Bio Diesel as an Alternative Fuel for Maritime Transport - An Overview.

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ABSTRACT

Movement of goods trough seaways and rivers is one of the most energy efficient modes of transportation. Majority of the ships and boats in maritime transportation use Diesel engines for propulsion and power requirements burning a variety of grades of fossil fuel. However with the advent of the concept of sustainable environment, this industry is also looking towards improving its energy efficiently and environment friendliness. This paper outlines the regulatory requirements for fuels and emissions from diesel engines from ships operating in international trade. While Bio Diesel is one of the alternatives for reduction of maritime emissions due to its very low or negligible sulphur content and amenability to complete combustion, its testing in a marine environment in India is limited. The paper gives an overview of some of the results of studies conducted internationally on the use of Bio Diesels in marine transportation. An estimate of requirement of biodiesel for Coastal shipping in India is presented. The paper stresses the need for increased testing of Biodiesel blends in marine engines to quantify the benefits and cost implications for use in coastal and river movement of cargo and passengers.

Introduction

Shipping has been an important human activity throughout history, particularly where prosperity depends primarily on international and interregional trade. The international shipping industry is responsible for the carriage of about 90% of world trade and is vital to the functioning of the global economy. Intercontinental trade, the bulk transport of raw materials and the import/export of affordable food and goods would simply not be possible without shipping. Notwithstanding the recent contraction in trade resulting from the present economic downturn, the world economy is expected to continue to grow and shipping will need to respond to the demand for its services. The growth of seaborne trade expressed in billion tonne miles from 1990 to 2007 is shown in figure1.

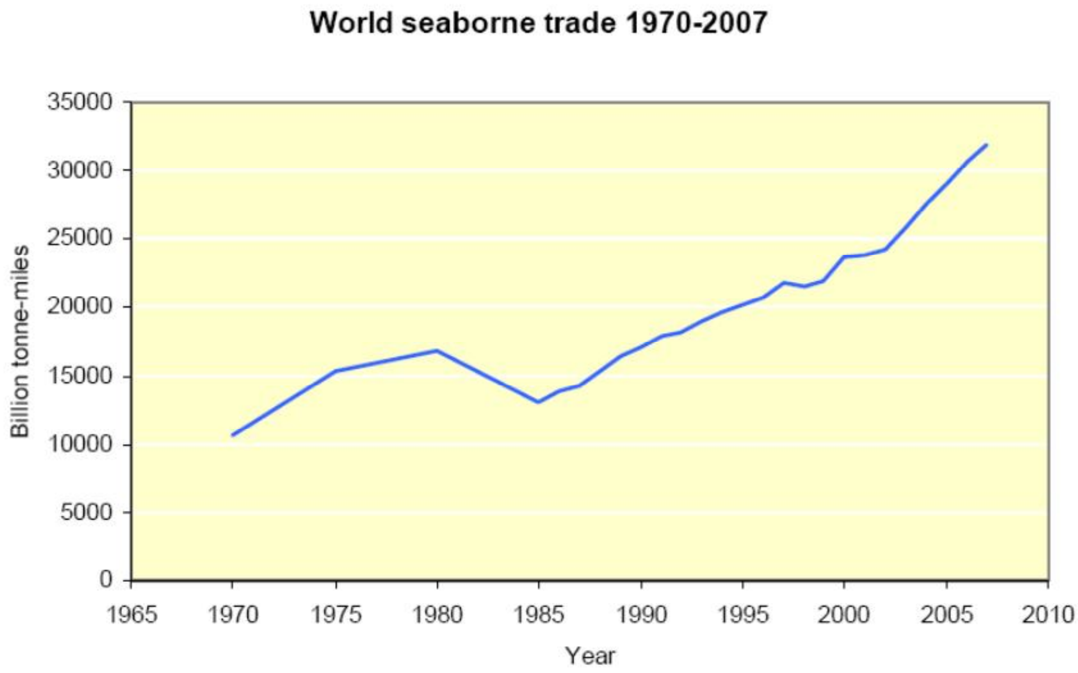

Figure 1: Seaborne Trade 1990-2007 in billion tonne miles (Fearnresearch)

Apart from trade and transportation, various other tasks are performed by special ships. These include offshore service activities, infrastructure development (such as cable laying, pipe laying and dredging), fishing, exploration and research, towing services, etc. The importance of shipping is summed up in the following statement made by Mr. Efthimios Mitropoulos, IMO Secretary-General "Without International Shipping, half the world would freeze and the other half would starve".

Air Pollution, Global Warming & Maritime Trade

In the 1960s, scientists demonstrated the interrelationship between sulphur emissions in continental Europe and the acidification of Scandinavian lakes. The 1972 United Nations Conference on the Human Environment in Stockholm marked the start of active international cooperation in combating acidification, or acid rain. Many believe the most important result of the conference was the precedent it set for international cooperation in addressing environmental degradation. Between 1972 and 1977 several studies confirmed the hypothesis that air pollutants could travel several thousands of kilometres before deposition and damage occurred. This damage includes effects on crops and forests. This also implied that cooperation at the international level was necessary to control problems such as acidification. Most acid rain is caused by airborne deposits of sulphur dioxides and nitrogen oxides. Coal and oil-burning power plants are the biggest source of sulphur dioxides while nitrogen oxides come from car, truck, and ship exhausts.

The Kyoto Protocol contains provisions for reducing GHG emissions from international aviation and shipping and treats these sectors in a different way to other sources due to their global activities that is, pursuing though the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) respectively.

