【欧州】【海事】

Maritime Issues - Introduction of alternative fuel vessels such as hydrogen and ammonia: FuelEU Maritime Initiative and the EU's effort to decarbonise maritime transport

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【概要：Summary】

The IMO's Marine Environment Protection Committee (MEPC) 's 76th meeting in June 2021 produced some results regarding the reduction of GHG emissions from maritime transport. The IMO 's three-phased work plan starting with initial consideration of proposals for measures from spring 2021 to spring 2022 with an open-end decision making is a signal that the IMO and its member states are ready to further discuss future proposals for mid-term measures. However, this translates into at least three more years without concrete and tangible measures to set a cap on GHG emissions from maritime transport or to reduce them. The delay in decision making at the IMO can be expected to lead to the introduction of some unilateral GHG emission reduction measures for maritime transport in the EU.

Considering alternative fuels with less GHG emissions for maritime transport, ammonia has the potential to serve as a viable solution, covering also demanding ship types and operational routes, such as deep-sea shipping. Ammonia could also be generated from renewable resources, making it one of the promising fuels that could meet part of shipping's future energy demand, while at the same time, it could deliver on achieving the CO_2 emission reduction targets. However, considering the long lifetime of vessels of about 25 to 30 years or longer, ship owners need to consider the risks of stranded assets, which makes them reluctant to invest into large vessels using alternative fuels. The EU-funded ShipFC project has been awarded $10 million from the EU to install the world's first ammonia-powered fuel cell on an offshore vessel. The fuel cell will be tested on land in a parallel project and the shipside ammonia system.

To achieve the reduction of GHG emissions and of local air pollution, especially in SOx, NOx and particulate matter in maritime transport, the transition to alternative fuels will also require adjusting the EU policy on alternative fuels in maritime transport.

The European Commission has presented the first-ever legislative initiative, FuelEU Maritime, requiring ships to progressively switch to sustainable marine fuels. The FuelEU Maritime proposal on the use of renewable and low-carbon fuels in maritime transport (COM (2021) 562 final 2021) was presented by the Commission on 14 July 2021, aa part of the European Commission's "Fit for 55" package of proposals. The FuelEU Maritime initiative could stimulate demand for low and zero-carbon marine fuels.

【記事：Article】

1. The EU's and the IMO's targets to decarbonise maritime transport

1.1. The EU's measures to addresses the GHG emissions from shipping in the European Economic Area (EEA)

Almost 90% of the global freight trade is seaborne and the intra-EU maritime transport and short sea shipping represents 40% of freight transport in terms of ton-kilometres. However, considering the share of shipping in the global anthropogenic GHG emissions, its share increased from 2.76% in 2012 to 2.89% in 2018, according to the IMO's "Fourth Greenhouse gas Study" of 2020 (IMO 2020). These GHG emissions are projected to further increase significantly if no ambitious mitigation measures are introduced.

Due to the exclusion of maritime transport from the UNFCCC's COP21 Paris Agreement, the International Maritime Organisation (IMO) is responsible for introducing meaningful, global measures to mitigate the CO_2 emissions from international maritime transport. However, since the IMO initially delayed its decisions on addressing the GHG emission problem, the EU acted unilaterally by introducing a Monitoring, reporting and verification (MRV) system for GHG emissions of maritime transport within the European Economic Area (EEA) in 2018, based on Regulation 2015/757.

Based on the EU's net-zero carbon emission target of 2050 in its European Green Deal, more efforts are required to reach additional GHG emission reduction. Therefore, the European Commission presented its "Fit for 55" package on 14 July 2021, containing measures to achieve a 55% reduction of GHG emissions by 2030, based on 1990 figures and the net-zero emission target in 2050. The proposed legislation will also include measures for the maritime transport.

The Regulation 2015/757, as amended by Regulation 2016/2071, addresses the GHG emissions from shipping within the EEA by introducing a MRV system. The EU's MRV only applies to large emitters, including vessels of 5,000 gross tonnage (GT) and above. The monitoring rules focus on CO_2 emissions, fuel consumption, distance travelled, time at sea and cargo carried on a per voyage basis and other parameters and started on 1 January 2018. Every year, the Commission publishes a report on the CO_2 emissions and energy efficiency information of the monitored fleet. On 19 May 2020, the European Commission published its first report SWD(2020) 82 final, "Report from the Commission. 2019 Annual Report on CO_2 Emissions from Maritime Transport". The system involved around 11,600 ships, and these ships emitted >138 million tonnes of CO_2 in 2018, which is about 3% of the EU's total CO_2 emissions. Out of the more than 44 million tonnes of fuels consumed, 70% was heavy fuel oils, 20% was marine gas oil and diesel. 3% was Liquefied Natural Gas (LNG).

