Comparison of Low Carbon Fuel Option for Commercial Shipping

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***Abstract*—This paper handles about the comparison of low carbon fueling mechanism for comfort shipping by reducing the pollution considerably. Shipping contributes quite a large portion to the total greenhouse gas emissions and other toxic emissions. This is mainly because of the reason that low grade bunker fuel is used in the vessels by eliminating tremendous amount of Sulphur dioxide. So it is high time to think about alternate fuel options for commercial shipping as world is facing bigger threats regarding environmental impacts like global warming, Green House effect, Ozone layer depletion and scarcity of traditional fuels on one hand and threats to human and aquatic life on other side. This primary step of this work is to understand the current systems and fuels that are being used by the commercial shipping. The carbon foot prints of these fuels and technologies are analyzed. The objective of this research is to investigate alternate fuel options that are available for commercial shipping that can reduce the emission, especially carbon emissions. This research has got relevance in the current shipping sector as various nations and I.M.O are implementing various rules regarding emission controls and efficiency rating of the engine. The study is also supported with the help of management tools like Q.F.D and SWOT Analysis. These justifies the selection, relevance and progress of the work. The work was successful in identifying and analyzing some of the most viable options for commercial shipping. More over as a research work, it is moral responsibility of every individual especially a professional to put some efforts to save 'Mother earth' and Crisis regarding health hazards and fuel availability.**

I. INTRODUCTION

The History of trade starts with the origin of human race ranging from exchange of goods through batter system in the Stone Age to the ultramodern commodities between Nations in the modern world and this evolution is still continuing. Various Statistics shows that the volume of trade has increased considerably in the last decade. The increase in the volume of the trade and commerce demands upgrade in technology especially in the field of transportation. From the ancient time onwards, the monopoly of the transportation of these goods has been with the shipping field and still other competitors are no were near. Low cost, Bulk carriage capacity and ease of transportation are some of the reasons why shipping is preferred for the transport of the international goods. As three- fourth of the world is surrounded by water prove to be an added advantage to this field. Even though it may consume more time when compared to Air cargo still it is considered as the most practical way of transportation of bulk goods across the globe.

Trade and commerce have been regarded as the major source of income for most of the countries. Now a day's shipping tourism is gaining more popularity. Even though there are different rules put up by various agencies in every field like safety, cruise, pollution control, most of them are not implemented correctly especially regulations regarding pollution. The Burning of fossil fuels produce several exhaust gases including Green House Gases and they are those gases which will not allow the radiations from sun including infrared radiations which is reflected back from earth's surface, there by entrapping heat in the earth. This effect is known as Greenhouse effect. Carbon –di-oxide, Methane, ozone and some other oxides of nitrogen and carbon mainly regarded as greenhouse gases. The percentage of Greenhouse Gases in atmosphere should be less than 1%.

II. LITERATURE REVIEW

Recent studies suggest that there has been a lot of changes in the climate and temperature of the earth due to the pollution caused by human interactions. Science and Technology has progressed a lot since the industrial revolution. Automotive sector has helped in this progress a lot but on the other part it has got some black sides just like the two sides of a coin. Global warming and ozone layer depletion are the major threats to the environment due to pollution. Besides these there are a lot of Air borne diseases caused by the air pollution containing carbon, Sulphur, Nitrous and other toxic components.

Fractional distillation

The commercial shipping sector flourished since the development of IC engines. Most of these engines use fossil fuels especially bunker fuels in the beginning and different varieties of diesel at the later stage. All the fossil fuels are obtained by the refining process of crude oil called Fractional distillation. Crude oil is the petroleum product obtained from the earth's surface. It is a mixture of hydrocarbon compounds which has different boiling temperatures and compound structures. The basic principle used for the distillation of crude oil is the difference in the boiling temperature of its components and as the name indicates different fractions are obtained at different temperatures.

