maritime risks and alternative fuel
Arief and AZM Fathalah (2022)	Review of paper on alternative fuel to power ship	Review	Best paper consideration
Munim et al, (2023)	Alternative fuel in shipping	Bayesian Best method	LNG, LNG-Wind, Wind, HFO and Natural Gas are considered to be the best alternative fuels
Stolz et al, (2022)	Economic analysis of renewable energy	First Order assessment	Ammonia and methanol are the most balanced fuels

	in shipping in Europe		
Huang et al, (2023)	Hybrid consideration as energy	Economic and environmental analysis	Hybrid can reduce emission
Shim et al (2023)	Alternative fuel and propulsion	Korean Green Ship Testbed with the introduction of battery cell and electricity	There will be eco-friendly power in time of cost, time and energy

Source: Authors compilation (2024)

3. Smart Ships and Smart ports: Smart sensors
   In an attempt to achieve zero-carbon emission by 2050, IMO believed that ships created in 1930 will be on voyage till 1950 and as such since 2015 initiated that high sulphur content fuel should be discouraged. Two major ways by which marine industry has reacted to this new order include: use of diesel oil (ultra-low sulfur heavy fuel) and installation of scrubbers to remove emissions at the stack (Gerdes, 2023). While it can be observed that energy from electric or battery cell may not be sufficient for tanker and big container vessels, tug boats and other ferry ships around the port can make use of electric propulsion system. There have been suggestions for IMO to introduce CO_2 tax charge so that the revenue generated through this means can be channeled for the production of the type of new fuel to be used by the ships through the efforts from research and development.

Different authors have worked on alternative fuels to propel ships in the maritime industry, of importance to review and establish a gap in literature are some of the previous work done as tabulated in table 2

While authors have examined the alternative fuels among the listed, none of them is able to conduct a SWOT analysis. In view of this, this paper examined the areas of weakness, strength, opportunity and threats for the nine areas of alternative fuels identified.

2. METHODOLOGY

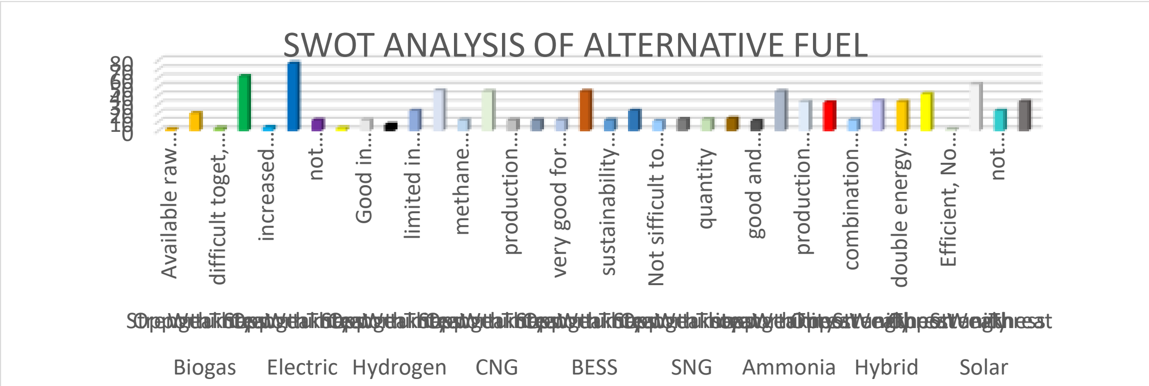
In order to carry out the SWOT analysis of the alternative fuel in shipping, a number of sailors and Chief Engineers who have worked onboard or working onboard on international voyage are needed to fill questionnaires relating to their experience and view concerning the IMO's decision to mitigate pollution, climate change and maintenance of cleaner water. Seafarers and engineers were targeted as they have experience of the various vessels and the type of fuel introduced including the ones that are to be built for the purpose of achieving better environment and climate change. Association of mariners at Porth Harcourt, Lagos, Warri and Calabar chapters were used as the population of this study. The population of the mariners was 102. Yamane formular was used to get the sample size of as presented in equation 1;

$$n = \frac{N}{1} + Ne^2 \qquad (1)$$

Where; $n = sample\ size, N = population, e = marginal\ error$

$$n = \frac{102}{1} + 102(0.05)^2$$

This gives 44 persons. Random selection of this sample was used to ansswer questions on the type of fuel and their SWOT analysis.



Source: author's computation (2024)

3. RESULT AND DISCUSSION

The analysis of the collected data from the mariners and engineers is indicated in the Figure 4.1 below. The respondents in Nigeria has been used as the scope to understand what is obtainable in global shipping industry as the practitioners are witnessing the change in policies by IMO and also seeing the different kinds of vessels that are to used for the purpose of pollution control, climate change degradation and environmental and sea pollution control.

