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Decarbonising Shipping – A Report on Technical Aspects

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Introduction

The aim of this Report is to provide a technical perspective on the ways of reducing Greenhouse Gas (GHG) emissions from maritime transport in line with the deliberations and initiatives of the United Nations International Maritime Organisation (IMO) and the EU “Fit for 55” package of proposals.

The Report is structured as follows:

Section 1 provides a brief background on issues concerning the ambition to decarbonise the maritime sector and presents the relevant EU “Fit for 55” package of proposals and global policies to decarbonise the sector.

Section 2 provides a short overview of the various options to decarbonise shipping (i.e. alternative fuels, propulsion technologies and emerging technologies).

Section 3 discusses the uncertainties regarding the transition of the maritime transport sector towards decarbonisation. Finally, conclusions are presented.

1. Issues concerning the proposals to decarbonise the maritime sector

a) Decarbonisation will not follow a linear trajectory

Setting a framework to achieve the decarbonisation goals and a carbon-neutral economy, can only be successful with regard to shipping if the technology and the carbon-neutral fuels become available.

This will happen through investment in innovation, building the necessary infrastructure and development of solutions that can meet the set goals in a cost-effective and sustainable manner suitable for ships competing internationally. It may be easier to model the reduction of emissions as a linear trajectory. In practice, however, that is not the case. With new technologies and fuels, experience has shown that initial uptake is slow. After experience is gained, the related costs and technology risks will be reduced and the new technologies will become more accessible to a larger part of the shipping community. This would result in an increase in the uptake and investment (a reinforcing cycle). Therefore, an exponential curve instead of a linear trajectory should be expected.

On the one hand, the trajectory of emissions towards full decarbonisation hinges on the introduction and market uptake of economically viable and safe low and zero emission fuels and technologies. Implementing the new technologies will require sufficient time and a joint effort from all stakeholders in the maritime value chain e.g., shipbuilders, engine manufacturers, the fuel producers and energy providers, charterers, port infrastructure and port operators.

On the other hand, in the course of meeting the decarbonisation goals, the ships will need to increase their efficiency. Increasing ship efficiency is a combination of multiple factors such as ship design as well as operational measures/choices such as improved voyage planning, more efficient interface between ships and ports, regular cleaning and maintenance of the propeller and the hull, installation of energy-efficient waste heat recovery systems, etc.



b) Brief overview of EU proposal for the maritime transport sector

The recently announced package of measures entitled “Fit for 55” involves a number of proposals for the reduction of the GHG emissions from the maritime sector for 2030 and beyond.

The **EU Emissions Trading System (EU ETS)** Directive extends the EU ETS to the maritime transport sector from 2023 (with a progressive inclusion of ships’ emissions). The measure shall apply to vessels of more than 5,000 GT for 100% of intra-EU voyages and 50% of voyages to and from EU ports, from or to ports outside the EU (extra-EU voyages). This initiative is thus aligned with the scope of the Monitoring, Reporting and Verification (MRV) Regulation.

The **FuelEU Maritime** Regulation proposes the reduction of the GHG intensity of energy used by the vessels by 6%, 26% and 75% in 2030, 2040 and 2050, respectively, compared to 2020. The scope of this initiative is also aligned with the MRV regulation. In parallel, the **Renewable Energy Directive** establishes fuel sub-targets to be applied horizontally to the transport sector overall (including maritime). The sub-targets cover biofuels and hydrogen provided that these are produced from renewable electricity.

The **FuelEU Maritime** also envisages the use of electricity when vessels are at berth using Onshore Power Supply (OPS). The measure will apply to containers and passenger ships only, as from 2030.

The **Alternative Fuel Infrastructure Directive** requires the development of the OPS in the majority of the EU ports by 2030 and the supply of Liquefied Natural Gas (LNG) in terminals in 2025.

c) Brief overview of global policies in place

The global shipping industry is fully committed to reducing shipping’s carbon intensity per tonne/mile by at least 40% by 2030, pursuing efforts towards 70% by 2050 compared to 2008 and to reduce total annual GHG emissions by at least 50% by 2050 compared to 2008, in line with the standing IMO Initial Strategy’s agreed targets.

The IMO adopted an Initial Strategy on Reduction of GHG emissions from ships in April 2018, due to be revised in 2023, which provides the framework for the development and adoption of concrete short-term CO₂ reduction measures as well as candidate mid- to long-term measures for achieving appropriately reduced emissions within agreed timelines and implementation schedules.