Air pollution from Maritime Activities and their impact

Emissions from the maritime transport sector represent a significant and increasing source of air pollution. Furthermore, emissions from ships are transported in the atmosphere over several hundreds of kilometres, and thus can contribute to air quality problems on land even if they are emitted at sea. This pathway is especially relevant for the deposition of sulphur and nitrogen compounds (Cofala *et al*., 2007). It should also be taken into account that, for economic reasons, many vessels use Internal Combustion engines burning heavy fuel oil with high sulphur content (The sulphur content of standard marine fuel is 2700 times higher than that of conventional diesel for cars). The main air emissions resulting from burning this type of fuel include Sulphur Dioxide (SO2), Nitrogen Oxides (NOX); Volatile Organic Compounds (VOCs); Particulate matter (PM); Carbon Dioxide (CO2) and other GHGs. The amount of gases emitted from marine engines into the atmosphere is directly related to total fuel oil consumption and the quality of fuel used which inturn depends on different factors such as hull shape, loading condition, roughness of hull and engine operating condition (Endersen *et al.;* 2003) .

As far as local air pollution is concerned, port areas have historically developed in very close proximity to urban areas, and port operations can affect the people living and working in these areas As a result, especially in port areas, ships contribute to harmful levels of pollutants such as particulate matter (PM10 and PM2.5), ozone (O3) and nitrogen oxides. PM can contribute to many serious health problems including premature mortality and asthma attacks (IAPH, 2007).

The presence of these pollutants has local and global impacts. Impacts on local (or regional) air quality are mainly linked to pollutants such as PM, NOx and sulphur, while the GHGs (*e.g.* CO2) have a global impact on climate. The negative effects on local air quality and human health are largely dominated by the presence of NOx, PM (2.5 or 10), acid deposition and nitrogen deposition. NOx emissions also can cause nutrient overload in water bodies, which can result in eutrophication. The excess of nutrient nitrogen can be detrimental to the fragile balance of ecosystems, including marine ecosystems. SO2 emissions also negatively impact public health; in particular, sulphate particles can induce asthma, bronchitis and heart failure. Sulphur and nitrogen compounds emitted from ships can also produce impacts not directly linked to human health. They can, indeed, cause acid depositions that can be detrimental to the natural environment (lakes, rivers, soils, fauna and flora). Emissions of these compounds at sea can exert an influence on vegetation and land-based objects many thousands of kilometres away[1]. Health effects can result in the reduction of oxygen delivery to the body's tissues and organs (such as the heart and the brain). CO can have significant cardiovascular effects on those who suffer from heart disease. The central nervous system can also be affected. Breathing high levels of CO can result in blurred vision, reduced ability to work or learn, and reduced manual dexterity. CO also contributes to the formation of smog (IAPH, 2007). At the global level, carbon dioxide is the most significant trace constituent that has an effect on global climate change.

The share of shipping with respect to GHG emissions in comparison with other modes is indicated in Figure-2

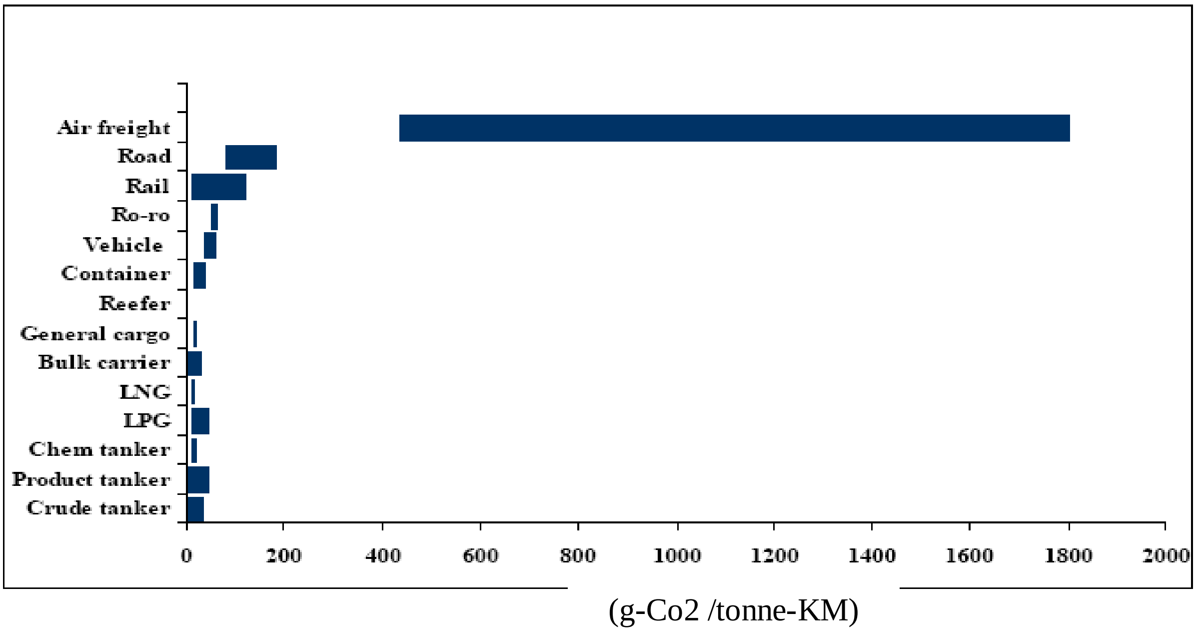

Figure 2: CO_2 Efficiencies by Cargo Carrier[2]

Regulatory Developments

In relation to control of air pollution from Ships, the IMO's Marine Environment Protection Committee had begun its work in the 80's. In 1989 a resolution was adapted by the IMO assembly [A-655(16)] calling for a reduction in usage of Halaons for fire fighting on ships. In 1991 another resolution was adapted [A-719(17)] which requested the MEPC which included among other regulatory mechanisms to Develop requirements for reducing air pollution resulting from ships' machinery and cargo handling operations. The subsequent work at the IMO resulted in the adoption of ANNEX VI of MAROPL in 1997. MARPOL Annex VI sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. The revised Annex VI with further reductions in the sulphur oxide emissions has been adopted in the year 2008 and has entered into force from 1st July 2010. The current legislation with respect to marine fuel quality and NOx emission limits is shown in Tables 1 & 2:

