INSIGHT BRIEFING SERIES

Ammonia as a shipping fuel

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The Getting to Zero Coalition is committed to accelerating shipping decarbonization by getting commercially viable deep sea zero emission vessels powered by zero emission fuels into operation by 2030 to put shipping on a path for full decarbonization by 2050. To unpack the different fuels and technologies options that could support the transition to zero emission fuels, the workstream on Fuels & Technologies has hosted a series of webinars, gathering perspectives from experts across the maritime value chain - shipowners, operators, charterers, financial institutions, classification societies, and NGOs. The insight briefing paper series aims to reach a broader audience and build a common understanding of the fuels, engines, and storage technologies that will enable the decarbonization transition.

The Insight Brief is based on analysis by Global Maritime Forum for the Getting to Zero Coalition, a partnership between the Global Maritime Forum and the World Economic Forum, made possible with funding from Mission Possible Partnership.

Date of the webinar: February 2021

Watch the webinar here.

Panelists:

- Yee Yang Chein, President and Group CEO, MISC
- Mark Darley, Marine and Offshore Director, Lloyd's Register
- Haeki Jang, Vice presidentHead of Ship Engineering Division, Samsung Heavy Industries
- Brian Østergaard Sørensen, Vice president MAN Energy Solutions

Moderator: Randall Krantz, Senior Project Advisor on Shipping Decarbonization, Global Maritime Forum/Getting to Zero Coalition

Executive Summary

Synopsis: There is no single fuel - no silver bullet - for future zero-carbon marine fuels, but there is increasing consensus that ammonia will have a key role to play. The mapping of Zero Emission Pilots and Demonstration Projects[1] provided learnings and set the stage for future deployment and scaling of ammonia fuels, infrastructure, and vessels. Ammonia bunkering, safety, and design, as well as the role of governments, will all play a critical role in the successful deployment of ammonia fuelled vessels.

Key takeaways:

> While main investments will be land based and market based measures such as a carbon price implemented, green ammonia has the potential to be scaled up from the production and end-user side.

> Green ammonia-powered vessels will benefit from a range of pilot and demonstration projects to be considered a significant candidate as a future fuel for the maritime sector.

> Safety and upstream considerations such as ship design and bunkering need to be at the top of the agenda.

Opportunities and challenges of ammonia being a zero emissions fuel candidate

Ammonia is a potential candidate as zero carbon fuel. The use for the shipping industry provides some opportunities and upside.

1 Mapping of Zero Emission Pilots and Demonstration Projects

Some challenges need to be overcome to scale it as a marine fuel:

Opportunities/upsides to ammonia:

- **Zero Carbon:** As there is no carbon atom in the ammonia molecule, it does not emit CO2 during combustion.

- **Energy density:** Ammonia has an energy density similar to methanol and more favorable than hydrogen. Additionally, it requires less cooling than cryogenic liquid hydrogen.

- **Low(er) cost:** Synthesis of Ammonia from zero carbon hydrogen using the Haber-Bosch process is efficient and fully scaled. The Haber-Bosch process requires less energy than the synthesis of methanol or e-methane, meaning that Ammonia will always be cheaper than either of these zero-emission fuel options.

- **Scalability:** Ammonia has a long-term potential. The decreasing cost of renewable energy will support the scalability of Ammonia as a marine fuel.

Challenges:

- **Overall cost:** Green ammonia remains more costly than incumbent fuels, with prices expected to drop with the scale-up of the production of green hydrogen.

- **Safety:** Ammonia is highly toxic, flammable and corrosive. It is a risk for humans and aquatic life in case of accident and leakage, requiring strict safety standards, measures, and training.

- **Regulatory collaboration:** A high level of alignment and harmonisation is needed between international standard setters and local regulators to scale the production, bunkering and use of ammonia as a shipping fuel.

- **Sustainability:** The production of ammonia requires a sustainability system consisting of a sustainability standard and a sustainability certification based on robust sustainability criteria in order to avoid negative impacts on environment, on society and on and socio-economic factors upstream in production processes.

Detailed Summary

About ammonia

Ammonia is a compound of nitrogen and hydrogen with the formula NH3. It has about half the energy density of bunker fuels and takes on a liquid form at -33C, so it does not have to be stored in high-pressure or cryogenic tanks. Ammonia is difficult to burn, so specialised internal combustion engines are currently being developed, which are expected to come to market in 2024. Green and blue hydrogen are potential feedstocks to produce zero carbon ammonia that can be bunkered both onshore and offshore before being combusted by onboard engines.

1. Pilot and demonstration projects

a. Pilot and demonstration projects are critical

According to Haeki Jang, Vice president Head of Ship Engineering Division, Samsung Heavy Industries, demonstration projects have the power to highlight technical challenges and maturity of technologies and support in the development of such new technologies. Such projects also shed light on the needs and gaps to be filled out by appropriate regulation. Pilot and demonstration projects cover the process from design to operation and make adoption easier to address risks. A pilot or demonstration presents an opportunity to assess fuel quality, types of engine combustion, bunkering options, safety, operations, and need for training based on knowledge sharing.