MEPC 77 in November 2021, in view of the urgency for all sectors to accelerate their efforts to reduce GHG emissions as emphasized in the recent IPCC¹ reports and the Glasgow Climate Pact at COP 26, recognized the need to strengthen the Initial IMO GHG Strategy during its revision process with a view to its adoption by MEPC 80 in spring 2023 and the 2050 level of ambition in parallel with the consideration and development of medium and long-term measures to ensure a GHG reduction pathway in line with the temperature goals of the Paris Agreement.

¹ IPCC stands for the UN Intergovernmental Panel on Climate Change



Without the development and commercialisation of alternative marine fuels the long-term goals of the IMO Initial Strategy for decarbonisation and the ambitious objectives of the European “Green Deal” and “Fit for 55” Package are not achievable. This is why the industry, along with several Member States with substantial maritime interests have made a proposal at the IMO to set up a Research and Development (R&D) Board and Fund (the IMRB / IMRF proposal²) to be funded by a mandatory contribution per ton of fuel consumed from each ship over 5,000 gt. The purpose of this initiative is to expedite the development of alternative fuels and technologies that the shipping industry needs to meet the decarbonisation targets but cannot develop by itself. It is the urgency of the situation that has prompted this initiative which demonstrates the shipping industry’s concern and willingness to contribute.

In parallel, the IMO Member States agreed and have started discussions on mid- and long-term measures, including Market-based Measures (MBMs) according to the agreed IMO work plan for medium- and long-term measures.

At the MEPC 77, IMO also recognized the merits of the shipping industry’s proposal which has been progressed for further consideration in spring 2022 alongside other proposed medium-term measures for the reduction of GHG emissions from ships.

The related IMO work stream that still needs to be completed concerns the development of Life Cycle Assessment (LCA) GHG / carbon intensity guidelines for all types of fuels. In this framework of ongoing discussions within IMO on LCA guidelines, the 27 EU Member States and the European Commission proposed in September 2021 a Well-to-Wake (WtW) certification scheme to be developed and validated by the IMO.

Allocation of Fuel Lifecycle Labels with default GHG emission factors based on feedstock and production pathways will enable categorisation of low carbon and zero carbon alternative fuels, including sustainable biofuels and the quantitative calculation of their WtT (Well-to-Tank) emissions. Also at the 76th session of the Marine Environment Protection Committee (MEPC) held in June 2021 the IMO member governments, including all EU Member States adopted a comprehensive package of legally binding technical and operational short-term measures to reduce CO₂ emissions from ships, which will enter into force on 1 November 2022.

More specifically, the measures adopted at MEPC 76 require ships of 400 gt and above to calculate their Energy Efficiency Existing Ship Index (EEXI) following technical means to improve their energy efficiency and all ships above 5,000 gt to establish their annual operational Carbon Intensity Indicator (CII) and CII rating. Carbon intensity links the GHG emissions to the amount of cargo carried over the distance travelled. The IMO will review the effectiveness of the implementation of the CII and EEXI requirements by 1 January 2026 to determine if any further amendments are necessary.

² Proposal for the establishment of an International Maritime Research Board/Fund (IMRB/IMRF).



2. Overview of key alternative fuel and vessel technology options

a) The different levels of technical and regulatory maturity of alternative fuels

LNG

Liquefied Natural Gas (LNG) is mostly composed of Methane (CH₄). LNG can have 20-25% less tank-to-wake CO₂ emissions and it is sulphur-free producing no SO_x emissions. However, methane has a comparative impact on climate change more than 30 times greater than CO₂ over a 100-year period when unburnt methane is released into the atmosphere (methane slip)³ which is an important parameter that needs to be addressed.

Since methane is the main component of LNG, liquefied methane produced from biomass (LBG) could easily blend with LNG.

“Green” LNG production and the liquefaction of natural gas to -173°C requires substantial energy input and storage capacity. Lack of LNG bunkering infrastructure for LNG-fuelled ships in major ports of call worldwide is a barrier to further widespread use of LNG as marine fuel.

Using LNG as fuel is more viable for tankers than for bulk carriers and general dry cargo ships. For container vessels, LNG could be viable on certain routes. The energy density of LNG is 40-45% lower than that of Heavy Fuel Oil (HFO). Hence, there is a high Capital Expenditure cost of fuel storage and containment systems for ships that are not LNG carriers.

