In a report produced by Coventry University (Sahayam, 2014) on C4FF's (Maritime Division of the Centre for Factories of the Future) efforts in developing the next generation of lean ships (Ziarati and Akdemir, 2015) it was noted that there should be a variety of means to reduce fuel consumption and emissions of harmful pollutants. The following are extracts from C4FF and BAU (Bahcesehir University) internal reports as well as the report by Coventry University.

The maritime environment covers almost two-thirds of our global area and provides a massive potential for inhabitant's well-being, with a variety of resources being the source for various economic and commercial activities. The EU's marine environment accounts for more than 40% of its GDP with its economy around 3 to 5 % (Marine 2013). However, in the perspective of increased competition in global trade, human accomplishments are exerting burden to the environment, causing a major threat to maritime ecology and sustainable activities. In particular, unless appropriately addressed, the growing demand for marine transport, development in coastal areas, security, tourism, fisheries and aquaculture, and so on will pose a big threat to the maritime environment and biodiversity. Innovation and technology provide one of the bases for the settling of improvement in sustainable commercial growth in ocean and sea-based activities with ecological conservation.

- The competition in an exposed global market, for advanced economies like the EU shoots from their ability to produce high value-added and pioneering goods and amenities. Therefore, research and development efforts are essential for increasing their eco-efficiency and to offer solutions for overcoming the use of unsustainable resources. (Maritimesun 2013)
- Many maritime and marine research activities are continuing in the EU; these initiatives need to be coordinated in the most effective manner.
- Exhaust gases are the primary source of emissions from ships. Due to the increase in traffic in the marine environment the emission rate of exhaust gases is increasing day by day. The proportion of emissions from ships is comparatively lower than other transport such as road, air and so on. Recent increase in global trade accounts for nearly 90% of increase in the rate of emissions.
- NOX, SOX and CO2 are the three gases forming the basis of greenhouse gases (GHG).

- Among the exhaust gases, CO2 plays a very important role in causing an increase in the global warming. So measures specifically for the reduction of CO2 are concentrated.
- IMO has and is continuing to play an important role in shaping the environment by setting the regulations for the control of emissions. (IMO 2012)
- IMO regulations address the efficiency of systems and the control of emissions and it was introduced on January 1, 2013. It includes EEDI, EEOI and SEEMP to be followed, especially in the Emission Control Area.
- IMO still closely monitors the prevailing international regulation, while functioning on new requirements causing an improved awareness of safety elements and ever changing aspects of the maritime industry.
- EU needs to focus on high quality maritime transport sector to compete the world by providing high service quality and high levels of safety, environmental protection and operational efficiency winning over low cost substandard services and protectionism (IMO 2012).
- Compliance is made challenging by a huge number of aspects that includes technological immaturity, monetary restrictions and uncertainty regarding implementation and the concerns of non-compliance.
- Hence, a global approach for effective emission control and development of energy efficiency systems is led by the IMO on account of the continued rapid growth of the world trade in the maritime transport (IMO2012).

Since, the life expectancy of a ship is more than 30 years, development of advanced technologies for reduction of pollutants and fuel consumption still remains as a main challenge (Akdemir, 2012). The European Commission, therefore, encourages on developing technologies and projects by proposing initiatives like FP7 generally termed as 7th Framework for Research and Development. (EC 2013) FP7 acts as a key tool in providing solutions for Europe's need, having a 'European added value'.

- C4FF Company has been at the cutting-edge of innovation and technological development and has been involved in developing European maritime education and training initiatives, with the support of the EU's funding streams since its inception (C4FF 2014).

- This company also established Mari Future, an international partnership of academic and vocational training institutions which supports innovation in the maritime industry. C4FF Chairman says ***"MariFuture (www.marifuture.org) will develop the future of the European maritime industry through innovation"*** and hence develops an energy efficient system (LeanShip – See Ziarati and Akdemir (2015)) for meeting the upcoming needs of European marine industry for effective emission control on account of the European Commission's proposal (C4FF 2014).

C4FF initially developed a product 'Idealship ' with respect to the requirements proposed by the TSB (Technology Strategy Board) in the UK. IdealShip is a product whose main objective was to increase the efficiency of ships. The LeanShip is a replica of IdealShip with more advanced features that involves the replacement of low cost laser CPS used in IdealShip with higher laser version trying to address the future regulations and needs in the European maritime markets.