In this process, crude oil is heated in a retort where the liquid crude oil converts in to gaseous form and passes through the different sections of the tower and then it's cools down .Since different components have different condensing temperatures, while Coming down the vapors condenses at different layers and at different temperatures as shown in figure .These include Gasoline , Diesel oil , Liquefied Petroleum Gas Bunker fuel oil , paraffin oil, Lubricating oil and some other products .

Bunker fuel is the most commonly used fuel by the ships, even though they have been replaced by high grade diesel oils in modern engines. It will not undergo complete combustion and will produce more emissions when compared to automobiles that use diesel and gasoline

Green House Gas effect

Green House Gases are those gases present in earth's atmosphere which acts like a blanket or a layer that doesn't allow the heat to pass through them there by entrapping the heat which result in the temperature rise and this effect is known as greenhouse effect. There is a small percentage of Green House gases present in earth's atmosphere naturally but due to human interactions its percentage has crossed all the danger limits. Main Greenhouse gases include Carbon di oxide, Methane, Nitrous oxides, Fluorinated gases and some other Carbon compounds (EPA, 2010).

Carbon di oxide

Carbon di oxide is the main cause of Global warming and major contributor to the Greenhouse gas emission. Carbon di oxide emissions in U.S.A in 2010 alone contributed 84 % of the total Greenhouse Gas emissions and around 72 % is its contribution to worldwide Green House gas emissions.

Methane

Methane is regarded as the second largest contributor among the greenhouse gases in the emissions. The contribution of methane to the total greenhouse gas emissions is about 9 % . While considering the case of global warming, it's effect is 21 times than that of CO_2 and contributes 20% of the total Green House Gas effect. It is estimated that since the industrial revolution the methane concentration in atmosphere has increased about 1.5 -2 times (BBC, 2009)

Nitrous Oxide

Nitrous oxide has got a higher potential regarding Greenhouse effect and global warming. It also accounts for health hazards and other environmental issues including acid rain. Nitrous oxide has the highest Global warming potential when compared with other gases. For example, it has more than 310 times impact towards Greenhouse effect than carbon di oxide. Nitrous oxide is formed mainly by the combustion of motor fuels, especially low-grade bunker fuels (EPA, 2010).

III. FUELS USED IN SHIPS

As mentioned Earlier Low-grade Bunker fuel is used mostly to propel marine engines but now it has been replaced by the diesel engines of different grades.

Diesel Fuels

The diesel used for marine purpose is different from what is used for the general purposes. Basically, there are three types of diesels are used for marine engines, distillate, inter distillate and residual fuels.

Distillate

This is the purest and most high-grade diesel fuel which is commonly known as Gas oil or Marine gas oil. During the process of distillation. Further classification of distillate fuels is possible for their specific use like in jet engines, ship engines, automobiles based on lowest grade of boiling fractions even though they are categorized under a common boiling range. For example, kerosene which is used as jet fuel, Land based diesel fuel used in automobiles, Diesel fuels for other train engines and stationary engines, Distilled diesel for marine purpose comes under the common name Distillate diesel fuel. So to differentiate these fuels are given each fuel, which is shown in the above table Like "DMX", "DMA" etc. Additives are also used to the distilled fuels according to their point of use. Distillate diesel used for the marine engines are classified under the fuel grade "DMB". They possess a lower value of Cetane index but higher density than that of marine gas oil.

Residual Fuels

During the process of Fractional distillation of crude oil, each fraction of the petroleum product get boiled at specific temperature. The Diesel oil that is left over without thermal decomposing are categorized under residual fuels. Their Industrial name is fuel oil or residual oil. They are regarded as the low-grade fuels but of low cost. Similar to distilled fuels they are also provided with different fuel grades based on the fuel quality. Residual fuels were used earlier for marine propulsion engines but due to the emission standards and regulations, this category can't be used as such in the present situation but often used to blend distilled diesel fuels. For example, for marine fuels, the sulphur content in the fuel should be within 0.3 and 2.0 m/m % but from August 10 2006, according to EU standards, it should not be greater than 1.5 m/m %.