Biofuels as a partial solution for international shipping

A substantial and sustained supply of efficient biofuels from renewable sources with worldwide availability for ocean-going shipping may not be feasible. Most renewable resources that can be used as biomass such as fields, forests and crops are needed to meet other more basic human needs. Ethically, allocating resources is non-negotiable when planning biofuel supply chains and production. For these reasons, second and third generation biofuels show the most promise for marine propulsion.

Hydrotreated Vegetable Oil (HVO), a promising candidate as a “drop-in fuel” in most cases can be distributed using the existing Marine Gas Oil (MGO) and HFO distribution systems, although some modifications may be required. Using existing distribution systems for the type of biofuel classed as Fatty Acid Methyl Ester (FAME) is more challenging.

Second generation biofuels such as HVO do not compete with food crops and are produced from lignocellulosic biomass such as corn stalks or from food residues. A large variety of processes exist for the production of conventional (first-generation) and advanced (second and third generation) biofuels involving a variety of feedstocks and conversions.

³ 4th IMO GHG Study, page 224, doc. MEPC 75/7/15.



Another 2nd generation biofuel-used cooking oil (UCOME oil) produced from waste sources is being used in pilot projects for shipping⁴.

Biofuels can be mixed with fossil fuels (the “drop-in” fuel option), enabling ships to start limiting their emissions. Biofuels are compatible with modern ship engines (all vessel types – large or small, deep-sea or short-sea trading vessels – can burn biofuels without requiring technical or design adjustments) provided these mixes – blends are safe and fit for purpose.

There is presently a clear gap between the cost of biofuels and fossil fuels for both aviation and marine applications. In the first instance, technology evolution will be needed to bring costs down and to derisk investments. It will also be important to evolve towards bio refinery approaches which can deliver a range of outputs. For instance, marine biofuels and bio jet fuels could be complementary as they are at different ends of the fuel spectrum (high vis-à-vis low specifications). Marine fuels are generally of low quality and marine engines can accept different fuel grades, while aviation fuels need to fulfil high quality standards. There will be competition for biofuel feedstock from all transport and other sectors. Currently, bio jet fuels are made from HVOs leading to direct competition for oleo chemical feedstocks. The ongoing electrification of road transport, however, should at some point beyond the year 2025 reduce the demand for oleo chemical biofuels for the road transport sector and more biofuels will be available for the marine and aviation sectors.

Biofuels having been tested on-board seagoing vessels show good fuel quality characteristics so far, few technical challenges and a reduced but not zero carbon content compared to traditional fossil fuels. The biofuel blends (mixtures of VLSFO with biodiesel/FAME and HSFO with biodiesel / FAME for scrubber-fitted vessels) for marine applications are immediately suitable for use, requiring no retrofit investments. Thus they are considered to be a part of the fuel mix solution towards meeting the 2030 carbon intensity targets for shipping (Bureau Veritas, Verifuel, September 2021).

Currently, however, there are no marine biofuel production pathways approved for blending with fossil fuels nor GHG factor default values established by the ISO or other certifying bodies for biofuels destined for marine applications.

For calculating the well-to-tank emissions for biofuels, the GHG factor default values related to cultivation, processing, transport and distribution will need to be taken into consideration.

Several studies predict that at most biofuels could supply fuel for 30% of the global fleet. Biofuels as “drop-in” fuels can be used primarily for containerships and for ships operating near densely populated areas, e.g., cruise ships and ferries.

Depending on their price and provided it is the responsibility of fuel suppliers to make sure that when mixed with fossil fuels the blends are safe and fit for purpose they can provide a partial solution for meeting sustainable decarbonisation targets for bulk/tramp shipping.

4 EU Stakeholder initiative, MAERSK, DSGC, Lloyd's Register: MAERSK/DSGC pilot. Second-generation biofuel deployment in large container ship, European Maritime Safety Agency (EMSA) and European Environment Agency (EEA), European Maritime Transport Report 2021, page 204.



Synthetic fuels (ammonia, methanol and hydrogen)

Ammonia

Availability in adequate quantities and at viable cost, development of suitable marine engines and of new bunkering infrastructure worldwide lack of predictability of the regulatory framework and safety issues related to the exposure of crew to toxic ammonia vapours during storage and handling are important challenges that need to be addressed.