[1] Regulating Air Emissions form Ships –State of the Art on Methodologies, Technologies and Policy Options-Joint Research centre, European Commission-2010.
[2] Maritime Transport and Climate Change-UNCTAD 2009

Table 1: NOx Regulations

Regulations	NOx Limit	RPM(n)
Tier 1		
Diesel engines (>130kW) installed on a ship constructed on or after 1 January 2000 and prior to 1 January 2011	$17\ g\ kWh^{-1}$	$n < 130$
	$45 \times n^{-0.2}\ g\ kWh^{-1}$	$130 \leq n < 2000$
	$9.8\ g\ kWh^{-1}$	$n \geq 2000$
Tier 2		
Diesel engines (>130kW) installed on a ship constructed on or after 1 January 2011	$14.4\ g\ kWh^{-1}$	$n < 130$
	$44 \times n^{-0.23}\ g\ kWh^{-1}$	$130 \leq n < 2000$
	$7.7\ g\ kWh^{-1}$	$n \geq 2000$
Tier 3		
Diesel engines (>130KW) installed on a ship constructed on or after 1 January 2016	$3.4\ g\ kWh^{-1}$	$n < 130$
	$9 \times n^{-0.2}\ g\ kWh^{-1}$	$130 \leq n < 2000$
	$3\ g\ kWh^{-1}$	$n \geq 2000$

Table 2: Sulphur Regulations:

Regulation	Region	Fuel oil	
		Sulphur (%) by weight	Implementation date
MARPOL Annex VI	SECA Baltic Sea	1.5	19.05.2006
	SECA North Sea	1.5	21.11.2007
	Outside SECA's	4.5	19.05.2006
MARPOL Annex VI Amendment	SECA Baltic Sea	1	01.03.2010
	SECA North Sea	0.1	01.01.2015
	Outside SECA's	3.5	01.01.2012
		0.5	01.01.2020*

*- Subject to feasibility review to be completed no later than 2018. If the conclusion of such a review becomes negative the effective date would default to 1st of January 2025

Furthermore the influence of GHG's especially CO2 on global warming presents shipping with the additional challenge of reducing its share of CO2 exhaust emissions in order to meet the global targets as projected by IPCC and UNFCC. As indicated earlier, shipping continues to be the most efficient means of transport when compared to other modes. Shipping contributes to only about 3% of the total GHG emissions. Historically, the evolution of shipping has been striving towards energy efficiency which has been driven primarily due to rising fuel prises which contributes to about 25-40% of the ship operating costs. The evolution of efficiency over time is indicated in figure-3

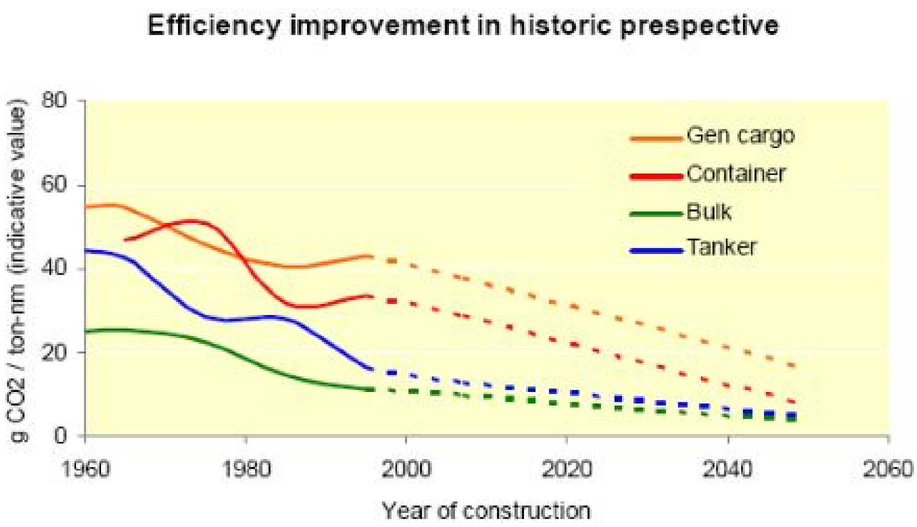

Figure 3: Indicated historical efficiency and "High Efficiency" scenarios[3]

Reduction of CO2 emissions is directly linked to saving fuel, because CO2 is one of the products of combustion being proportional to the fuel consumption. Fuel is a significant part of the total cost of operating a ship. Shipowners have therefore focused on fuel economy long before the greenhouse effect was an issue and the climate debate began. Shipbuilding is a mature technology, and engines have been optimized for fuel economy using best available technology ever since the introduction of engines. Figure 4 illustrates the continued development of engine efficiency for large two-stroke engines. Since the oil crisis in the early seventies, the efficiency of ship diesel engines has improved by 20%, but the efficiency penalty as a result of NOx regulation has resulted in stagnation in the improvements[4].

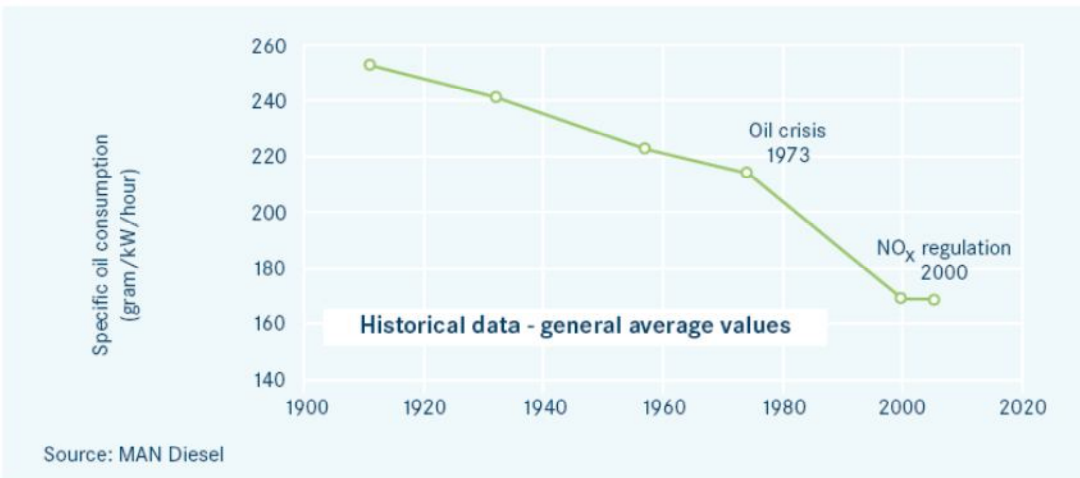

Figure 4: Improvement in specific Fuel Consumption of Marine Propulsion Engines over time