Energy efficiency in Global Climate

Energy Efficiency

The ships' energy efficiency depends not only on the amount of fuel consumed, but also on the quantity of work undertaken on account of transportation and also on the level and amount of actions and so on. Indeed, efficiency is defined as 'the difference between the volume of energy fed into machine in the form of fuel , effort and the volume that comes out(in form of movement) as a result of energy fed '.Limiting the observing requirements to consumption of fuel would provide only the input (i.e the volume of energy consumed)which is one part of the equation but it does not consider the output produced by the combustion, which can be calculated further by measuring the terms of distance sailed, available capacity, cargo carried, ship speed and so on (IMO 2013).

1. We are living in a carbon- constrained world, where the future development of the ships bound to stabilize the emissions of GHG to a level, on account of which the global climate change can be prevented to some extent.
2. Energy efficiency is estimated to be a main feature for all the firms that operate ships, including the marine equipment industry (IMO 2013).

The growth of the world economy and the shipping sector are increasing exponentially hand in hand. This increase has also caused a substantial increase in GHG emissions, as the ships are run on fossil fuels. The emissions from ships can be illustrated in the Figure 1 below:

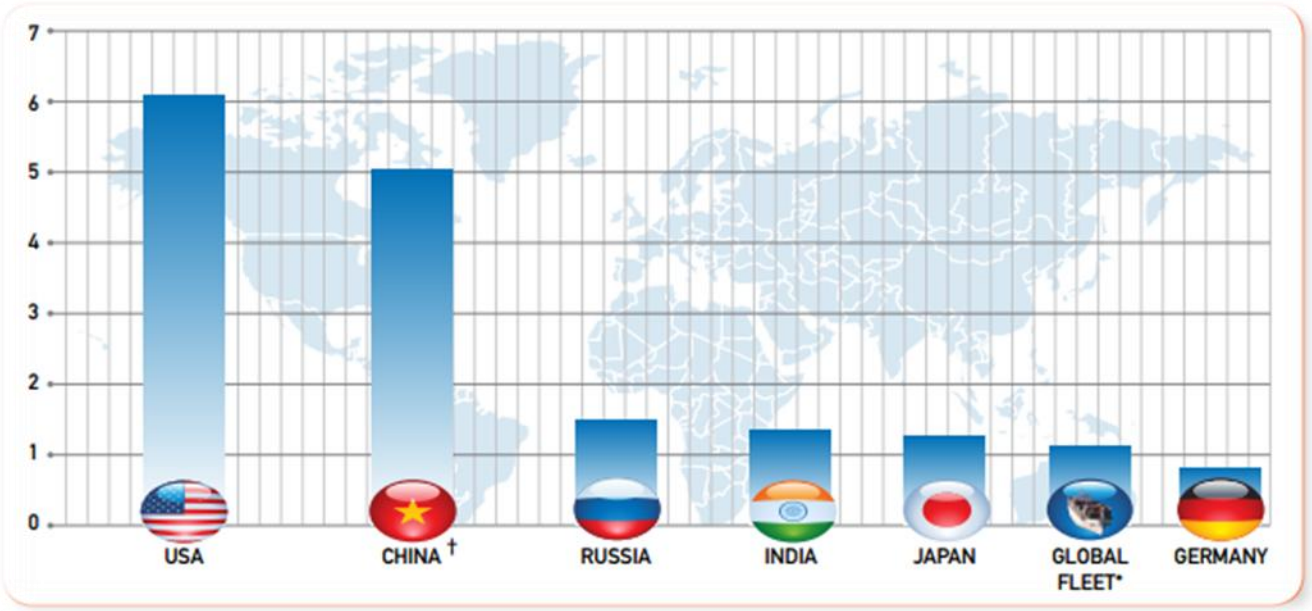

Figure 1: CO2 emissions from shipping in comparison Source: Oceana

According to second IMO GHG study, Buhang et al (2009) argues that, about 870 million tonnes of CO2 have been estimated to be emitted from the international shipping and it is expected to grow by 200% to 300% by the end of 2050, in the absence of regulations. So, cost effective strategies have to be undertaken in order to reduce the emissions and to avoid dangerous climatic changes by reducing the emission rate from 25% to 75% below the current levels. The upcoming maritime regulations are mentioned in the Figure 2 below.