1.2. The IMO's Initial Strategy 2018 and the MEPC 76 results on GHG emission reduction

Following the EU 's adoption of the Regulation (EU) 2015/757 on the MRV system, in April 2018, the IMO's Marine Environment Protection Committee (MEPC) 72nd session adopted the initial IMO strategy on reduction of GHG emissions from ships, on GHG emission reduction for international shipping and related guiding principles (RESOLUTION MEPC.304(72)).

The IMO's initial goals to reducing GHG emissions from ships are set in the Initial Strategy 2018 in Paragraph 3, "levels of ambition". The IMO strategy includes a reduction of CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, and towards 70% by 2050, compared to 2008. The GHG emissions from international shipping should peak a.s.a.p. and the total annual GHG emissions should be reduced by at least 50% by 2050 compared to 2008.

In a first step, in a three-step approach towards achieving a reduction of GHG emissions in maritime transport, the IMO introduced a new mandatory fuel consumption data collection system (IMO DCS). However, the IMO's initial strategy does not give a schedule for the set-up of legal restrictions on CO_2 output. It is rather a framework for IMO member states to set levels of ambition to reduce GHG emissions.

Meanwhile, the IMO's MEPC 76 meeting in a remote session from 10 to 17 June 2021, adopted amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI, which combine technical and operational approaches to improve the energy efficiency of ships and to reduce their GHG emissions (IMO 2021). MARPOL Annex VI has 100 Contracting States, who between them represent 96.65% of world merchant shipping by tonnage. The new measures will require all ships to calculate their Energy Efficiency Existing Ship Index (EEXI) to improve their energy efficiency and 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 distance travelled. Ships will get a rating of their energy efficiency (A, B, C, D, E - where A is the best).

The requirements for EEXI and CII certification are expected to come into effect from 1 January 2023. This means that the first annual reporting will be completed in 2023, with the first rating given in 2024. A review clause requires the IMO to review the effectiveness of the implementation of the CII and EEXI requirements, by 1 January 2026 at the latest, and, if necessary, to develop and adopt further amendments.

The MEPC 76th remote session discussed submissions on how to progress the next stages, leading to the revision of the initial GHG strategy in 2023. The MEPC 76 adopted a work plan to make progress with candidate mid- and long-term measures. An initial proposal suggested a mandatory levy of $100 per tonne CO_2 equivalent on heavy fuel oil, but no decision was taken. This proposal will be further considered at the intersessional working group meeting.

The MEPC 76 also adopted a work plan to develop mid- and long-term measures to further cut shipping's GHG emissions. The three phased work plan starts with initial consideration of proposals for measures from spring 2021 to spring 2022, followed by the phase II assessment and selection of measures to further develop from spring 2022 to spring 2023. Finally, in phase III, the development of (a) measure(s) to be finalised in within (an) agreed target date(s).

The agreement on the work plan is considered being a signal that the IMO and its member states are ready to further discuss proposals for mid-term measures. However, this will translate into at least three more years without concrete and tangible measures or decisions on how to set a cap on GHG emissions from maritime transport or to reduce GHG emissions.

1.3. The EU's MRV system review

Considering the introduction of the IMO Data Collection System, based on the EU MRV Regulation's Article 22, the EU's MRV Regulation had to be reviewed and amendments need to be introduced to ensure alignment with that international agreement. Accordingly, on 4 February 2019, the European Commission adopted a proposal COM(2019) 38 final to revise the EU system for monitoring, reporting and verification of CO_2 emissions from maritime transport (Regulation (EU) 2015/757), taking appropriate account of the IMO's global data collection system for fuel oil consumption of ships, and to facilitate the harmonious implementation of the EU and IMO systems. However, the Commission considered this IMO effort in three phases not efficient enough to reduce GHG emissions from international shipping.