Despite the current unfavourable economic conditions, projected growth in international trade suggests that GHG emissions from shipping would continue to increase, unless effective regulatory, technical and operational measures were agreed and implemented without delay.

[3] 2nd IMO GHG study-MEPC 59-Inf 10
[4] Climate Change & Shipping :European Community Ship owners Associations (ECSA) Position Paper-2008

Thus, there remained an urgent need to address GHG emissions from the maritime transport sector and to step up mitigation efforts.

The regulatory mechanism for reduction of GHG from shipping is currently focussed on the following

1. A mandatory Energy Efficiency Design Index (EEDI) for new ships.
2. Development and implementation of an Energy efficiency management plan by ship operators and use of the same for differential/preferential tariffs and treatment at ports/charterers etc.
3. Emissions trading scheme.

Technical options for reducing Air pollution from Ships

There are a number of options available for reduction of harmful emissions from combustion of fuel from Marine Diesel Engines.

NOx

NOx emissions are a primarily dependent on Combustion temperature and the time available for combustion (mean piston speed). The Slow speed engines (Rpm<130) have stricter limits than higher speed engines and are more difficult to control. While all marine engine manufacturers have implemented Tier 1 and Tier II requirements with suitable modifications to the combustion parameters and equipment, Tier III requirements pose a great challenge. Some of the techniques available for reduction in NOx are Exhaust gas recirculation, internal engine modifications, water injection, humid air motors etc. Another technique which is being seriously pursued is Selective Catalytic Reduction (SCR). SCR is a system for after-treatment of exhaust gases. It can reduce emissions of NOx by more than 90%, and operates better with low-sulphur fuel oil.

Sulphur dioxide

Sea-going ships burn extremely dirty fuels that contain on average 2.5–3% sulphur. Emissions are directly proportional to the sulphur content of the fuel, and the simplest way of reducing them is to use fuel oil with low sulphur content. Because of its higher quality, low-sulphur distillate fuel has the advantage of making for smoother engine running, with less risk of operating problems and less maintenance costs. It also significantly reduces emissions of PM and several other harmful substances. However the cost of low sulphur fuel is very high compared to the residual fuel which are predominantly used in ocean going ships. Fuel occupies nearly 40% of the operating costs of an ocean going ship and any increase in the expenses due to change in fuel will greatly effect the overall costs of transportation and hence on the cost of products that are transported. A possible alternative option is to install flue gas cleaning, or scrubbers. This is a relatively new technology, and trials are ongoing. There are still some questions regarding e.g. abatement efficiency, use in harbour areas, and waste production and handling.

GHG-CO2

Exhaust gases are the primary source of emissions from ships. Carbon dioxide is the most important GHG emitted by ships. Both in terms of quantity and of global warming potential, other GHG emissions from ships are less important. Mid-range emissions scenarios show that, by 2050, in the absence of policies, ship emissions may grow by 150% to 250% (compared to the emissions in 2007) as a result of the growth in shipping. A significant potential for reduction of GHG through technical and operational measures has been identified. Together, if implemented, these measures could increase efficiency and reduce the emissions rate by 25% to 75% below the current levels. While the reduction of Co2 is primarily focussed on reduction of fuel consumption or increase in efficiency of the power plant by getting more work out of the fuel being utilized, there are other options such as switching over to low carbon fuels such as LNG and Bio Diesel which are expected to contribute to about 5-15% reduction in the emissions[5].

Use of Alternative Fuels

Fuels with lower life-cycle CO_2 emissions include biofuels and liquefied natural gas (LNG). The use of biofuels on board ships is technically possible; however, use of first-generation biofuels poses some technical challenges and could also increase the risk of losing power (e.g., due to plugging of filters). These challenges are, nevertheless, overshadowed by limited availability and unattractive prices that make this option appear unlikely to be implemented on a large scale in the near future. However, it is believed that LNG will become economically attractive, principally for ships in regional trades within ECAs where LNG is available. It is projected that the CO2 reduction options using alternative fuels would range between 38 million tons to 157 million tons by the year 2050 depending upon a number of scenarios projected[6].

Biodiesel-Characteristics

Biofuels today comprise approximately around 2% of the total transport fuel requirements. The so called first generation biodiesels are produced through a process known as transesterfication known as FAME (Fatty Acid Methyl Ester). In the process the feedstock oil reacts with methanol at high temperature and pressure over an alkaline catalyst. This stage is followed by numerous separation stages (also including neutralization with acid) which yield the biodiesel product and a crude glycerol by-product. From one litre of feedstock oil and 0.1 litres of methanol, the FAME process can produce ~0.95 litres of biodiesel and 0.1 kg of glycerol.

FAME biodiesel can be used pure (B100) but is typically blended with regular diesel at 5% (B5) or 20% (B20). The quality of biodiesel varies considerably depending on the feedstock. The cetane number for biodiesel produced from certain feedstocks (e.g. soybean and sunflower) is lower than allowed in some regions. FAME biodiesels tend to have poor cold weather performance (palm derived biodiesel in particular) since they form gels at relatively high temperatures. FAME biodiesels can also be unstable, i.e. prone to degradation by oxidation. Despite these drawbacks, biodiesels have the advantage of virtually zero sulphur and ash content and have a very similar energy density to regular diesel.

