INSIGHT BRIEFING SERIES

Alternative fuels: Retrofitting ship engines

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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: September 2021

Watch the webinar here.

Panelists:

- Amar Parikh - Retrofit Development Manager, Man Energy Solutions
- Lampros Nikolopoulos - Projects & Dry Docking Engineer, Euronav
- Harry Robertsson – Technical Director, Stena
- Ulrik Frorup - Special Project & External Affairs Director, Bureau Veritas

Moderator: Emma Skov Christiansen, Lead, Shipping Emissions & Ocean Agenda, World Economic Forum/Getting to Zero Coalition

Executive Summary

Synopsis: The latest technology is not just available for newbuild ships. By some estimates, if shipping is to fully decarbonize by 2050, half of the vessels on the water by mid-century will have been retrofitted to run on scalable zero emission fuels. The webinar addressed the topic of retrofitting as an opportunity for existing vessels to meet the latest standards and regulations, improve GHG emission performance by burning the next generation of zero carbon fuels, and still remain attractive as a business asset.

This insight brief goes a bit beyond the scope of the webinar to encompass fuel optionality and will be followed by further insight briefs which will dive deeper into the different approaches and pathways available to ship owners in order to manage their transition risks.

Key takeaways:

> Retrofitting offers the possibility to remain flexible on the transition pathway. Indeed, it is an opportunity to tailor the vessels to meet global standards and adapt to fuels availability.

> The decision of retrofitting can emerge from identifying and analysing the cost benefit of retrofitting existing vessels or acquiring new fleet. Planning is the key to success for retrofitting as 12 to 14 months are needed upstream to prepare the vessel to be retrofitted.

> To accelerate the retrofitting process, panellists concluded

there is a need to develop a common view on what retrofitting is and engage stakeholders along the value chain.

The webinar was attended by participants from the maritime sector such as engine makers, shipowners, cargo owners, ports, classification societies, energy producers, financial institutions and government. A poll was conducted with the 100+ participants to understand their familiarity with retrofitting. Two thirds (68%) of participants acknowledged having no direct experience with retrofitting, far fewer had been involved directly (19%) or had organisational experience (13%) in retrofitting vessels. As retrofitting implies the involvement of the whole supply chain, the results from the poll demonstrate a significant opportunity for the industry to be more engaged and take more actions.

Detailed Summary

About retrofitting

The transition to zero-emission fuels will see key milestones reached within the next decade and, given that most deep-sea vessels are built for lifespans of 25 years plus, the shipping industry must prepare for this transition as soon as possible or otherwise risk being left with stranded assets. For example, as market-based measures to promote zero-emission shipping are introduced, the operating costs of fossil fuel powered vessels will increase significantly. This will leave fossil fuel ship owners with the choice of paying to offset their emissions, retrofitting their vessels, or retiring vessels potentially ahead of schedule.

As decarbonization technologies are being developed at a more rapid pace than ever before, retrofitting presents an opportunity for existing and future vessels to be equipped with the latest technologies as they evolve. Retrofitting and identifying retrofit-ready vessels for existing fleets can enable the shipping industry to prepare for the transition to shipping decarbonization. There is an opportunity in the not so far future for existing vessels to meet the latest International Maritime Organisation (IMO) and European Union Emissions Trading Scheme (EU-ETS) legislation demand, improve GHG emission performance and remain attractive as a business asset via retrofitting.

The Transport Research and Innovation Monitoring and Information System (TRIMIS) defines retrofitting as the installation on-board ships of state-of-the-art or innovative components or systems. This could, in principle, be driven by the need to meet new regulatory energy and emission or other environmental standards or by the ship owner's interest to upgrade to higher operational standards.

About fuel optionality

As ship owners attempt to navigate the transition from fossil fuels to zero-emission fuels, they are exposed to risks both in terms of the potential for stranded assets, but also the risk of investing in the wrong technology. Given the long lifespans of vessels, ship owners that do not prepare their fleets to be transitioned to zero-emission fuels will face the risk of being left with stranded assets that are

too expensive to operate. However, zero-emission fuels are not yet commercially viable and there is still uncertainty as to which fuels and technologies will achieve the required scale.

To solve this dilemma, ship owners can adopt a strategy of fuel optionality which would allow them to prepare for multiple future technology scenarios without having to pick winners or make significant investments in the immediate future. Within the broad strategy of fuel optionality several approaches exist, including building vessels with the prospect of either a shorter lifespan or a later retrofit consideration, building dual or (potentially) multi fuel vessels, using drop-in fuels, and finally preparing vessels at the building stage for future retrofits. Importantly, the strategy of fuel optionality focuses on preparing to switch from conventional fuels to scalable zero emission fuels, it does not mean ship owners will be able to easily switch between different zero emission fuels in the future.