Intermediate Fuel Oil

This category of diesel fuel oil was recently developed and this fraction is not readily available from the fractional distillation of crude oil but by blending distilled diesel fuel with the residual oil to obtain required properties. Intermediate Fuel oil has also got different grading based on the properties and proportion of blending. These types has got great significance considering the increased standards of emissions and increased cost of fuels. Since they are blended for specific application, there are no common properties for this type. The specifications of the Intermediate Fuel oil are defined by "American Society of Testing and Materials"

IV. SCOPE OF RENEWABLE SOURCES OF ENERGY

The history of shipping starts with wind sails, which was a form of renewable source but in modern times high energy propulsive power is required for fast movement of the cargo. Renewable sources are the perfect alternative source of energy which has got zero emissions with zero energy output. But there are lot of limitations in harvesting energy from the renewable sources. The shipping sector is open to various renewable sources of energy like sun, wind, Tides and so on.

Wind and solar energy always gained attention of the engineers as an alternate fuel which can be extracted but the main problems in these is that they can't provide the entire energy required for the propulsion and the other is the high cost of installation and requirement of high floor space and energy storage facilities. The electric energy production in land by solar energy shows that the transmission losses are high. Eco Marine Power's "Aquarius Marine Renewable System" (MRE) is a sophisticated system which combines the energy output from wind and solar for ship propulsion. The wind energy is harvested with the help of wind sails Called "Energy sails" which can beoriented according to the direction of wind and solar energy is harvested with the help of Photo Voltaic Cells. The energy derived can be stored in Li-polymer batteries and is supplied to main engines. The whole system is co-ordinated by a control system which gives the best possible power output. The working of the control system is similar to that of an ECU (Electronic Control Unit) in an M.P.F.I (Multi Point Fuel Injection) system and it can operate at temperature from 5^0C to 55^0C.

This system is highly effective when the ship is at port and found to be highly effective in reducing emissions

of carbon and Particulate matter at the port. The energy output from the solar cells in the current scenario is 500Kwp which can be possibly increased to 1Mwp with an up gradation in technology (Eco Marine Power Ltd, 2011)

Wind turbines and solar turbines can be installed on land but was thought impractical on-board ships due to space limitations. But the advancements in the technology made that dream possible as a wind mill and turbine was successfully installed on a ship developed by "Samsung Heavy Industries, South Korea"

V. LAWS AND REGULATIONS REGARDING EMISSIONS FOR COMMERCIAL SHIPPING

In the beginning stage of commercial shipping in the modern age, the attempt was only to produce high power output which may enhance fast movement of goods and cargo. Shipping is preferred mainly because of its low operating cost and high goods carrying capability. There were no perfect rules and regulations regarding neither on emissions nor on fuel consumption but the scarcities of fuel and studies based on environmental effects caused by the marine emissions forced various agencies to enforce certain laws and regulation regarding emissions from ship.

Even though there are several laws forwarded by several agencies and local authorities, International Maritime Organization (IMO) is regarded as the supreme authority to take decisions in related with International Shipping. Currently there are more than 150 countries across the world as the members of IMO which follows its rules and regulations. Marine Environmental Pollution Committee (MEPC) is a wing under IMO which implements the emission laws in international shipping. The initial step towards emissions was done on 1973 regarding Oil and spill emissions in the ocean which was amended in 1978. This regulation is referred as MARPOL73/78. The restrictions regarding air pollution from ships was brought in 1988 and amended in 1997 by MEPC. These regulations are put together as MARPOL 73/78/97. The key points of this law is mentioned below