Second-generation biofuels are beginning to reach the commercial stage. Second-generation technologies are not based on edible crops and include a diverse range of pathways and products. The products are made from almost any combustible biomass using gasification and synthesis technologies.

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[5] 2nd IMO GHG Study-MEPC 59-Inf 10

[6] Assessment of IMO efficiency Measures- Lloyds Register and DNV –MEPC 60 Inf 18.

Algae can also be used to produce biodiesel, ethanol, butanol and aviation biofuels. It requires CO2 (at fairly high concentrations) and nutrients (including nitrogen, phosphorous, iron and silicon) as feedstocks. The technology is still at the research stage. It is also possible to produce biodiesel, gasoline and aviation biofuel from a sugar source using genetically modified organisms; this is also at the research and development stage.

Second-generation ethanol is indistinguishable from first-generation ethanol. Butanol has many advantages over ethanol: it has higher energy density (close to gasoline); it is less corrosive and can be transported in existing pipelines; it can be blended at high levels in gasoline without requiring modification to vehicles; and it can also be blended with diesel[7].

Use of Bio Fuel in Maritime Industry

A number of studies have been carried out on the feasibility of using biofuels and particularly biodiesel 100% (B100) and blends ranging from 5% (B5) to 20% (B20). The implementation and use of biodiesel products, from B1 to B100, has met with mixed success. Probably the most significant tests and studies of biofuel for marine applications have been conducted by The Washington State Ferry System (WSF) and Celebrity Cruise Lines/ Royal Caribbean Cruise Lines (CCL/RCCL)[8]. These tests were conducted during actual marine use on both gas turbine and diesel propulsion systems, over extended periods, and include both operational and emissions testing. Some of the findings vis a vis the characteristics of the fuel are as follows:

1. Energy Content: Bio Diesel has approximately 10% less energy content than marine Diesel oil. Hence the power generated by the engines is lower along with a corresponding increase in fuel consumption necessitating increased storage volumes. The energy content for various fuels is shown in figure 5.
2. Water and Storage: Biodiesel is highly hygroscopic and can hold excess water content when exposed to humid conditions. The Water –Biodiesel Fuel emulsion thus formed does not separate either by settlement or reduced by known chemical means. This emulsion is known to cause blockage of fuel filters / injectors and cause corrosion in engine parts.
3. Microbial degradation: Biodiesel is an excellent medium for microbial growth and water presence enhances this condition.
4. Technical suitability: Biodiesel and its blends can be used in engines without any major modifications. However the properties of current generation biodiesels when used as a stand alone fuel (B100) create problems in the storage and supply system to the fuel injectors often leading to clogging of filters and cavitations in the pumps.

[7] Repowering Transport-World Economic Forum April 2011
[8] The Use of Biofuels in the U.S. Maritime Industry-MARAD 2010

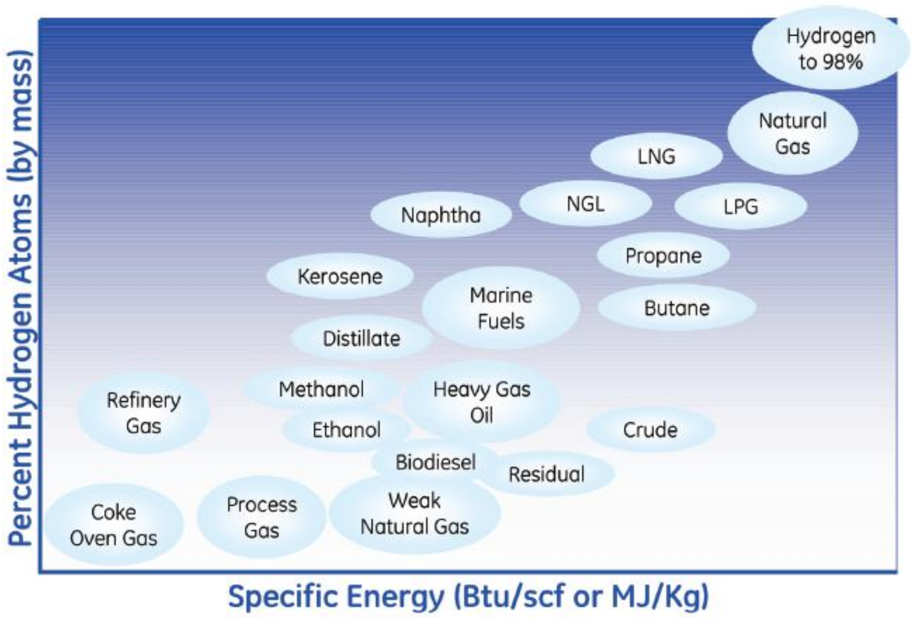

Figure 5: Addressing Gas Turbine Fuel Flexibility General Electric-4601 (06/09)

5. There has been better experience with the blends ranging from 5% to 20%. The results showed that the problems experienced with 100% biodiesel were non existent when used as blended fuel. However the tests have used a biocide to prevent microbial growth and clogging of fuel filters.

Impact of Biodiesels on emissions:

As sea transport is a very energy effective form of transport, greenhouse gas emissions from sea transport is lower than other modes of transport. Nevertheless, as the importance of facing the threat of global warming is becoming more urgent, sea transport needs to face this problem. In addition use fossil fuels in ships leads to other emissions such as SO2, NOx and particulate emissions which can lead to serious environmental and health issues. Use of biofuels can reduce these emissions. The combustion reactant with biofuel will for instance be air which consists of 79 % Nitrogen and 21 % Oxygen leading to NOx-emissions from combustion. Combustion results in a number of very complicated reactions and the products formed are depending on many factors. The degree of mixing of the biofuel and air can regulate the reactions happening once the biofuel is ignited. In an ideal scenario with complete combustion there would be no emissions of carbon monoxide or unburned hydrocarbons, but this would increase emissions of NOx which is heavily influenced by the combustion temperature. This is evident from figure 6 which shows that the current generation of biofuel can help in reducing the greenhouse gas emissions with marginal (around 2% for B20 blend) slight increase in NOx emissions (Birath, 2006).