Figure 2: Upcoming Maritime regulations Source: GL

In this competitive world, developing an energy efficiency system should answer all the questions which were posed by the partners of C4FF (mentioned in Appendices) for proving the excellence of the system as listed below:

- Will the system benefit the ship owners in safe operations?
- Can we measure the gain in terms of improved safety?
- Will the system benefit the shipyards in allowing them to get a better set of competencies?
- Will the marine equipment suppliers be better placed off to provide the exact products to the ship owners and the yards?
- If so, how will it enable to work for better regulatory frameworks?

Though, many efficiency systems already exist in the industry, the changing regulatory requirements and increase in the global trade and fuel rates forces the development of a new system for handling the above scenario (Climateactionprog 2013).

A clear outlook of the roadmap for reduction of emissions from ships was identified by having a review of recent publications, IMO reports and various reports from classification societies, learnt societies especially the German Lloyd's Academy. These reports provided

guidance for all the ship operators, ship owners and shipyards that are looking to implement EEDI on the current vessels and also on the future mandatory requirements of the ships.

Kollamthodi et al (2008) claims from an interview with the Norwegian ship association that, the charterers (contractors) are ready to pay higher amounts for energy efficient ships when comparing other normal vessels (Sustainable shipping, 2012).

On the other hand, Faber et al. (2011) concludes that, the ship owners investing in ships that are fuel efficient will not be able to recoup their investments unless otherwise their own ships are being operated or by having a long term agreement with charterers. But an argument, on the other side is, investments in the energy efficiency vessels increase the rate of success for winning contracts and hence provides a better utilisation of ships. A recent view by Lloyd's List (2012) claims that many major operators in the market of different vessel types might not be ready to pay premium rates for energy efficient vessels, but they are forced to take the best ship complying with the environmental performance. Congruently, ships that are low efficient are forced for short-term contracts or lower rates than those that with the higher efficient ones.

Standards of IMO in regulating the emissions

According to the IMO (2013a), a significant potential strategy for reducing GHG emissions in maritime transport can be fragmented into three categories:

- Operational efficiency changes lessens the consumption of fuel taking into account the variations in environmental conditions.
- The practicalities of the voyage and commercial realities of operations and technological advancement that improve ship fuel efficiency.
- Alternative energies (especially fuel) with lower net lifecycle of GHG emissions.

International shipping is a highly regulated industry; key regulations are coming into force by IMO, the main regulatory body for controlling the maritime transport emissions (IMO, 2012).

According to GL (2012), IMO has mandated certain measures related to energy efficiency in international shipping as listed below:

- **Energy Efficiency Design Index (EEDI)** mandates energy efficiency standards for new ships
- **Energy Efficiency Operational Index (EEOI)**
- **Ship Energy Efficiency Management Plan (SEEMP),** a management tool for ship owners.

These three standards came into force on January 1, 2013 within a new chapter of MARPOL Annex VI. Also, it has been mentioned that EEDI will be applicable only to certain ship types such as General cargo ships, Passenger ships, Container ships, Bulk carriers, Ro-Ro cargo ships (which includes vehicle carriers)combination carriers , Gas carriers , Ro- Ro passenger ships that excludes shipping with diesel electric, steam turbine and hybrid propulsion and finally the Tankers.Complex technologies will be involved in building a ship efficiency system by the marine suppliers since the life expectancy of vessels is estimated to be around 30 to 40 years and also of the mandatory regulations to be met as set by IMO. (Oceana 2013)

The EEDI (Energy Efficiency Design index)

EEDI is made compulsory for all the newly constructed ships. This technical measure is more important and aims at promoting the usage of more energy efficient engines and equipment in the ships for controlling the emissions. EEDI is a performance-based mechanism and it leaves the option of technologies to the used for the design of a ship to the industry (Fathom shipping 2011).

Principles of EEDI

- The acceptable EEDI (base line definition) depends solely on the deadweight of the ship and the ship type.
- A ship is seen as ‘efficient’ if it is slow and big.
- The base lines are developed from regressions over existing databases.
- A new building; then must have an EEDI below the prescribed baseline.
- All ships above the baseline will be excluded from the market.

IMO (2013) aims to improve the energy efficiency of ships by implementing the EEDI in new ships. The EEDI comprises of highly complex equation and expressions to calculate the

amount of CO2 as a result of the ship's transport voyage. The equation for EEDI is shown below:

EEDI = (CO2 emission) / (transport work)

The ship types which do not satisfy the formula above, steps are taken by IMO to design a new formula for addressing larger emitter ships in future.