Therefore, the proposed revision of Regulation (EU) 2015/757 not only aims at facilitating the simultaneous utilisation of the two systems, but it also intends to preserve the objectives of the current EU legislation, to stimulate the uptake of energy efficiency solutions and inform future policymaking.

On 16 September 2020, the European Parliament adopted amendments requiring shipping companies to reduce, on a linear basis, their annual average CO_2 emissions, relative to transport work, for all their ships, by at least 40% by 2030, with penalties for non-compliance. In order to obtain data on transport work, the reporting of "cargo carried" per voyage would remain mandatory, which is one of the main differences to the IMO's DCS. In addition, the amendments introduce environmental performance labelling of ships, and calls for inclusion of methane and other greenhouse gases besides CO_2, and better supply of shore-side electricity in ports. The Commission would have to review the regulation in light of future IMO measures and would assess any new global market-based emission reduction measures adopted by the IMO with respect to their ambition and environmental integrity. The file was referred back to the ENVI Committee with a mandate to start trilogue negotiations. The decision and final agreement are still pending, but meanwhile a new amendment of the Regulation (EU) 2015/757 will become necessary, as on 14 July 2021, the European Commission has presented a proposal to include maritime transport into the EU-ETS (COM(2021) 551 final).

2. Alternative fuels and propulsion systems to decarbonise maritime transport

Although shipping is one of the more climate friendly transport modes, in particular in comparison to freight transport on roads, the maritime transport's GHG emissions need to be reduced. Therefore, measures like the replacement of fossil fuels with other low or zero carbon emitting energy sources and also the introduction of new propulsion systems in maritime transport need to be considered, as well as the development of low- and zero- emission vessels. Given the long lifetime of ships of typically 25 to 30 years, meeting the IMO's ambitions and the EU's GHG emission reduction targets for 2030 along with the net-zero carbon emission target for 2050, ultra-low and zero-emission solutions for shipping are required.

The new generation of vessels that utilises hydrogen or other CO_2 emission neutral fuels need to be developed in the next decade in order to be available for deployment by 2030. Zero-emission vessels (ZEV) need to enter service by 2030 in order to achieve the 2050 targets in emission reduction. Accordingly, the planning, designing and building of ships will already have to include considerations how to switch to non-fossil, zero emission technologies such as wind, hydrogen fuel cells and batteries in the 2020s. Accordingly, the shipping industry is seeking commercially viable zero emission fuels and propulsion systems for general utilisation by 2030.

The Lloyd's Register (LR) and the University Maritime Advisory Services (UMAS) study entitled "Zero-Emission Vessels 2030. How do we get there?" aims to demonstrate the viability of zero-emission vessels (ZEVs) elaborated pathways towards the introduction of zero emission ships. The study concluded that ZEVs would need to enter the fleet in 2030 and they would have to form a significant proportion of new built ships from that time onward. A more recent LR and UMAS study entitled "Zero-Emission Vessels Transition Pathways" examined three key energy types for the shipping industry in the transition to a zero-carbon future by 2050 (LR-UMAS 2019). The study confirms that zero carbon is possible but early action, particularly between 2020 and 2030, is needed. From a practical perspective, if zero-emission vessels (ZEV) need to enter service by 2030, anyone planning to finance, design or build

a ship in the 2020s would need to consider how to switch to non-fossil, zero emission technologies such as wind, hydrogen fuel cells and batteries later in the vessel's operational life (LR-UMAS 2019). Therefore, the decade 2020 - 2030 will be the most significant to see full-scale pilots and prototypes, batteries in short-sea markets, or hybrid solutions as well as on-shore power supply to reducing the dependency on fossil fuels.

The study also points out that long distance ocean transport would need carbon neutral biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia as alternative low to zero carbon emission fuels and propulsion systems (LR-UMAS 2019). There exist a number of different hydrogen fuel cell propulsion systems in development or trial stage and trials with alternative fuel options such as LNG, methanol, biofuels (including bio-methanol), LPG (Liquid Propane Gas), DME (Dimethyl Ether) ammonia, nuclear and hydrogen (including bio-hydrogen) are taking place. The simplest solution identified so far for deep-sea vessels would be a form of liquid fuel to replace heavy fuel oil (LR-UMAS 2019).