- Setting up of standards for oxides of nitrogen in relation with the power output of the engines. It also covers the measures to reduce NO_x emissions and installation of equipment.
- Regulation regarding Percentage of sulphur in the marine fuel so as to reduce SO_x emissions. The percentage of SO_x emissions is restricted to "6.0g SO_x/kWh or less".
- Methods to reduce Carbon emissions and "Volatile Organic Compounds (VOC_S)
- "Requirement of Shipboard incinerators"
- Reduction in the usage of Chlorofluorocarbons (CFC) and other ozone depleting components.
- According to MARPOL VI, the sulphur content used for the fuels used in ships should be less than 4.5% and it should be less than 1 % in special emission areas (OECD, 2011)
- MARPOL VI of I.M.O regulation also brings out CO_2 emission restrictions for all ships above 400 GRT. It is a credit system based on the specific fuel consumption and emissions of the ships. According to this the ships have to surrender their credits in case of excess emissions during the loading and unloading of ships at the ports. (OECD, 2011)
- The oil spillage from the ships should be 12 Nautical miles away from the shores and the oil content in wastes should not exceed 15 ppm. (OECD, 2011)

VI. DISSCUSSION

The significance of shipping sector was mentioned in the Introduction and literature review part as 90 % of the world trade is handled alone by the shipping sector using the cheapest fuel amongst the entire transportation sector. Obviously, the pollution caused by the shipping sector will be high due to high volume of transport and use low grade fuels. So a small change in their fuel options can bring a lot of changes regarding pollutions, moreover human health and safety. It is estimated that the particulate emissions from the ships alone causing around 60,000 Lung cancer deaths.

The evidence for greenhouse effect is been quite visible in the form of unexpected climate changes, droughts and flooding. The overall temperature of the planet earth is on the rise. Extinction and damage of various species has been occurred to the marine ecosystem. Most of these changes are brought about by the Human activities and interference. Oxides of carbon, nitrogen, sulphur and some solid components

are responsible for these changes. Unfortunately, all the components are constituted in the shipping emissions that too in large quantities.

Black carbon is an emission constituent which is present only in shipping emissions when compared with other modes of transportation. Black carbon is referred as 'soot' which is in solid state. The formation of black carbon is due to incomplete combustion and low-grade carbon fuels. Black carbon causes global warms the atmosphere by absorbing sunlight which dries up the surrounding area and reduces their ability of reflecting light, there by entrapping the heat. Black carbon when deposited on ice or snow, it accelerates the rate of melting and it uncovers the ice exposing the underground which also contributes for heat entrapment. So, it is regarded as a positive loop pollutant where the effect of one warming phenomenon can stimulate or excite other effects.

VII. L.P.G AND L.N.G

From the above table it is quite clear that the traditional fuels like Residual and distilled variants of diesel give higher emissions when compared with fuels like L.P.G and L.N.G. This justifies the credibility of this research and from the further investigation, it is clear that there are a lot of alternate options for commercial shipping which can cut down the carbon emissions to a considerable extend. The various aspects like performance, efficiency and economic feasibility have to be verified while choosing amongst these options.

The performance history of L.P.G and L.N.G in automobiles proves that they are giving the same performance characteristics with low emissions at a very low operating cost. From the literature review conducted it is clear that they can be successfully used in marine conditions. Scarcity of fuel is one of the biggest challenges faced by the conventional fuels while Natural gas is one of the fuel sources that are abundantly available from which L.N.G and L.P.G are derived. The chemical composition of L.P.G and L.N.G are almost same differing in the proportion of their components. Their chemical composition is clearly listed in literature review as methane is main component for both of these fuels. Along with methane there are varying proportions of hydrocarbon components like butane and propane. The main advantages that can be seen at glance over the traditional fuels are

- Cost of these fuels are very low when compared with the distilled variants of diesel
- Carbon emissions will be reduced to one third
- Availability of the fuel is high
- Higher efficiency
- No sulphur emissions as Neither methane or butane or propane does not contain any traces of sulphur in their composition
- Very low rate of NO_x formations as they undergo complete combustion at almost in every loading conditions
- Very low particulate emissions and oil spills to water, avoiding threats to aquatic life
- The maintenance cost on engines can reduced to a larger extend as they leave very little carbon deposits on engine components especially at injectors

Hydrogen

As discussed earlier, the energy potential of hydrogen is immense. Even the energy in sun is derived from the fusion reaction of hydrogen atoms. The instability and Intense operating conditions required for the functioning were the hindrance in utilization of hydrogen as a fuel.