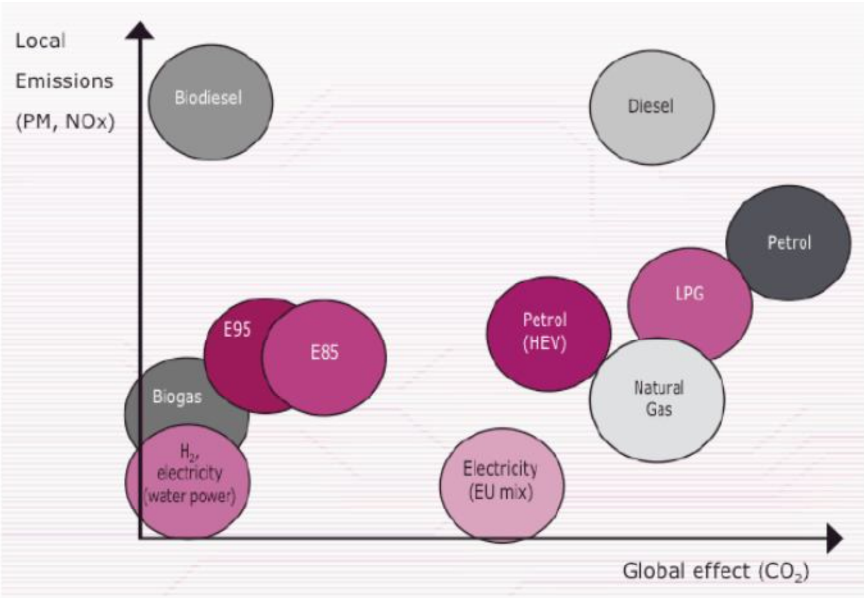

Figure 6: Local Emissions in relation to global effects for different fuels[9]

While some of the tests conducted on heavy duty highway engine reported in the study conducted by EPA shows that there is a slight increase in NOx (about 2% for B20 lend), the same study commented that the same may not be inferred as applicable to non-road engines[10]. Figure 7 shows the average impacts on emissions form biodiesel blends on heavy dusty highway engines.

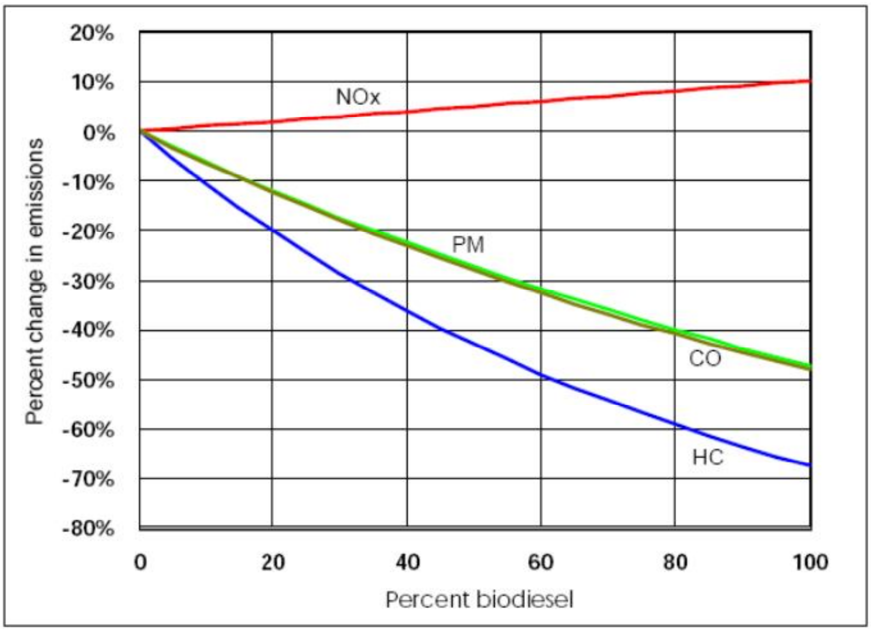

Figure 7: Average Emission impacts of Biodiesel for heavy duty highway engines.

[9] E85 consists of 85% of bioethanol and 15 % of gasoline fuel. E95 consists of 95% of bioethanol and 5% of gasoline fuel. LPG refers to Liquid Petroleum Gas.

[10] A Comprehensive Analysis of Biodiesel impacts on Exhaust Emissions-U.S. Environmental Protection Agency (EPA)-2002

Other tests conducted using biodiesel blends with Marine Diesel on stationary engine showed a decrease in NOx along with a decrease in PM, CO and HC with a sight increase in volumetric fuel consumption (Kallgeros *et al.*; 2003). Similar results were reported when Biodiesel was used on recreational boats (Zhou *et al.*; 2003) whereas studies conducted on outboard engines in recreational boats showed increasing NOx with increased blending ratio while the other emissions showed a decreasing trend (Murillo *et al.*; 2006).