Currently, there are three options in consideration, including biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia. Each of these three solutions has its challenges, but hydrogen and other synthetic non-carbon fuels like ammonia seem to have the highest potential as a long-term solution (LR-UMAS 2019).

Ammonia and hydrogen are currently the most discussed potential alternative fuels that the shipping industry could switch to in medium and long-term. However, commercially viable vessel designs have yet to emerge and hydrogen-powered fuel cells for ship propulsion is still at an early design and trial phase, with applications in smaller passenger ships, ferries or recreational craft. The utilisation of hydrogen-powered fuel cells or ammonia will also require the amendment of the legislative framework, including the IMO's International Code of Safety for Ships using Gases or other Low-Flash-Point Fuels (IGF Code). Meanwhile, countries can test the technology in their territorial waters.

The shipping industry and trade groups are meanwhile urging the European Commission to advance the development of ammonia and hydrogen as the best marine fuel options for new ship orders to enable the shipping industry to accelerate decarbonisation. Therefore, the coalition of groups urged the European Union to prioritise the two fuels ammonia and hydrogen as part of its draft FuelEU Maritime initiative.

3. Ammonia as alternative fuel and the state of the ShipFC project

Fuel Cells are an alternative propulsion system for maritime transport, which utilises hydrogen or ammonia as energy source. Since fuel cells have been already used in auxiliary and low-power propulsion machinery, they could play a greater role as propulsion systems in the future, especially if the hydrogen is produced using renewable energy sources.

The potential of ammonia (NH3) as a fuel was demonstrated as early as 1822, when ammonia was used to fuel a gas locomotive. Ammonia could be utilised as a direct fuel for internal combustion engines but also in fuel cells. Ammonia is considered being an alternative fuel in maritime transport, as it gives a clean combustion without generating CO_2 or SO_x. It is easily liquefied by compression and is not highly flammable or explosive in contrast to hydrogen, although containers of ammonia may explode when exposed to high heat. According to the Research Associate at the University of Strathclyde, Michail Cheliotis (Cheliotis 2021), ammonia presents certain technical challenges, but the safety trade-off between ammonia and hydrogen favours ammonia. Cheliotis et. al. emphasises that "It is less explosive, requires less complex storage and transport solutions, and it is a well-known commodity from industry. Based on this experience,

the necessary safeguards can be built in." (Cheliotis et al. 2021). Another important aspect for the utilisation of ammonia in shipping could be that there already exists an established and reliable infrastructure for storage and distribution of ammonia. When generated by renewable energy sources, ammonia has no carbon footprint and emits almost no CO_2, SOx or particulate matter when burned in engines. Although ammonia is a GHG in the sense that it absorbs infrared radiation, ammonia is short-lived and broken down easily and is never a problem like CO_2 or methane. In fact, the large difference for CO_2 is the long time period is takes to remove CO_2 from the atmosphere, which is 20-200 years for 65% to 80% of CO_2. Instead, ammonia has a lifetime in the atmosphere of only one week. Since ammonia is so short lived in the atmosphere and reactive, it has an effective global warming potential of zero, despite absorbing the right frequencies of infrared radiation to otherwise be a GHG.

Therefore, ammonia is expected to find favour as a fuel in the maritime industry as it does not need cooling, unlike LNG or liquid hydrogen. It also has a higher energy density than liquid hydrogen, making it simpler to store in the quantities needed to deep-sea ships. However, the ammonia production depends on high energy supplies, predominantly natural gas, which makes it like hydrogen only climate friendly if produced from renewable energies.

According to Cheliotis et al. 2021, in summary, the main issues that should be considered when handling and transporting ammonia are its flammability and toxicity. Despite this, ammonia is much less flammable and explosive than either hydrogen or methane. However, an issue that arises with the use of ammonia in shipping is the need for large-scale production infrastructures for green or blue ammonia. The main challenges for ammonia as a marine fuel is the lack of a commercial technology and the need to develop large-scale production infrastructures for green or blue ammonia(Cheliotis et al. 2021).