In this context, during the deployment of LNG engines, the design screening process has been the opportunity to identify issues and improvements from an early stage with the possibility to reduce significant costs. On the other hand, regulation, policy and financial rules can evolve based on stakeholder's experience. From those outcomes, practical and realistic alternatives can be drawn.

Yee Yang Chein, President and Group CEO of MISC, spoke about the need for training that must be taken into consideration before the demonstrations start. As Yee Yang Chein mentioned, offshore and onshore workers should benefit from education on a try and train methodology. This back and forth methodology is used to train newcomers by the Maritime Academy in Indonesia.

b. Learnings from demonstration projects

Shifting from words to action through pilot and demonstration projects is a lengthy process. Brian Østergaard Sørensen, the Vice president from MAN Energy Solutions, mentioned that the wide spectrum of participants on demonstration projects allows to cover the technical side and the regulatory framework with multiple parallel initiatives. From its perspective, this brings confidence to the market. Demonstration projects are opportunities to collect key learnings and point out the most valuable solutions by engaging the maritime value chain.

For example, MAN Energy Solutions has developed a timeline to deliver commercially viable ammonia-burning engines by 2024. During the screening phase of one of their pilot projects, MAN Energy Solution had the opportunity to learn that some materials are intolerant to ammonia. The same project provided information that ammonia does not have great combustion characteristics. Furthermore, emissions from the engines must be handled, both NOx, possible N2O and ammonia. N2O is a much more potent greenhouse gas than CO2.

In addition, Brian Østergaard Sørensen mentioned that while the scaling phase of ammonia has to be economically feasible for shipowners, rapid deployment can be envisioned by means of the ability to retrofit traditional engines to be able to use ammonia.

2. Ammonia bunkering, safety, and design

a. *Ammonia bunkering and supply*

Currently, the use of fuels is regulated by the International Maritime Organization (IMO) through the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL). From a technological and operational perspective, loading and unloading ammonia as a commodity at the terminal is similar to bunkering ammonia as a fuel. However, the option of bunkering ammonia from cargo terminals will not be a viable solution. In such a case, terminal accessibility for large cargo could be limited and will require a high amount of time.

For handling ammonia, there is a high need to encourage a concept of universal seafarers and onshore workers that are capable of handling all kinds of engines and bunkering. In the longer term, marine bunkering infrastructure should consist of bunkering from bunker ships and bunkering from onshore storage.

b. *The implications of ship design and layout for safety*

One of the primary drivers of vessel design is the need to figure out how to reduce the risk of exposure to crew in case of a leak. Mark Darley, Marine and Offshore Director, Lloyd's Register, explained that this is why design and layout must be treated with a high level of safety, from concept to material selection (protecting the structures from corrosive exposure of ammonia) and finally operational measures. Many relevant technologies and design concepts already exist in the market to handle ammonia.

At the top of the agenda, special considerations should be made to risk assessment to prevent accidents. This would take into consideration the probability of leakage, gas detection systems, and certification along the supply chain. Also, new regulations and rules development are needed and could be extended and fortified from existing rules.

Ammonia is highly toxic - more so than traditional fuels. At ambient temperature and pressure, it is a corrosive and flammable gas and there is a high risk for human exposure through inhalation and skin contact with long-lasting effects. It can have similar impacts on aquatic life. According to Sørensen of MAN, a general good practice would be that "onboard and onshore staff must have appropriate personal protection equipment. In addition, all the tanks must be in good condition, leaks prevented, and ensuring gas cannot be released to a confined place".

3. Government action and investments are needed to scale the use of ammonia

a. *The role of collaboration*

Governments have a role to play to overcome high costs and other stumbling blocks to take ammonia to a greater scale, and building trust within the industry necessitates public-private collaboration. Clear directions and guidelines are needed as a common framework for engine specifications, ship design, handling operations and infrastructure for bunkering, and sustainable production. This process could encourage realistic technical solutions as proof to convince others. The leadership of the IMO and collaboration among governments is needed to set global rules and standards.

There is a need to move from conventional ammonia - made from fossil fuels - to scalable green or blue ammonia, synthesised from renewable hydrogen or fossil fuels and CCS, respectively. Therefore, involving the private sector in designing regulations and procedures will enable deeper engagement of the maritime sector and allow for feedback from the field.