Energy Efficiency Operational Index (EEOI)

Energy Efficiency Operational Indicator (EEOI) is an indicator developed by IMO that deals with the information regarding the ship's efficiency in operations. This EEOI calculation is based on an individual ship's consumption of fuel and data on the achieved transport work (e.g. The total count of passengers carried, Cargo mass, and so on.) resulting in a figure of emission of CO2 per ton nautical mile. Unlike the EEDI, this indicator is not limited to new vessels and can be used to gauge the 'real' efficiency of a ship in operation and to measure the effects of any changes, such as hull and propeller cleaning, slow steaming, improved voyage planning, etc. However, as the EEOI calculation depends on ship activities and operations, it will vary, possibly considerably, over time and between voyages. It cannot therefore be used to establish a fixed figure – e.g. a 'label' reflecting the ongoing performance of a vessel (DNVNL 2013).

EEOI = (Fuel Consumption * Carbon Conversion)/ (Distance sailed * Cargo Transported)

The EEOI can be improved by increasing the amount of cargo transported or by applying any measure aiming at reducing fuel consumption (e.g. slow steaming, vessel modifications, weather routing, etc.).

Ship Energy Efficiency Management Plan (SEEMP)

SEEMP is an operational measure developed by IMO that establishes a cost-effective mechanism in improving the ship's energy efficiency. This measure also assists the shipping companies in providing an approach for managing ship and fleet efficiency performance

over time with the help of the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool. The assistance on the development of the SEEMP operational measure for new and existing ships includes best practices for efficient ship's operation, as well as procedures for deliberate use of the EEOI in new and already existing ships (MEPC.1/Circ.684). The EEOI measure also enables ship operators in measuring the ship's fuel efficiency in operation and also to monitor the effect of any variations in operation, e.g. more frequent propeller cleaning or improved voyage planning or introduction of technical measures such as a new propeller or waste heat recovery systems. The SEEMP further urges the operator and ship owners at each phase of the plan to consider new practices and technologies when looking to optimise the ship's performance (BTG 2014).

Why SEEMP?

• A plan to improve the energy efficiency implementation in a ship' operation.
• Fuel cost is the prime cost element for shipping companies. The type of vessel helps to predict 35-65% of operational costs.
• Improvements in Energy efficiency provides cost savings of 5-15% and helps in bringing down GHG emissions
• Environmental impact based port fees.
• Global players such as a (IKEA, DHL, etc.) are demanding the data related to the emissions.

Who should implement SEEMP?

• Ship operator, ship- owner or charterers can develop SEEMP as it is a ship specific plan.
• Based on the characteristics of individual ships and companies the SEEMP plan can be adjusted.
• SEEMP is a management tool restraining the on-board executive burden.

Feasibility of integrating the new product

An assessment on what the state-of-art is, in terms of energy efficiency for determining where the focus of the research should be, can be found by answering the question **'How energy efficiency of the ships can be increased in future?'** (Ziarati 2012) Energy efficiency is

the most important feature in terms of cost and revenue in industries that are operating ships

- On considering the surplus of ships, slow steaming was opted to be the best solution in reducing the emissions, but as the business demands, this created a big issue and was not a feasible solution.
- In contrary to the above statement, Jafarzadeh and Utne (2014) that the matching of the turbochargers in engines would effectively reduce the emission rate. In addition, the researchers should focus more on improving the hull resistance and propeller efficiency to further cut down the emission rates.
- On looking into longer time scale, cheap transportation formed the medium for supporting the shift from fordian to post fordian production as well as globalization. This requires more attention and findings from researchers who develops solutions.(Agnolucci 2014)
- Vergera et al (2012) argues that reducing the emissions in the marine environment is complex as compared with other sectors, due to the restrictions in the atomized nature, weight and structure of the ships both technically as well as operation. He also identifies certain policies and methods, focusing on some of the issues such as ship resistance, propulsion augments and new fuels.

According to Johnson (2013), the ship's resistance can be reduced by radically eluding the wave formation at a greater speed ratio. While Vergera et al (2012) concludes stating that the rate of initial and final emission depends on the growth rate of the maritime transport. Use of solar energy and LNG would best replace the emission of CO2 into the atmosphere.

In reference to the above reviews and arguments, continuous growth in the retrofit market is booming, on account of the changing regulation to meet the global standards. Hence the methods for emission reduction should be focussed more on forecasting the future with high complex technology for showing better results.

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