Fuel cell research could involve also ammonia instead of hydrogen for fuel cells. In fact, one important project to show the utilisation of ammonia in a fuel cell onboard of a ship is the ShipFC project. The ShipFC project has received funding under the EU's Horizon 2020 programme from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No. 875156. The ShipFC project has been awarded $10 million from the EU to install the world's first ammonia-powered fuel cell on an offshore vessel for its ShipFC project. The project started on 1 January 2020 and will continue for 5 years to 31 December 2025. The key aim of the project ShipFC is to demonstrate the viability of high-power ammonia fuel cell onboard Eidesvik PSV "Viking Energy". In December 2023, the Solid Oxide Fuel Cell (SOFC) Energy System should be installed and tested onboard. The ShipFC project is expected to demonstrate that long-range zero-emission voyages with high power on larger ships is possible.

The ShipFC consortium of 14 European companies and institutions is co-ordinated by the Norwegian cluster organisation NCE Maritime CleanTech. The University of Strathclyde (UK) and National Centre for Scientific Research Demokritis (GR) will assess safety criteria. Norwegian members of the European consortium include NCE Maritime CleanTech, Eidesvik Shipping, Equinor, Prototech, Yara, and Wärtsilä Norway, responsible for fuel systems, ship's design and stability, and vessel energy management. Fraunhofer IMM (GE) will assist in the development and construction of the ammonia fuel cell system. Persee (FR) will provide expertise on energy management controls and data. Replicator vessel owners are StarBulk Management (bulk vessel), North Sea Shipping (offshore construction vessel) and Capital Ship Management Corp (container vessel).

The fuel cell will be tested on land in a parallel project and the shipside ammonia system will be

supplied by Wärtsilä. Norwegian crop nutrition company Yara has been contracted to supply the green ammonia, which will be produced by electrolysis by using hydrogen from water electrolysis and nitrogen separated from the air. The green ammonia will be delivered to Viking Energy in containerised form to enable easy and safe refuelling.

According to the Fraunhofer Institute for Microengineering and Microsystems IMM (2021), a small fuel cell prototype should be ready by the end of 2021, to be followed by an actual-size prototype by the end of 2022. In the second half of 2023, the first ammonia-powered fuel cell ship Viking Energy will put out to sea. After that, other types of vessels, such as cargo ships, are planned to be equipped with ammonia-powered fuel cells. The demonstrator is expected to prove that the ammonia fuel cell technology works at scale and suggest how surrounding innovation barriers such as missing fuelling infrastructure can be solved (ShipFC 2021).

4. FuelEU Maritime initiative to drive shipping's decarbonization

The increase of the net GHG emission reduction to a 55% reduction by 2030 requires an adjustment of several pieces of legislation within the "Fit for 55" legislative package. The European Commission has announced to revise the EU Emissions Trading System (EU-ETS), including maritime, a revision of the Energy Tax Directive, the amendment to the Renewable Energy Directive (RED) to implement the ambition of the new 2030 climate target and the amendment of the Energy Efficiency Directive to implement the ambition of the new 2030 climate target (EED), as well as the Revision of the Directive on deployment of alternative fuels infrastructure, which also could affect maritime transport. A shift to sustainable alternative fuels in maritime transport is critical to achieve the reduction of GHG emissions. The transition to alternative fuels will also require to adjusting the EU policy regarding the alternative fuels for maritime transport. The Commission plans to introduce a goal-based approach, which would set increasingly strict GHG intensity targets to be met for the energy used on board of ships.

The FuelEU Maritime initiative aims to increase the use of sustainable alternative fuels in European shipping and ports, in an effort to drive decarbonization and sustainability within the industry. The FuelEU Maritime proposal on the use of renewable and low-carbon fuels in maritime transport (COM (2021) 562 final 2021) was presented on 14 July 2021, aa part of the European Commission's "Fit for 55" package of proposals. he FuelEU Maritime initiative aims to increase the use of sustainable alternative fuels in European shipping and ports.

The draft FuelEU Maritime initiative envisages the introduction of a goal-based fuel GHG intensity target (a.k.a. thresholds) which will be expressed in Well-to-Wake (WTW) CO_2-equivalent emissions to account for all the life cycle GHG emissions (CO_2, CH_4, N_2O) of the different fuels and relevant engine technologies. From the environmental perspective not all alternative fuels can promise a (net-)zero carbon future to shipping, because very few are both sustainable and available at scale to meet the sector's growing energy demand.