1. Retrofitting: Design and fuel options

There is a growing wish from the shipping industry to meet sustainability goals and emission reduction targets, and there is growing demand to do so from customers as demonstrated by the First Mover Coalition (FMC) and the Cargo Owners for Zero Emission Vessels (CoZEV) initiatives. According to Amar Parikh, Retrofit Development Manager for Man Energy Solutions, currently available technologies can improve vessel efficiency and enable a reduction of the total cost of ownership. Adhering to new and adaptive regulations such as the International Maritime Organisation (IMO) Energy Efficiency Existing Ship Index (EEXI) not to mention impending future emission regulations can stimulate the deployment of current and future retrofitting options. A Transition Strategy study[1] conducted by the University of Maritime Advisory Services (UMAS) and the Getting to Zero Coalition indicates that by 2046 the number of retrofits will reach around 35,000 vessels [Figure 1].

1 UMAS & Getting to Zero Coalition (2020). A Strategy for the Transition to Zero-Emission Shipping.

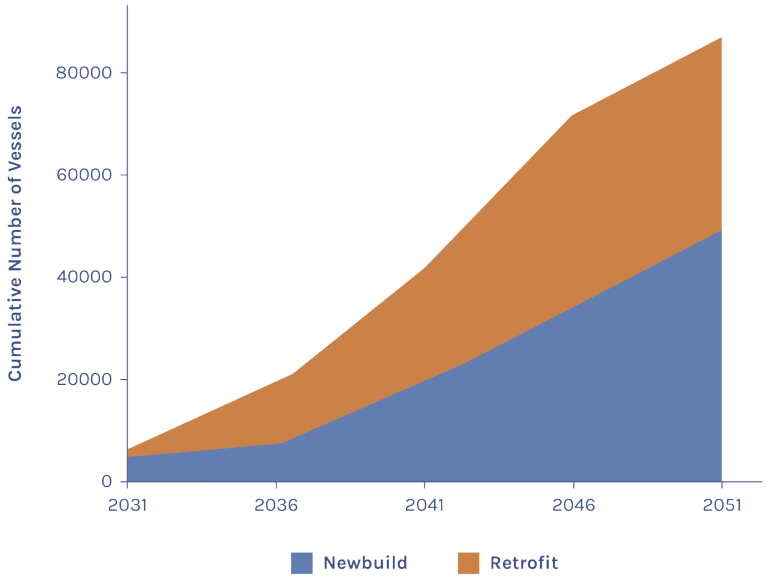


Exhibit 1: *Amount of newbuilding and retrofitting to zero-emission fuels*

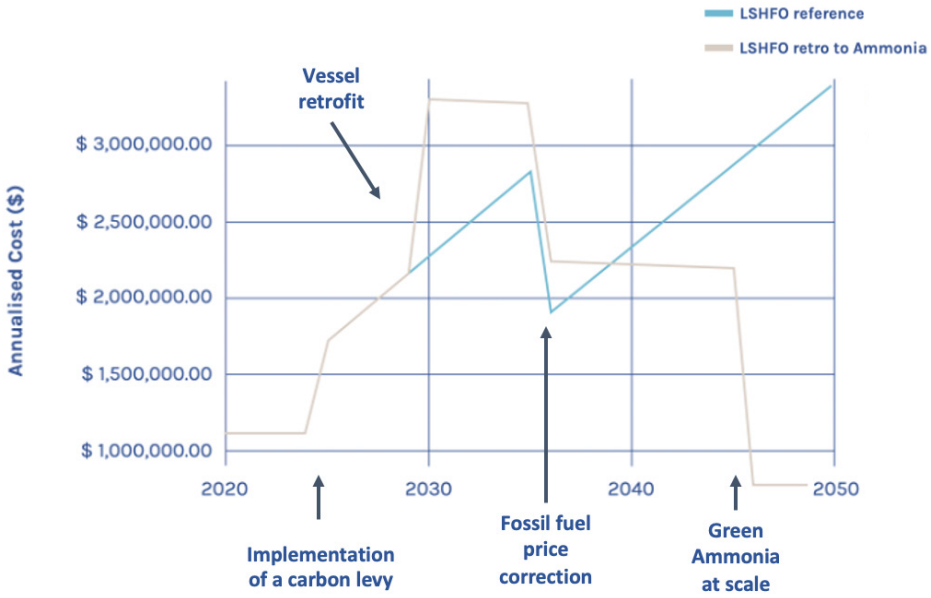
Source: *UMAS & Getting to Zero Coalition (2021)*

The Transition Strategy analysis found that vessels retrofitted to run on scalable zero emission fuels could comprise nearly half the global fleet by 2050. As pointed out by MAN Energy Solutions, Engines have different design specifications for each fuel, requiring different core technologies. For example, methanol and LPG engines can be retrofitted to run on a second fuel, or can be designed for exclusive methanol and LPG use.