In one of the tests carried out in India, it was found that blends of Pongamia Pinatta Methyl Ester (PPME) and diesel could be successfully used in diesel engines without any modification, with acceptable performance and better emissions including a reduction in NOx of about 40% with a blend of B40 as shown in Figure-7.(K.Sureshkumar *et al.*; 2007)

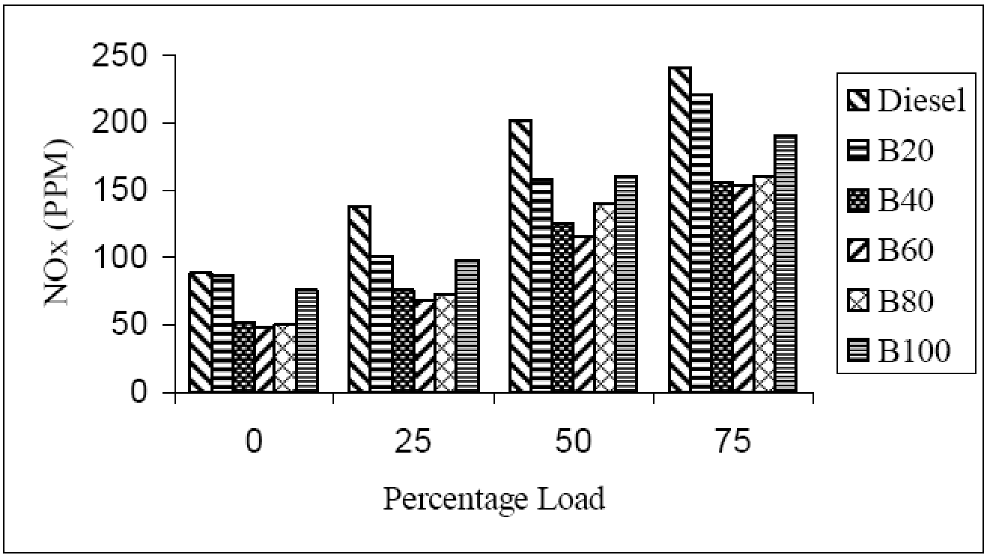

Figure 8: Variation of NOx Emission with load

Based on the engine performance, the tests showed that the blends B20 and B40 are comparable and better in some aspects than that of fossil diesel, and from emission point of view, blends B40 and B60 are superior to diesel. It showed that the biodiesel up to 40% (B40) could replace the diesel in diesel engine applications of transport sector, with less emissions leading to energy economy and environmental protection.

Preliminary Estimation of Biodiesel quantity and associated emissions in Indian Coastal Ships:

Considering the background on the use of biodiesels so far, it may be worth exploring the usage of biodiesels in the coastal shipping fleet. One of the main criterions for making this assumption is the shelf life of the fuel. The Indian coastal fleet is mainly composed of vessels in the services sector (like Tugs, OSV's etc) and only a very few cargo carrying vessels. These vessels do frequently refuel and hence the opportunity of using biodiesel blends arises.

The fuel consumption by ships is generally estimated using two methodologies[11]

a. Bottom up approach based on actual fuel sales

[11] 2nd IMO GHG Study –MEPC 59-inf 10

b. Top down approach based on activity data.

The approach presented is however based on data published by International Transport Forum In association with OECD[12]; Indian Shipping has a contribution of less than 2% of total CO2 emissions from transport sector in India in the year 2007. The following assumptions were made in estimating the fuel consumption and the emissions based on published information.

1. The Domestic navigation is assumed to consume light Diesel oil / gas oil only and assumed to have a conversion factor of 3.206 tonnes of CO2 per tonne of fuel[13].

2. The NOx, SOX and PM are calculated based on the following factors

Emission	Factor (Kg emitted per tonne of fuel)	Reference
NOx (Considering that all ships are powered with Medium Speed Engines Only)	57	EMEP/CORINAIR
SO2 (Considering MDO of 0.5% sulphur)	10	CORINAIR
PM10	1.1	CORINAIR

3. The consumption upto 2015 has been assumed to be increase in a linear fashion.

4. The reduction potential for B40 blend is assumed to be as follows:
    a. The fuel consumption is assumed to increase by 10% over the Diesel alone figure due to the blending with Biodiesel.
    b. NOx has been assumed to have a variation of upto 2% increase.
    c. SO2 has been calculated on the basis of CORINAIR emission factor for the component of fossil fuel in the blend only as the sulphur content in the biodiesel is negligible.
    d. CO2 has been calculated on the basis of CORINAIR emission factor for the component of fossil fuel in the blend only as the biodiesel component is considered carbon neutral.
    e. PM reduction is calculated at 20% reduction in accordance with 2002 EPA study on heavy duty engines.

Figure 9 shows that by 2015 the fuel required for domestic navigation is approximately 0.9 million tons (Diesel Oil). However when blended with Biodiesel the consumption would touch a figure of 1.0 million tons. Considering 40% of this is Biodiesel, the requirement of Biodiesel is approximately 0.4 million tons/year.

[12] Reducing Transport Greenhouse Gas Emissions- Trends & Data 2010 Published by ITF in association with OECD.
[13]MEPC.1 Circ 681