Ahead of the adoption of the EU's FuelEU Maritime initiative a new study entitled "FuelEU Maritime - Avoiding Unintended Consequences. Efficacy and implications of potential measures, including new EU fuel standards, to help decarbonise international shipping", commissioned by the European Community Shipowners' Associations (ECSA) and the International Chamber of Shipping (ICS), explores the implications of potential measures under the FuelEU Maritime initiative. It concludes that if the proposal is properly designed, it could contribute to addressing the barriers identified in the IMO GHG Strategy.

The FuelEU Maritime initiative could stimulate demand for low and zero-carbon marine fuels, which is currently negligible, but it must also address how to handle the requirements globally and the fuel quality responsibilities.

The additional analysis in this new study explores the key policy drivers for the FuelEU Maritime initiative and the policy options being considered by the EU institutions.

The potential advantages of the FuelEU Maritime initiative include the initiative's contribution to addressing the barriers identified in the IMO GHG Strategy, stimulation of demand for of low and zero-carbon marine fuels which is currently negligible, building economies of scale in the supply of low and zero-carbon marine fuels, potentially bringing down their cost and to provide the shipowners and operators with encouragement to use low and zero-carbon marine fuels.

Potential disadvantages of the FuelEU Maritime initiative include the risk of being in conflict with the goal-based approach to reducing the carbon intensity of shipping, reflected in the amendments to MARPOL Annex VI approved by IMO in November 2020. It could also risk the adoption of fuel standards at others but those agreed globally by IMO and ISO. There could arise also significant challenges of enforcing EU maritime standards among fuel suppliers outside EU jurisdiction among others. It would also include the risk of undermining IMO negotiations to implement the Initial Strategy on Reduction of GHG Emissions from Ships, and thereby set back global efforts to adopt measures for absolute emissions reduction, among others.

Regardless of the European Commission's good intentions with respect to FuelEU Maritime initiative, there is a risk that non-EU States may object to this unilateral introduction of EU standards outside of the global framework provided by IMO.

5. Conclusion

The IMO's three-phased work plan starting with initial considerations of proposals for measures from spring 2021 to spring 2022 is a positive signal, confirming the IMO and its member states are willing to further consider current and future proposals for mid-term measures. However, it also could lead to a delay of at least three more years without concrete and tangible decisions on setting a cap on GHG emissions or introducing measures to reduce GHG emissions.

This delay can be expected to trigger further measures at EU level. The EU could introduce unilateral measures on reducing GHG emissions from maritime transport within the EEA. In this context, the first step will be the inclusion of the maritime transport into the EU-ETS to achieve an earlier start of CO_2 emission reduction in maritime transport.

Furthermore, the introduction of low to zero emission vessels in the next decades needs preparation work like the testing and introduction of alternative fuels and new propulsion systems. The lifetime of ships of 25 to 30 years on average highlights the urgency of enrolling alternative fuels as soon as possible. The transition to alternative fuels needs to start now in order to avoid that fossil fuelled ships will still service global trade and EU-trade for decades to come. Vessels that use new low to zero carbon emission fuels like biofuels, hydrogen, ammonia or other potentially CO_2 emission-neutral fuels would have to be already available by 2030 in order to achieve the IMO's 2050 target.

The type of propulsion and alternative fuel selected will have a direct impact on the vessel's emissions, including GHG, NOx, and SOx. However, from the environmental perspective, not all alternative fuels can promise a (net-)zero carbon future to shipping, because very few are both sustainable and available at scale to meet the sector's growing energy demand. Currently,

in the deep-sea maritime transport, which accounts for 80% of the global CO_2 emissions from shipping, the majority of new vessels are still being planned and built to use fossil fuels. In future, the utilisation of the alternative fuel ammonia could be expected to be pushed forward. However, it must be considered that ammonia is only suitable as an eco-fuel if the nitrous oxide (dinitrogen monoxide) produced during production, transport and combustion is eliminated by special cleaning systems. Furthermore, ammonia is very toxic to aquatic life with long lasting effects and its utilisation will have to be carefully considered when using it as alternative fuel in maritime transport. Another main challenge for ammonia as a marine fuel will be the development of large-scale production infrastructures for green or blue ammonia, among others.

In any case, it can be expected that ammonia will play an important role in the hydrogen economy and also in the decarbonisation of other sectors.

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