Some of the reasons why hydrogen can be suggested as an alternate source of commercial shipping are

- The Calorific value and energy output per unit of hydrogen is very high when compared with all other fuels
- There are no carbon or sulphur emissions
- The emissions from hydrogen utilization is water and other harmless compounds
- Hydrogen can be either used directly or can be coupled with other technologies
- There are different ways through which hydrogen can be extracted
- No oil spills to water
- The vibrations and noises of the engine will be reduced
- Successful history of performance in automobiles and small ships.

Even though the hydrogen has got immense potential, the technologies for the utilization of hydrogen is still

not fully fledged but recently due to strict emission regulations, manufacturers have focused their attention towards this fuel. Some of the drawbacks considered of direct usage of hydrogen as a fuel are

- The technologies for extraction of hydrogen is generally costlier
- Hydrogen is highly unstable so safety concerns are high
- The conversion of hydrogen in to liquid state requires high pressure
- Storage of hydrogen is difficult
- Transmission losses are high
- Refuelling facilities of hydrogen is not developed

Fuel Cells

Fuel cells are regarded as the future fuel of the marine systems as they are mostly preferred for the mobile applications. The most effective way that hydrogen can be utilized is when it is coupled with the Fuel cells. Hydrogen fuel cells are well known for its performance in terms of efficiency and emissions. The advantage of fuel cells over the rest of the fuel options are they can easily adapt to a number of fuel choices depending on the availability of the fuel.

As discussed earlier, the output from the fuel cell is the resultant of electro chemical reaction and electric power output from the system can be used for the propulsion of the system. The unique characteristic of fuel cell is that with a little adjustment, they can be available to deliver power output in a wide range. This makes them flexible to use in every part of energy requirement of the ship nevertheless small or big. For example, an experiment with NASA proved that they have successfully extracted energy from fuel cells ranging of the range 40KW while some of the manufacturers are ready to produce fuel cells with power rating of 11 MW (U.S congressOTA, 1986).

Taking a hydrogen fuel cell in to consideration, the discharge of hydrogen ions and oxidation reaction between them produces the required D.C current, the resultant of which water is formed as a by-product. A very small quantity of nitrogen and CO_2 are discharged to air, this is an extra ordinary performance regarding the emission standards. A large quantity of heat also released as result of these chemical reactions which can be transformed to the fuel processing unit or the reformer unit for the production of hydrogen, this improves the overall efficiency of the system. The operating range of an ideal fuel cell for marine application varies between 750 -1500^{0}C

Another parameter used to measure the efficiency of generators and fuel cells are the heat rate. Heat rate may be referred as the thermal energy supplied to produce a unit electric power output, usually expressed in terms of “British Thermal units per kilo watt hour”. Currently PAFC fuel cell gives a heat rate of “8500” Btu/KWh for A.C currents. This is equivalent to the heat rate produced by a most efficient generator. (U.S congress OTA, 1986).

Renewable Sources of Energy

Sun is the source of all energy. Nature holds lots of energy that is available free of cost but the technology for extracting this energy are minimum so it was thought that it may not be practical for Mobile applications like shipping. The Minimum power requirement of small commercial ship is about 750 KW. So the energy from the renewable sources was not sufficient enough to provide the complete propulsive power for shipping. But the initial investigation suggests that energy from renewable sources can be successfully used to provide power for electric requirements and emergency power needs. These sources can also be used for the power requirement of the ship at special modes

One of the major problem associated with utilizing hydrogen as a marine fuel was the high fuel processing cost of producing hydrogen .Even though hydrogen can be produced from various sources, each one consumes a lot of energy which reduces the overall efficiency of the system and cost of the fuel .But as per discussed in the literature review, when photo voltaic cells are used to provide energy required for the electrolysis of water for the production of hydrogen , they together will provide a good solution for the fuel crisis problem along with very low emission.

