# CLEAN MARINE TRANSPORT SOLUTION FOR SUSTAINABLE FUTURE[1]

**Professor Dr Reza Ziarati** BSc (Eng), PhD (Eng), Cert Ed, CMechE, CElecE, CMarEng, CEng, FIMechE, FIET, FIMarEST, C4FF

On behalf of all GreenShip Project Partners

To reduce $CO_2$ emissions, shipping industry has started to implement some of the potential areas for energy efficiency that would lead to a substantial reduction both in energy use and in ship emissions as shown in Figure 6. This efficiency improvements could lead to some 60% overall reduction of fuel requirements and in ship emissions for a given ship. (Wang & Lutsey, 2013)

Another way of achieving this is to use Ammonia and extend the use of Flettner rotors and sails to assist in propelling the ships.

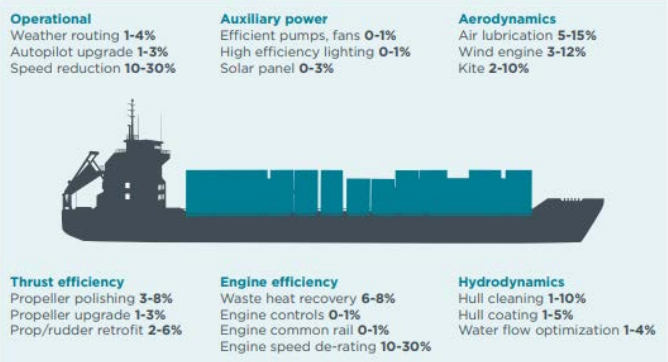



*Figure 1 Potential Fuel use and $CO_2$ reduction from various efficiency approaches for shipping vessels*

C4FF in their studies have shown that provided the government invests in local supply chains and provide funds for shipping companies to take advantage of energy savings as well as encouraging port electrifications through renewable energy; these could substantially reduce the level of $CO_2$ emissions by 25% by 2030 to counter the expected increase of possibly by 30% as shown in [Figure 7].

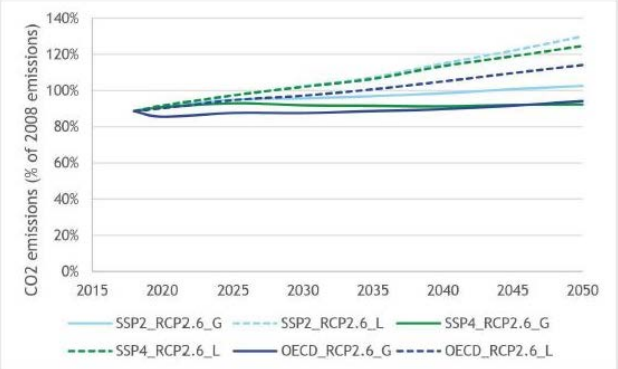
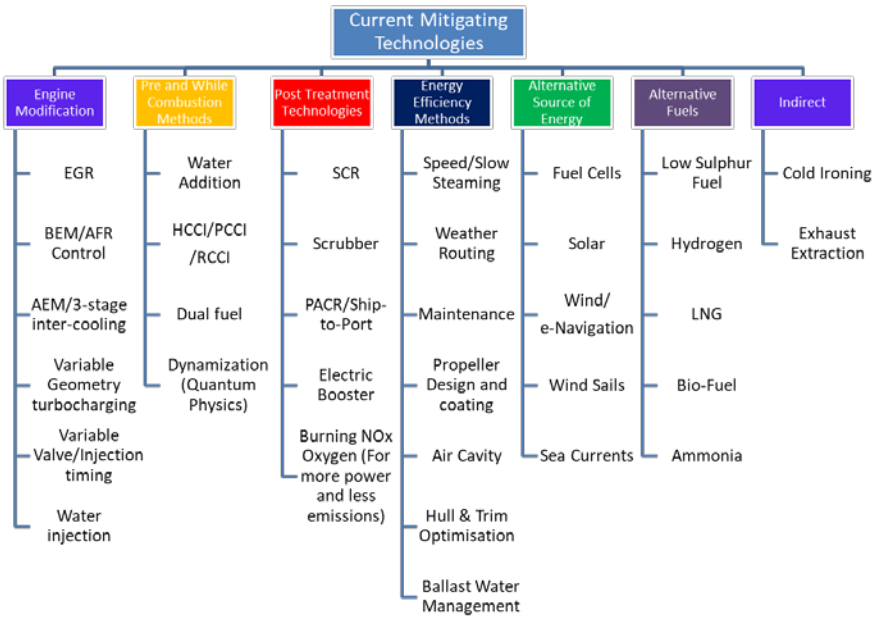



*Figure 2 Projections of maritime ship emissions as a percentage of 2008 emissions*

To overcome the level of $CO_2$ Emissions shipping industry has started to implement some of the potential areas for energy efficiency by using the following mitigation technologies.