“Green” ammonia is zero-carbon ammonia produced using renewable electricity, water and air. The potential high cost of the production of green ammonia is a major consideration. The method for producing ammonia with no carbon footprint has not yet been developed for industrial use nor for shipborne application.

Ammonia Internal Combustion Engines (ICE) are still at the development stage with MAN Energy Solutions leading the way to developing a commercial, ammonia-fuelled, two-stroke engine. The first engine tests are underway for delivering a complete engine shipboard installation by 2024.

Due to low energy density, storage tank requirements will be almost three times larger than traditional conventional fuels. However, ammonia has higher energy density compared with liquified hydrogen (LH) (see relevant section below).

Creation of Nitrous Oxide⁵ (N₂O) and ammonia emission (slip) are important issues associated with the safe storage, handling and on-board combustion of ammonia as an alternative marine fuel. The engine manufacturers (MAN ES, November 2021) are confident that the creation of Nitrous Oxide can be addressed through after treatment equipment with Selective Catalytic Combustion (SCR) technology, in the unlikely event that engine tuning is not sufficient to handle all N₂O emissions.

After treatment equipment will result in increased operating costs of ammonia-fuelled ships.

In addition, a minimum amount of pilot fuel will need to be injected to initiate full-load fuel combustion in ammonia-fuelled marine engines, thus ensuring safe and stable combustion. The need for a pilot fuel for ammonia-fuelled engines entails that ammonia may not be considered a zero carbon fuel on a Tank-to-Wake (TtW) basis.

Global safety regulations are needed to enable safe use of ammonia as marine fuel⁶.

⁵ Commonly known as “laughing gas”, which is a chemical compound with the chemical formula N₂O.

⁶ The IGF Code Working Group collects information on the safe use of ammonia as marine fuel, in the framework of the IMO Sub-Committee on Carriage of Cargoes and Containers (CCC).



Methanol

Notwithstanding the absence of bunkering infrastructure and the lack of information regarding the future cost of carbon-neutral methanol, dual-fuel methanol engine and fuel-supply systems (DF methanol ICE) are an option being examined primarily as a future marine fuel for a certain segment of short sea shipping with a very limited number of vessels (approximately 10) running on methanol globally (DNV GL, 2020). Methanol can be a stable and safe hydrogen carrier since it is the simplest alcohol with the lowest carbon content and highest hydrogen content of any other liquid fuel. It can be used to produce hydrogen for fuel cells and the methanol industry is working on technologies that would allow methanol to produce hydrogen for fuel cells.

Safety concerns, lower energy density and increased costs of the fuel storage system continue to make this fuel less suitable for the oceangoing bulk fleet.

Hydrogen

The low volumetric energy density of liquefied hydrogen (LH) and the high cost of the fuel storage system make the use of LH in deep-sea shipping very difficult. The situation is different for LH in short-sea shipping on fixed routes covering limited distances with frequent port calls, which due to their relatively low energy demand are more likely candidates. DNV is working with the Norwegian Government on putting a new hydrogen-powered ferry into service.

If a renewable source of electricity is used, electrolysis is an almost carbon-free process for hydrogen production. Potentially, using green hydrogen to make green ammonia, has the advantage of making another fuel which can be either combusted or used in fuel cells.

Due to safety considerations, ships burning synthetic fuels (ammonia, methanol and hydrogen) will require specially trained crews.

Fuel cells

In the future, a ship running on fuel cell technology will not necessarily require an internal combustion engine. Recognizing that fuel cell technology for ships is still in its infancy making predictions on the future development of fuel cells is challenging. The technology is not mature enough and it cannot provide a solution for large ocean-going ships in the foreseeable future. In addition, a significant cost reduction and size up-scaling is needed for fuel cells to become commercially viable. Specialised crew will also be required.

Electrofuels

Electrofuels based on “green” hydrogen – from water electrolysis using renewable electricity – can be synthesized with nitrogen or non-fossil carbon dioxide. No information on the cost of these electrofuels as “drop-in” fuels is readily available. Electrofuels are at a very early stage of development.



b) Propulsion Technologies

All available alternative propulsion technologies other than the conventional ones using shaft and/or propeller for the main and auxiliary engines being developed at the moment can offer improvements in fuel consumption but cannot replace conventional internal combustion engines. Currently, the only available auxiliary propulsion method is wind-assisted propulsion (WASP) and its main forms are: Fixed Sails or Wings, Kites and Flettner rotors. Based on the findings of the IMO 4th GHG study⁷, the immaturity of these technologies is confirmed by the negligible penetration rate they have in shipping.

c) Emerging Technologies

R&D for developing propulsion system(s) using onboard pre-combustion or post-combustion Carbon Capture and Storage (CCS) technologies is an ongoing process.