Another field of application of renewable sources is for providing off shore power supply and when the ship is at harbour. Wind turbines at shores are gaining more and more popularity as even in the sea wind turbines by the leading manufacturers from which large amount of energy is extracted.

Passive Methods to Reduce Emissions

Apart from alternate fuel options, there are a lot of passive methods to reduce emission and fuel

consumptions. Even though they are not a fuel option, considering their effectiveness they can be regarded as a fuel option. There are lot of methods suggested by various organizations and agencies some of them are

Speed reduction

Speed reduction is one of the simplest methods of reducing emissions as by reducing the speed of the ships to the economy mode, the fuel consumption decreases. The rate of carbon di oxide production is directly proportional to the fuel consumption. According to I.M.O, a 10 % speed reduction can bring about a reduction of more than 23 % of total emission emissions. But an experiment done by 'Hapag-Lloyd, they have achieved 50% reduction in fuel consumption by a speed reduction of 5 knots (Harrould- Kolieb 2009).

Unlike the other means of transport, the speed reduction is very much effective in shipping in reducing fuel consumption may be 10 times more than road transport and more than 70 % than aviation. Reduction of operating cost is an added benefit to this method. The reduce emissions include carbon di oxide, Nitrous oxide and black carbon.

To understand the effect of speed reduction, considering a case study in which 10 ships (namely Group A) were designed to travel at a speed of 16 knot speed while another group of 14 (Group B) ships were designed to travel at a speed of 10.5 Knot speed (. When these two groups travelled the same distance, Group A consumed 140,000 metric tonnes of fuel while Group B consumed only 60,000 metric tonnes of fuel

- Difference in fuel Consumption = 57 %
- Difference in number of ships= 4

The speed reduction in Los- Angeles's port resulted in 49 % reduction in particulate matter reduction and 37 % reduction in nitrous oxide. (Harrould- Kolieb 2009).

Some of the reasons why speed reduction can be applied are

- No additional cost
- No complexity like other methods, can be easily achieved with in all ships
- Reduction of various emissions are very high when compared with other modes of transportation
- If implemented by law, It will be fulfilled
- Can be applied to every fuel
- Great remedy to current fuel crisis and emission concerns

Exhaust Gas Re circulation

The efficiency of a typical I.C engine varies from 35-50%. The rest of the input energy is wasted through different media like exhaust gas, Engine cooling, Lubricating oil. Around 25% of this loss is contributed by exhaust gases. If this energy can be extracted and used for energy production, this will improve all over efficiency of the system.

There are different means, in which the exhaust gas can be used like it can be used to heat up the intake air, can be used for the electric power generation, Used for fuel heating and so on. So the potential of utilization of Exhaust gas is very high since the commercial ships use High compression diesel engines. Since this energy is obtained free of cost, It not only improves the efficiency of the system but also reduces the fuel consumption considerably, thereby cutting down emissions to a larger extent.

On Shore and off shore power supply

A brief description of on shore and off shore power supply was discussed in the renewable energy sources. Vessels harbourers at ports for quite a long time for the process of loading and unloading of goods. These processes require a lot of power to meet the electrical and emergency power requirements of the ship. Generally, this is accomplished with the help of small Auxiliary Engines working on low grade fuel oils. As discussed earlier, since it is long process, the net emissions is very high during this process.

Burning of high sulphur content fuels in the ports which is in Human Inhabitant territory creates high risk of health hazards than when they are in the deep sea. So it is clear that, if low carbon fuel options are used to derive the power requirements of the ship at the ports, they can reduce the global emissions of commercial shipping sector to a larger extend.

On shore power supply is also known as 'cold Ironing'. This name has been derived from supplying the power output from outside source while the main engines of the ship are shut down.