[1] Based on IMechE COP26 policy paper, 2021




**Nomenclature:**
EGR- Engine Gas Recirculation
BEM – Before Exhaust Method
AEM- After Exhaust Method
ECR – Selective Catalytic Reduction
PACR – Plasma Assisted Catalytic Reduction
Air Cavity - A thin sheet of

*Figure 3 Current mitigation technologies in marine industry*

## Ship Energy Efficiency Management Plan (SEEMP)

The IMO has also introduced regulations (DNV, 2014) such as the Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SSEMP) and Energy Efficiency Operational Index (EEOI) on January 1st, 2013. SEEMP is an operational measure 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 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). SEEMP therefore is a plan to improve the energy efficiency implementation in a ship’s operation, reported to provide cost savings of about 5 to 15% and help to bring down GHG emissions. (Ziarati, 2017)

Each Ship of 400 GT and above shall keep on board a ship specific SEEMP. Operational management tool applicable for all ships of 400 GT and above shall include:

- Improved voyage planning (weather routeing/Just in time arrival at port)
- Speed and power optimization
- Optimised ship handling (ballast/trim/use of rudder and autopilot)
- Improved fleet management
- Improved Cargo handling
- Energy Management
- Monitoring tools (Energy Efficiency Operational Indicator)

In a 2021 report into decarbonising shipping, the IMechE recommended (Institution of Mechanical Engineers, 2021):

1. The UK Governments support the development of a ship demonstrator using retrofitted wind sails. This will allow ship owners and users to understand how renewable wind can be used as primary propulsion on modern ships and could provide a compelling exhibition at COP26.
2. The UK shipping industry and users work with government on creative funding sources to build a ‘2050 now’ ship that demonstrates how a fully autonomous fuel ship, that creates and manages its fuel could operate.

3. The International Maritime Organisation rethinks its recent low ambition announced in November 2020 and seeks to aim for a substantial reduction closer to 70% to meet the requirements of the Paris Agreement.

Based on findings (Ziarati, 2017), it is recommended in this report that the UK Government should actively create funding schemes to invest in technologies that will specifically decarbonise shipping and meet the urgent need to reduce our emissions at sea such as: Slow steaming when admissible; Use of sails and flettner rotors; Weather routing and use of sea currents; Green energy – wind and sun (Flettner rotors/Cylinders; sails & solar panels); Engine efficiency; Hull and trim optimisation and Propeller Polishing; e-navigation; Ballast water management; application of AI , VR and Quantum Physic focusing on Virtual arrival, advanced communications, JIT, predictive requirements and use of quantum physics in fuel molecular restructuring.

In terms of fuels, many ships have started using LNG, especially those operate terminal to terminal, but since this leads to an unacceptable level of methane leakage and slip with the possibility of leaked LNG combusting therefore for safety reason and methane use of such fuels should be kept to minimum.

Some alternative future fuel options are recommended in Figure 9 :

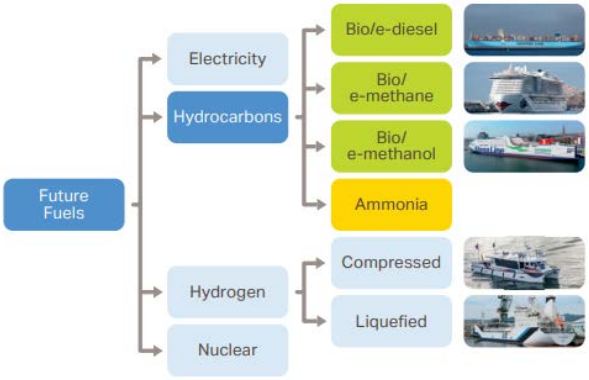



*Figure 4 Alternative future fuel options for marine industry*

## On the sea – Ammonia-powered ships

Although poisonous, on ships Ammonia (NH3) is a practical way of storing large volumes of hydrogen. Ammonia is liquid below -33 Degree Celsius or at room temperature at 10 bar. Volumetric energy density of liquid ammonia is a third that of diesel and can be burnt directly in diesel engines with a suitable catalyst that provides long term pathway to fuel cells (Zero Emissing HGV Infrastructure Requirements, 2020).

IMO[2] has set a new decarbonisation milestone and new ammonia-powered vessels planned. The IMO's new regulation is intended to drive the decarbonisation of global shipping. Scheduled to be enforced by 2023, New Regulation 28 mandates: "a linear reduction in the in-service carbon intensity of ships between 2023 and 2030, such that the global fleet achieves an average reduction of at least 40% by 2030 when compared with 2008. The initial trials with internal combustion engines and gas turbines have been successful but one application which is considered promising is with fuel cells[3].