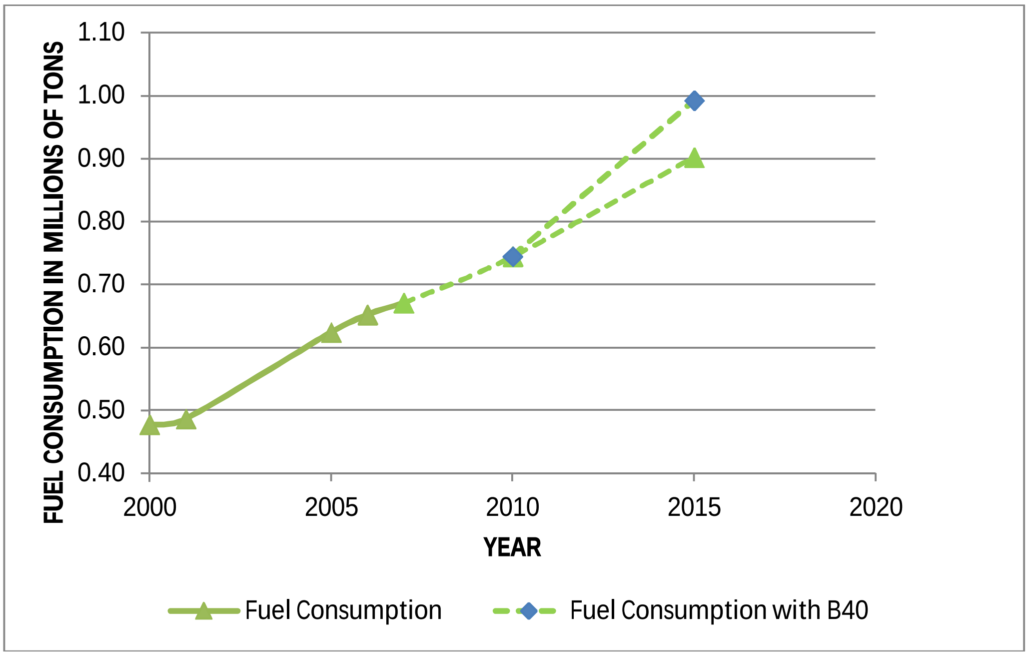

Figure 9: Fuel Consumption in Indian Coastal Ships

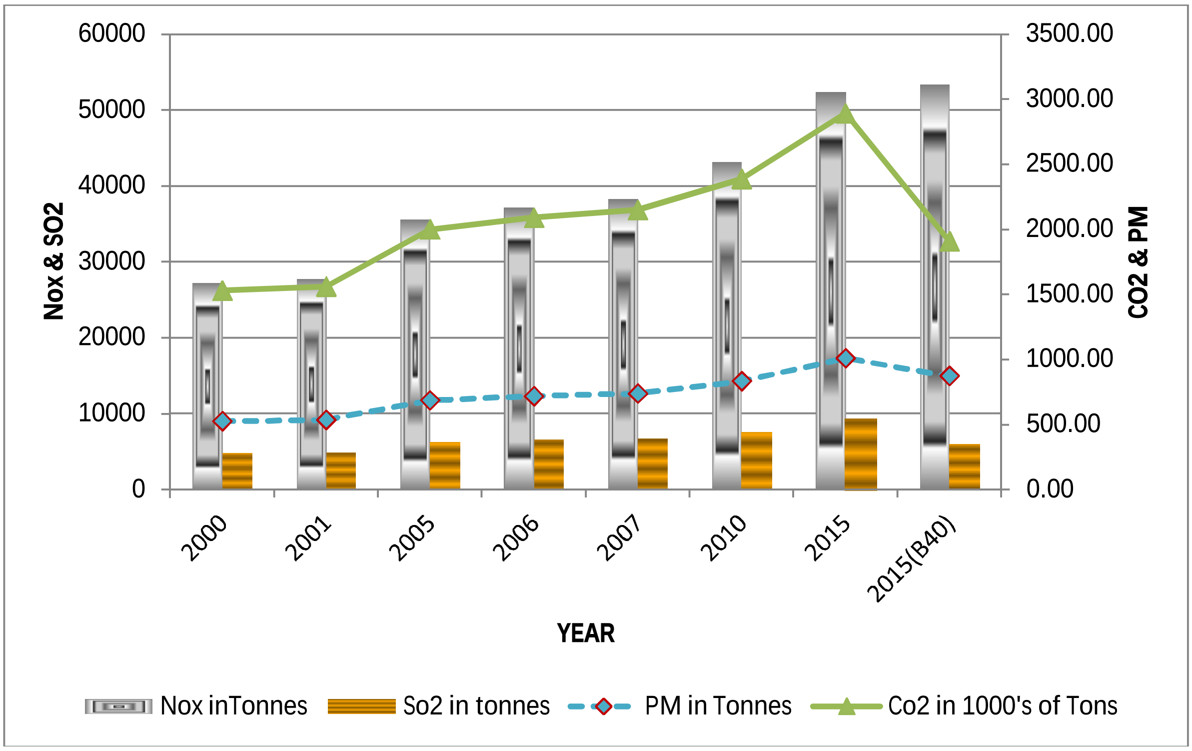

Figure 10: Emissions Estimations

From the above it is expected that with the exception of NOx which may increase slightly (if comparison with road vehicles is made). However it can also be seen from other studies that the NOX decreases with addition of Biodiesel blends. Also there are other methods to control NOx such as retardation in timing etc without having the need to undertake extensive modifications or retrofitting of additional equipment.

Conclusions:

It is clearly evident that biodiesel with several desirable characteristics would allow modern diesel engines to use biodiesel without engine modifications and without any reduction in the engine performance. Also the supply chain logistics and infrastructure requirements remain unaffected in comparison with other alternative fuels such as LNG. The strong advantage of the use of Biodiesel seems to be the fact that independently on the raw material used for the production, its addition into the marine fuel improves all the emissions and especially particulate matter which comprises a serious problem for the diesel and marine diesel engines, especially in polluted areas such as ports and beaches.

Over recent decades, substantial RD&D in biofuels has been undertaken in OECD countries as well as in developing countries. Several conventional biofuels have reached commercial production and further technology improvements have been made. Several significant improvements have also been made to advanced biofuel conversion routes, such as marine algae which give better overall (well to wheel) CO_2 factors.

One of the main deterrents in using biodiesel and its blends is in the specification of fuel used for marine use. Currently Marine fuels are specified under ISO 8217-2010 Petroleum Products- Fuels (class F) where it is mentioned that “The fuel shall be free from bio-derived materials other than '*de minimis'* levels of FAME (FAME shall be in accordance with the requirements of EN 14214 or ASTM D6751). In the context of this International Standard, “*de minimis*” means an amount that does not render the fuel unacceptable for use in marine applications. The blending of FAME shall not be allowed”.

Therefore along with the development of the fuel, testing and demonstration has to be increased significantly during the next 20 years, to ensure that advanced biofuels reach full technology maturity so that it is made acceptable as a blending ingredient beyond 5% finding acceptability to be included in the international standard for fuel specification and also be economical to the users.

Indian Maritime University (Visakhapatnam Campus) is open to take up collaborative demonstration projects along with biodiesel manufacturers, engine makers and other interested parties to make this happen for the benefit of the Maritime Industry.

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