The recent on shore power supply system developed by ABB systems claims that, they can reduce the total emissions by 20 % and they can provide power supply at on shore and off shore conditions. This was a replacement of Traditional A.C power supply systems to innovative D.C circuit system by which the operational efficiency of the ship will be increased by more than 20 % (Port Technology International, 2011).

Quality Function Deployment (Q.F.D)

According Famous author John Ruskin "Quality is never an accident but the result of intelligent effort". Q.F.D is a power management tool which helps to determine the customer satisfaction level and the extend of quality. Q.F.D also gives a chance to compare various aspects different types of commodities deploying the same function. Points will be rewarded for each factor determining the performance of each type. The total marks obtained for each option will give an idea about their performance in the market

Since in this paper, an investigation is done to find out all the possible alternate fuel options for commercial shipping, along with their economic and practical feasibility, Q.F.D will clarify the suggestions and performance of each fuel option in comparison with the rest of the fuels that can be used in marine conditions.

This paper considers the low carbon fuel options for commercial shipping, since every option has bigger contributions towards this field, there has been a tight encounter between these options. That is the primary reason why all of these options have got marks with much difference. The marking scheme is based on the literature review and discussion done on the fuel option. As discussed, various aspects of each fuel option are included, they justify their selection and their practical implementation in future.

The interesting factor obtained from Q.F.D is that apart from all other fuel options, In direct methods become the lead option. This is mainly because of the reason their performance can be achieved without any additional cost to the existing systems. Some of the measures like slowing down the speed was found to be very effective than some of the fuel options. Another advantage of this option is that they can couple many of the fuel options together and produce much better results. Their capability of extracting renewable energies is tremendous and update in technologies can bring much better results.

Renewable sources of energy and fuel cells also show very good results, as they are referred as future fuels of marine vessels due to their peculiar characters. Apart from past, the technologies for extracting the renewable energy resources has developed and the combination of more than one source can bring out wonders. This is because of the reason of immense energy potential held by them and mostly they are available at free of cost with absolute zero emission. The main hindrance in their usage was the high cost of installation and the absence of exact technology. The transmission losses are also regarded as a problem for the effective utilization of renewable sources.

Fuels are well known for their viability for mobile applications. The flexibility of the fuel cells to various fuel types is an added advantage to the fuels in marine conditions. They have got higher potential justified by the high marks obtained for them. The main weak points of the fuel cells are high installation cost and fuel processing cost in regards with that of hydrogen. The emission sides of fuel cells are perfect as water is the main by product formed and very little other emissions. They can effectively control the current situation of high rate of particulate emissions and black carbon emissions.

Fuel cells are ideal in marine conditions but the fuel processing costs increases the operating cost of the vessel, so coupling many of the fuel options, fuel cell can be the future fuel option of commercial shipping

The performance obtained from Q.F.D for other fuel options are not so bad as they are very close to each other in terms of point, like some has got their own strengths at their field and got weakness in some field. Even though high distilled diesels shows low score they have got upper hand in the cost of fuel processing and coupling with existing systems, they can be easily applied to new ships too But the problem is they still give particulate emission and oil spills to water at smaller quantity. As the rules and regulations are becoming narrower once they might be also outdated.

Controllable Parameters / FUEL OPTIONS	COST OF FUEL	AVAILIBILITY	EFFICENCY	REDUCTION IN CARBON EMISSIONS	SAFETY	REGULATIONS	PARTICULTE EMISSION REDUCTION	OVER ALL EMISSION REDUCTION	PRACTICAL FEASIBILITY	FUEL PROCESSING	TOTAL PROPULSIVE POWER	WEIGHTAGE
HIGH DISTILLATE DIESEL	4	6	6	4	9	9	4	4	9	4	8	64
L.P.G	6	8	7	7	6	6	6	5	7	6	7	71
L.N.G	7	8	7	6	6	5	6	5	6	7	7	70
HYDROGEN	2	8	9	9	4	4	8	8	4	2	9	67
FUEL CELLS	8	7	9	7	6	7	6	7	5	4	7	73
RENEWABLE SOURCES	10	4	4	10	8	9	9	9	4	3	3	73
NUCLEAR FUEL	6	4	8	7	3	4	4	8	4	3	8	59
IN DIRECT METHODS	9	3	7	7	9	9	5	7	6	9	6	77