[2] https://www.ammoniaenergy.org/organization/international-maritime-organization-imo/
[3] https://www.ammoniaenergy.org/articles/safe-and-effective-new-study-evaluates-ammonia-as-a-marine-fuel/

## References

Air Transportation Actions Group (ATAG). (April 2019). *Fact Sheet 2: Aviation and Climate Change.*

(November 2017). *Beginner's Guide to Sustainable Aviation Fuel.* Air Transport Action Group (ATAG).

Catapult Connected Places. (March 2021). *Transition to Zero-Emission Transport.*

Christine Akrofi. (April 2020). A Guide to Sustainable Aviation Fuels. ADS.

Climate Change Committee. (May 2019). *Net Zero - Technical Report.* UK.

Climate Change Committee. (December 2020). *The Sixth Carbon Budget - Surface Transport.*

Cuenca, O. (2020, 7 29). Scotland unveils rail carbon reduction plans. *International Railway Journal* .

de Melo, G., Ziarati, R., & Koivisto, H. (2021). Towards Zero ship Emissions II - Project Greenship. *The International Association of Maritime Universities Congress 2021.* Alexandria, Egypt.

Department for Business, Energy & Industrial Strategy. (2021, Feb 02). 2019 UK Greenhouse Gas Emissions, Final Figures. *12* , 1-25. London, UK. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

Department for Transport. (2021). *Decarbonising Transport - A Better Greener Britain.* London: DfT.

Department for Transport. (2021). *Great British Railways: The Williams-Shapps Plan for Rail.* London: HM Government.

Department for Transport. (2020, Aug 05). National Travel Survey: England 2019. London, UK: DfT. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/906276/national-travel-survey-2019.pdf

Department for Transport. (2021, Feb 02 ). Road Traffic Estimates: Great Britain 2019. London, UK: DfT. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/916749/road-traffic-estimates-in-great-britain-2019.pdf

DNV. (2021). *Energy Transition Outlook.* Oslo: DNV AS.

Green Car Congress. (October 2020). MAN presents hydrogen roadmap; use in fuel cells and combustion engines.

Institution of Mechanical Engineers. (2021). *Accelerating Decarbonisation in Shipping: A No Regrets Approach Using Wind Power.* London: IMechE.

Institution of Mechanical Engineers. (2020). *Accelerating Road Transport Decarbonisation - A Complementry Approach Using Sustainable and Low Carbon Fuels.* London: IMechE.

Institution of Mechanical Engineers. (2019). *The Future for Hydrogen Trains in the UK.* London, UK: IMechE.

Institution of Mechanical Engineers. (2013). *Transport Hierarchy.* London: IMechE.

McKinsey & Company. *Hydrogen-powered aviation, A fact-based study of hydrogen technology, economics, and climate impact by 2050.* Belgium.

Network Rail. (2020). *Traction Decarbonisation Network Strategy.*

Railway Industry Association. (2019). *RIA Electrification Cost Challenge.* London: RIA.

Railway Industry Association. (2021). *Why Rail Electrification.* London: RIA.

Robert Thomson. (2020). *HYDROGEN: A FUTURE FUEL FOR AVIATION?* Roland Berger.

Royal Aeronautical Society. (2019-2020). *Air Travel - Greener by Design.*

Shirres, D. (n.d.). Rail traction decarbonisation. RailEngineer.

The International Council on Clean Transportation. (2020). *CO2 Emissions From Commercial Aviation 2013, 2018 and 2019.* Washington, DC, USA: ICCT.

The National Academies of Sciences Engineering. (2016). *Commercial Aircraft Propulsion and Energy Systems Research: Reducing Global Carbon Emissions.* Washington, DC: The National Academies Press.

Transport & Environment. (December 2020). All new lorries must be emissions-free in the 2030s if the UK is to decarbonise by 2050.

Vodafone Institute for Society and Communications. (2021). *homeworking Report.* The Carbon Trust.

Wang, H., & Lutsey, N. (2013). *Long term potential for increased shipping efficiency through the adoption of industry leading practices.* Washington, DC, USA: ICCT.

Wołek, M., Szmelter-Jarosz, A., Koniak, M., & Golejewska, A. (2020). Transformation of Trolleybus Transport in Poland. Does In-Motion Charging (Technology) Matter? *Sustainability , 12.*, 9744.

Yiu, Y. (2020). How Much Damage Do Heavy Trucks Do to Our Roads? *Indside Science* .

(2020). *Zero Emissing HGV Infrastructure Requirements.* Ricardo Energy & Environment reference.

Zheng, X. S., & Rutherford, D. (2020). *Fuel Burn of New Commercial Jet Aircraft 1960 - 2019.* Washington, DC, USA: International Council on Clean Transportation.

Ziarati, R. (2017). TOWARDS ZERO SHIP EMISSIONS – PROJECT MARIEMS. *Proceedings of The International Association of Maritime Universities (IAMU).* Varna.