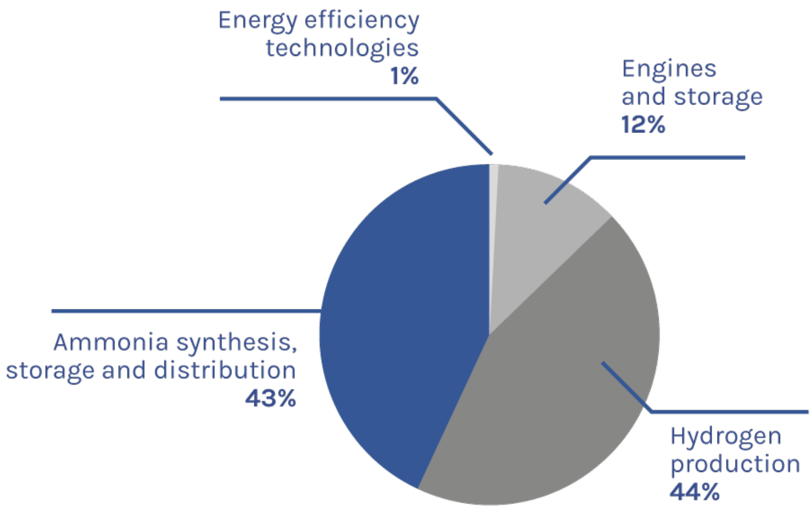
b. The need for investment

For shipping's decarbonisation to be in line with the Paris Agreement temperature goal, we must reach at least five percent zero-emission fuels in international shipping by 2030. A study[2] conducted by The University Maritime Advisory Services (UMAS) and the Energy Transitions Commission (ETC) showed that if shipping is to be fully decarbonized by 2050, the scale of cumulative investment needed between 2030 and 2050 to achieve the IMO target is approximately USD 1-1.4 trillion. This study considered ammonia as being the primary and least-cost zero carbon fuel choice adopted by the shipping industry, and feedstock will be green and blue hydrogen. In this case, the major need for investments is upstream and land-based. Indeed, production, storage and bunkering represent 87% of investment while only 13% of investments are related to vessels - including machineries and onboard storage for new and retrofitted vessels.

2 Krantz (RK). Søgaard (KS). Smith (TS). (2020). The scale of investment needed to decarbonize international shipping.

Exhibit 1: *Investment breakdown across vessels and land-based infrastructure*

Source: *The scale of investment needed to decarbonize international shipping. (2020)*



Rob Stevens, Vice President Ammonia Energy and Shipping Fuel at Yara, has highlighted the need for first movers to get assistance through a cost differentiation between conventional and green ammonia to close the competitiveness gap in order for ammonia to become cheaper in the near-term. In addition to policy measures, the Getting to Zero Coalition has recently highlighted,[3] market-based-measures (MBMs) to support the decarbonisation of shipping by closing the competitiveness gap between fossil fuels and zero-emission fuels. Those MBMs aim at increasing the costs of using fossil fuels through setting a price on carbon, and/or reducing the costs of zero-emission alternatives, through tax breaks, RD&D funds, subsidies, or a combination of these.

According to a recent Getting to Zero report, in order to achieve 50% GHG emissions reduction by 2050 compared to 2008 (-50% scenario), the carbon price level averages US$173/tonne CO2. For a 2050 target of full decarbonisation (-100% scenario), the average carbon price would only need to be slightly higher: around US$191/tonne CO2. In both scenarios, according to the model, the price level begins at US$11/tonne CO2 when introduced in 2025 and is ramped up to around US$100/tonne CO2 in the early 2030s at which point emissions start to decline. The carbon price then further increases to US$264 /tonne CO2 in the -50% scenario, and to US$360/tonne CO2 in the -100% scenario.

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3 Rojon. I, Shaw. A, Blaxekjær. L, Kulaksiz. A.(2021). Policy Options for Closing the Competitiveness Gap Between Fossil and Zero-Emission Fuels in Shipping

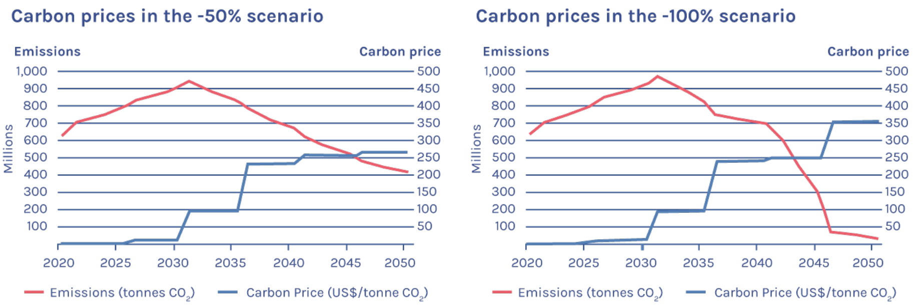

Exhibit 2: *Carbon prices in the -50% scenario VS in the -100% scenario*

Source: *Policy Options for Closing the Competitiveness Gap Between Fossil and Zero-Emission Fuels in Shipping (2021)*

Conclusion

Ammonia is one of the zero emission fuel candidates that will drive the transition for shipping decarbonization. Ammonia bunkering does not imply major changes, and supply is already available in some terminals. Demonstrations and pilot projects are critical, as the scalability will emerge from learning and lowering of costs. Addressing safety issues and technical challenges has implications on ship design and layout. In addition, government actions and regulations will provide additional direction and guidelines for technical deployment.

According to the Getting to Zero Coalition, policy instruments and market-based measures are required to close the competitiveness gap between conventional and zero emission fuels to encourage mass uptake. To achieve zero emission by 2050, today's carbon price level averages US$173/tonne CO2 should ramp up to US$100/tonne CO2 in the early 2030. To scale ammonia, investments are needed, the vast majority of which is necessary upstream in hydrogen generation, fuel synthesis and port infrastructure. For this to succeed, collaboration with relevant land-based industries and suppliers will be critical.