VIII. SWOT ANALYSIS

SWOT Analysis is a management tool to understand and analyses the Strength, Weakness, Opportunities and Threats of the project. It helps to understand various aspects of projects and gives a crystal-clear idea. The Swot Analysis for this project has been plotted below.

Strengths

- Reduces various Emissions
- Helps in fight against Greenhouse effect and global warming
- Solution for fuel crisis
- Reduces operating cost of commercial shipping
- Leads to discovery of new fuel options
- Higher efficiency
- Reduces threat against Human and aquatic environment.

Weakness

- High Initial investment
- Difficult to couple with current technologies
- Production and processing cost of many fuels are very high
- More studies have to be conducted on the reliability of various systems
- Complexity in working
- Renewable technologies depend on the mercy of nature

Opportunities

- Comply with all the regulations by IMO and various agencies
- Improves the sea boarder across the world
- Increased rate of pollution by traditional fuels
- Support and Subsidies from Various governments and agencies
- Increasing volume of trade across the globe.

Threats

- Unawareness and Negligence of effects of pollution by developing countries
- Safety of various systems including Hydrogen
- Restrictions in usage of certain fuels in certain countries
- Actual efficiency of many systems may vary from theoretical efficiency

IX. RECOMMENDATIONS AND SUGGESTIONS

All the fuel options analyzed were good with higher potential and ability to reduce overall emissions. The reduction in total emissions from the commercial shipping sector can reduce the global emissions by more than 10 %. This project indicates that even a small step towards emission can bring about bigger change. Some of the suggestions and recommendations that have been observed during the study was the following

- More researches and experiments have to be performed to develop new fuel options not only for shipping sector but also for the entire transport sector
- Awareness must be brought among all the nations, especially about the impacts of global warming, greenhouse effect and ozone layer depletion
- Relaxation of rules and regulation for ships with low carbon fuel options
- Strict Implementation of emission laws and constant monitoring
- Maximum utilization of all the available resources
- Better Hull design and Special coatings on the propeller can reduce considerable amount of emissions
- Employing the ships with High efficiency engines
- In co-operating more than one fuel options to obtain maximum efficiency
- Proper maintenance of various systems can improve efficiency of the engine there by reducing fuel consumptions and overall emission

- Mandatory employment of Auxiliary devices like catalytic convertors and scrubbers, they can reduce the emissions to larger extend.
- Promotion and Subsidies for technologies related with renewable sources of energy.
- Up gradation of current systems and technologies

X. CONCLUSION

This project regarding Low Carbon Fuel Options for Commercial Shipping revealed many facts shipping sector. Since shipping sector alone handle s more than 90 % of the world's trade, it is essential to understand their emission impacts. From the study conducted it is clear most of the ships uses low grade bunker fuel oil whose emission contribute a lot to Green House emission, Global Warming, Ozone Layer depletion, Oil spills and Health hazards to human race.

These impacts are clearly visible by the impacts of sudden climate change, floods, droughts and other natural disasters. Commercial Shipping sector contributes to more than 3 % of total carbon di oxide emissions in the current scenario and this will be increased by 3 times by 2050 if this rate continues. This can alone raise the global temperature by 2^0C.

So this project has got great significance in the current scenario serious emission effects and fuel crisis. It is the duty and responsibility of every engineer to put some efforts to reduce the adverse effects of various technologies. Most of the fuels studied and analysed were suited for commercial shipping which can reduce the emissions and fuel consumption.

This project went through the exact aims and objectives which was mentioned in the beginning and the fuel analysed may be future fuel options for commercial shipping and hence the project was completed successfully.

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