Figure 4.1 shows all the alternative fuels that are likely to be used in the shipping industry with the sole aim of detrmining their SWOT analysis. Biogas as will have low cost and its availability is high, it will reduce pollution but the resources from sugar cane, biological transformation and other raw materials may lead to food insecurity as the threat using this fuel. Electric ships seems to be one of the best with no cost except for recharging but the power may not last unlike as witnessed in fossil fuel powered engines. The risk of shocks and carelessness with safety is a serious concern using this fuel. As good as it may sound to make use of hydrogen because of it environmental friendliness, its production and sustainability raised major concern. Compressed Natural gas is another alternative fuel that is very good to propel ships but it needs pressure and very volatile but it is good for the environment. The only disadvantage considered of BESS is that, battery power is not always as strong as the use of fossil fuel engines and its continuous usage or sustainability. Synthetic Natural Gas is seen as Biogas also but across the SWOT analysis, it does not show strong strength and opportunities across the parameters of SWOT. Ammonia and hybrid show certain level of being the best options for mariners and engineers except for its production, corrosiveness and volatility, hybrid is a bit at advantage compare to ammonia. The is very cheap in terms of cost but has limited power, weakness of battery were the common experience while its sustainability make be challenged.

3.1 Benefits

Energy5 (2023) explained the benefits of using alternative fuel by the ship owners. It maintained that, the usual fuel cost will not be the same and as such, the ship owner will save some cost while using alternative fuel. However, this cannot be ascertained because the price or cost of alternative fuel at present is a bit higher in some countries than others. Nonetheless, using multiple fuels tend to force price to the minimum. Considering that, presently, the alternative fuel is not available globally, this ascertain that the fuel cost will enhance the profitability of the business will take a little time. According to DNV GL in its survey, 20% of fuel operating cost expenses will be saved using energy efficient fuel by ships.

Reputable for following the IMO regulation can increase patronage and compliance shows commitment of ship owners to sustainability. This will boost loyalty of customers, stakeholders' interest and investors' interest.

a) Increase in communication
b) Costly repairs diminished
c) Fishing explored
d) Vessel performance monitoring, weather prediction and routine
e) Tourism
f) Reduced emission of carbon
g) Greenhouse or climate change

3.2 Challenges

In the case of retrofitting of ships and upgrade to modern, the shipping companies will have to first of all invest in retrofitting before they can benefit from it. It is a big challenge to first of all get the money and then divert saved money on this investment though they can gain from it but it will be in the long run. In order words, shipping companies are faced with challenges of seeking financial options and for investment in new energy technology. For effective monitoring of finance and weighing the options of whether the new investment generates revenue compare to when fossil fuel was being used; tracing of consumption and calculating rate of return on investment is critical for shipping companies.

While retrofitting and upgrade ships to modern ones with new technologies and energy efficiency, many ships many not be upgraded and be compatible with new technology. It is important that feasibility assessment be carried out and compatibility test be assessed as ships used to be complex and requires specialized mechanism to function.

Energy5 further explained that, disruption that will occur during the processes of ship upgrade and retrofitting is a call for concern. There will be loss in revenue and ship down time as they are probably undergoing retrofitting. Ships transport what we wear, eat, vehicle we drive and fuel that propel them. Hence the entire supply chain will be disrupted.

In the view of Koutsouranks (2023) the problem with alternative fuel is about production, storage and consumption. There are concerns about the introduction of alternative fuel in the area of supply, cost, safety and infrastructure. There is increase in demand for shipping and the mismatch for emission free-vessels.

- Proving the effectiveness of technologies can be difficult owing to varying conditions that influence fuel consumption (for example, draught, trim, loading condition, speed, fouling and adverse weather), but also because of varying data accuracy.
- Ship-owners tend not to share the results of equipment trials, either because the data is not available or for reasons of confidentiality.
- Performance estimation and measurement protocols vary widely.
- Measurements may have been carried out on a different ship type.
- There is no standardized format or terminology for performance claims – a 5% improvement could be described in terms of fuel savings, energy savings or power savings, and that improvement could be relative to main engine consumption only, or in laden condition only.

4. CONCLUSION

The increase in hydrogen consumption for energy across the scenarios may be expected to lead to more hydrogen being traded between nations, but this will depend on how the global hydrogen economy develops. The type of hydrogen production (whether green or blue) and relative costs of production, transport and conversion to liquid hydrogen or ammonia all determine the extent to which hydrogen for energy use becomes a globally traded commodity.

Although green hydrogen could be produced in a wider variety of locations and co-located with demand, differences in production costs, existing infrastructure and government policy means some trade between nations is likely. While there are plans for blue and green hydrogen production in consumer regions such as the EU and China, the lowest cost green and blue hydrogen may be produced in countries and regions such as Australia, the Middle East, Africa (e.g. Morocco and Namibia) and South America (Chile) (IRENA, 2022b). Countries with strategies to increase hydrogen demand in the near term – Japan, South Korea, Singapore and Germany – have bilateral trade agreements with these producer countries

A number of issues affect the extent to which hydrogen in these countries might be exported by ship:

1. Competing demand for hydrogen/ammonia within the producer country
2. feasibility of a pipeline connection to a consumer country
3. The relative cost of transport by ship versus pipeline
4. The relative cost of imported green hydrogen/ammonia (points 1-3) versus grey/green/blue hydrogen/ammonia produced in the potentially importing country

The number of ships required to transport ammonia depends on:

- Ship size
- Ship speed
- Distance travelled
- Time between trips

Considering all the aforementioned issues, it is imperative for IMO to consider this SWOT analysis and observe all areas of interest with a view to formulate polices and encourage sustainable ship building and fuel that is to be used to achieve the vision of 2050.

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