A proposed method being tested is reforming methanol to hydrogen which is then burned in a reciprocating engine that has been upgraded to burn multiple fuel types and is specifically optimised for hydrogen use. The concept allows for a closed CO₂ loop ship propulsion system while maintaining the reliability of well-established marine engine technology. Another proposed method being tested by Mitsubishi Heavy Industries (MHI) is using amine solvent to absorb CO₂ from flue gases which is a proven technology for use onshore.

The CAPEX (capital expenses) and OPEX (operational expenses) of the commercial application of these projects, including the HyMethShip project 2020⁸, are so far unknown.

Table 1 summarizes the main limitations of onboard CCS considering the main features of ships.

7 Figure: Extract of table from the IMO 4th GHG Study with penetration rates of propulsion technologies in ships

Group		Penetration rates (% of ships applying a technology)				
		2018	Scenario 1		Scenario 2	
			2030	2050	2030	2050
Group 12	Reduced auxiliary power demand (low energy lighting etc.)	50.0%	100%	100%	55.0%	80%
Group 13	Towing kite	(0.0%)	(100%)	(100%)	(5.0%)	(30%)
	Wind power (fixed sails or wings)					
	Wind engine (Flettner rotor)					
Group 14	Solar panels	(0.0%)	(100%)	(100%)	(5.0%)	(30%)

8 HyMethShip: Horizon 2020 project. Hydrogen-methanol ship propulsion system using on board pre-combustion carbon capture; European Maritime Safety Agency (EMSA) and European Environment Agency (EEA), European Maritime Transport Environmental Report 2021, page 203



Table 1: Limitations of on board CCS in a typical marine vessel

Features of marine vessel	Limitations of onboard CCS
Offshore	Tank storage of solvent and captured CO ₂
Limited space	Sizes of equipment
Limited utilities	Supply of heat, electric powers and cooling utilities
Constant movement	Construction limitation (such as heights of the columns)

Source: Applied Energy, June 2017

For onboard application, captured CO₂ stored in tanks as a cryogenic liquid will occupy considerable space and will have to be unloaded when ships reach a port. Another considerable limitation is that the equipment size of CCS systems should be minimized covering less space and less weight. Special consideration should be given to the height of the absorber and the stripper, which are the two main components for the carbon capture process. Studies showed that the total height of the columns for CCS onshore applications could be around 50 meters, which makes such a packing height unrealistic even for larger vessels.

Technologies such as CCS onshore could allow bridging the current technological gap between fossil fuels and the zero-emission fuels needed to decarbonise shipping. However, this technology (CCS) has yet not been fully developed, for industrial use, or for shipborne application.

3. The Journey of shipping towards decarbonisation is an uncertain and a complex one

Main considerations

- a. The maritime transport sector involves several stakeholders who are not all affected to the same extent (or at all) by the policies proposed by the EU “Fit for 55” package and the overall ambition to decarbonise the sector in the longer term as per the IMO “roadmap”. Different decisions are required in accordance with different priorities which may not be mutually compatible.

In particular, shipowners take the decision to purchase vessels charterers hire the vessels and determine the transportation of the cargoes and its parameters. Yet, shipowners alone are being made responsible for compliance with most regulations or proposals such as the FuelEU Maritime, the EU ETS proposals, the LCFS proposal and the 2050 decarbonisation targets at the IMO. In addition, shipyards and marine equipment manufacturers build vessels which can incorporate different levels of technological progress resulting in different energy efficiency possibilities for the vessels. Thus, shipbuilders play an important role in delivering technological options to the market which can comply with the increasing requirements to decarbonise the maritime transport sector. Similarly, energy producers and fuel suppliers should provide the necessary fuel options to the maritime sector.

Indicatively, the FuelEU maritime initiative does not apply to the fuel suppliers, whereas the Renewable Energy Directive appropriately sets overall transport (including maritime) GHG



intensity reduction targets on fuel suppliers. The above considerations indicate the complexity of the effort to decarbonise the maritime transport sector and raise a market coordination problem which requires careful actions from policy makers and market stakeholders and proper apportionment of responsibilities.

- b. Newbuilding vessels require capital-intensive long-term investments for a lifespan of 25-30 years and regulatory certainty in terms of applicable global regulations in order to remain sustainable internationally. Changes in the regulatory framework in view of the remaining lifespan of the vessel will most likely affect decisions for vessel retrofits. Retrofitting vessels will probably have an important role to play in transitioning the shipping industry towards decarbonisation. However, a cost-benefit analysis will be required on a case by case basis and financial incentives provided.
- c. As the shipping industry embarks on a long and uncertain period of transition into a multi-fuel low and zero carbon future, shipowners already face the difficult task of deciding which fuel and marine propulsion technology to opt for or how to “future-proof” their fleets and assets and avoid “stranded investments” or tonnage shortages leading to restrictions of trade and/or very high freight rates.

Nowhere is the uncertainty greater than in the bulk/tramp shipping segment. Bulk/tramp shipping due to the service it provides and the cargoes it carries is itinerant by nature and does not operate on the basis of a schedule or published ports of call. Thus its *modus operandi* is inextricably linked to and heavily relies on a universal fuel being available globally allowing ships to call at any port. A proliferation of new zero carbon fuels bodes ill for their global availability which in turn casts doubts over the viability of the bulk/tramp shipping *modus operandi* and its ability to continue to operate as it has been operating for a century or so serving seaborne trade and supporting world economic growth in an incomparably cost-effective manner.

- d. Decarbonisation requires a new generation of zero-carbon fuels and propulsion technologies that do not yet exist. The investments in fuel production and in supply infrastructure represent by far the major share of the total cost of decarbonisation for the shipping sector. Consequently, the greening of fuels and ships is the responsibility and area of expertise of out of sector stakeholders who must provide the international shipping industry with safe and fit for purpose propulsion technologies and maritime fuels available worldwide.

In general, the alternative energy source to be selected and carried on board must have a sufficiently high energy density compared to the energy density of VLSFO⁹ and MDO/MGO¹⁰ to maximize the available cargo space but crucially without compromising safety. As stated these efforts require the active contribution of all actors in the maritime value chain, the fuel producers and suppliers especially but also the shipyards, engine manufacturers, classification societies, ports and charterers.

⁹ Very Low Sulphur Fuel Oil

¹⁰ Marine Diesel Oil /Marine Gas Oil



- e. The first priority must be a massive effort in R&D and a shift of technological paradigm towards safe and truly zero carbon alternative fuels. Once new and economically viable fuels are developed fuel and energy suppliers will have to start producing them and ports will need to have the right infrastructure in place.
- f. In the coming decades, fossil fuels will likely remain much cheaper than zero-carbon alternatives unless the former are heavily taxed or the latter heavily subsidised (or both). In general the question of the macroeconomic implications of fuels for ships becoming more and more expensive is a major one. The disruption and economic implications of the departure from fossil fuels, the universal fuel for shipping and the global economy over the last 80-90 years and the introduction of a number of new carbon neutral fuels and technologies creates a totally new situation. It seems *prima facie* that technologies that capture most or all of the CO₂ from fossil fuels will cause less disruption and should be investigated further.

Concluding remarks

The present Report offers a regulatory and technical perspective on the prospects for decarbonising the maritime transport sector. It briefly presents, the challenges and complexities of the task from a technological point of view and the various stakeholders who need to cooperate to accomplish the task.

There can be no doubt that significantly more research is required to develop cost-effective low carbon and zero-carbon fuel options which can be produced to scale. At the same time, investments in infrastructure will also be required already in the coming years.

Alternative fuels such as ammonia, methanol or hydrogen need a new generation of internal combustion engine and advancements in technology not yet developed for ocean-going ships which will need to be developed by other stakeholders-energy providers, engine-builders and shipyards. This also requires the development of regulations and technical rules for the safe design and use of the new fuels onboard ships in parallel with the technological progress needed for their uptake.

Depending on the fragmentation of the future fuel landscape and the length of the transitional period towards a new era the shift to a multi-fuel future may in fact herald the end of low-cost seaborne trade and its mainstay, the international bulk/tramp shipping model which is responsible for over 84% of global seaborne tonne-miles.

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