2. The case for retrofitting

Under the assumption that carbon pricing will be introduced in the future, Figure 2 below demonstrates the likely evolution of annualised operating costs for a low-sulphur heavy fuel oil (LSHFO) vessel in comparison to an LSHFO vessel that has been retrofit to ammonia. The chart shows that the fossil fuel powered LSHFO vessel's operating costs will increase over the years to 2050. Conversely, the chart shows that the higher initial costs of the ammonia powered vessel drop significantly as green ammonia production is scaled up.

Exhibit 2: *Evolution of Annualised Costs (carbon price and low-cost fuel scenario)*



Accepting that fossil fuel powered vessels will increasingly become commercially unviable to operate, the question for ship owners becomes which zero-emission fuel should be used. Despite the consensus around the need to transition to zero-emission fuels, uncertainty remains around exactly which zero-emission fuels and technologies will become dominant. Given the long lifespans of vessels, the shift to zero-emission fuels will impact vessels that have already been built, those that are being built now, and those that will be built in the near future. This creates a dilemma for ship owners, given that they know they must factor-in a transition to zero-emission fuels now, but have incomplete information on exactly which zero-emission fuels and technologies will be used in the future. Embedding a degree optionality for the future retrofit at the ship's design stage is therefore a desire for many ship owners.

3. Retrofitting: Challenges

One challenge of retrofitting is that there is little experience across the value chain. This relatively low experience related to retrofit, as well as the limited physical capacity of yards will likely be barriers contributing to bottlenecks for retrofitting. Vessels in operation

are business assets and therefore cannot be docked for too long at the time, which highlights the need for shift retrofitting processes. “There is a high cost for the first retrofit, a lot of resources and money are allocated to it and there is a need to incentivize first movers,” said Amar Parikh. Naturally, the uncertainty around cost and fuel availability provides challenges to the asset holders looking to retrofit existing fleets. Considering that retrofit for a container vessel can cost more than USD 30 million, the payback must include different factors such as the opportunity cost of the yard stay while the vessel is out of operation, the operating patterns and fuels prices, as well as the actual cost of engine and vessel conversion.

Given that retrofitting a vessel will require the vessel to be out of the water for at least a few months, it is essential that appropriate planning and preparation occurs in advance of dry docking to ensure the vessel is operational again as soon as possible. Best practice guidance is that the retrofit should be planned at least 12-14 months in advance of dry docking. On top of this planning, there is potential for severe shortage of dry dock availability at yards.

It is likely that larger vessels will need to transition to zero-emission fuels sooner due to their operating profile. The first retrofits will likely be those with the highest demand pressures and higher margins, e.g. large cargo vessels and cruise ships. This means that the first decarbonization retrofits will start to take place within this decade, with retrofitting activity continuing into the 2030s and early 2040s for other vessel types.

4. Accelerating retrofitting via demonstration projects

During the webinar, Stena shared the lessons learned from the retrofitting process. To begin, there is a need for a detailed timeframe. Indeed, retrofitting is more complex than building a new vessel and time for regulatory development should also be considered. Additionally, in this process, there was uncertainty regarding the fuel rates and the approval of a new fuel to be used for shipping. Finally, one of the takeaways is about the workforce leading the retrofitting. Vessel crews and shipyard personnel need to be skilled, prepared and motivated, as retrofitting work is intense. Finally, the crew need to be trained to operate the retrofitted vessel.

Methanol retrofit project by Stena

With a budget of approximately 11 million Euros, the Swedish company Stena has retrofitted to methanol a fourteen year old cargo passenger vessel with a length of 240 metres the passenger capacity is 1,300 persons. The methanol pathway was selected for retrofitting as it showed to be the most cost-effective option.

The outline below describes the process that Stena used to identify their retrofitting pathway:

- 2013: the company identified the suitable vessel and decided to take the route to retrofit to methanol to cope with coming regulations. The budget for this project was 11 millions euros. The company obtained a grant of half of that from the

European Union for this project.

- 2014: during the project development phase, in partnership with Wärtsilä they developed and tested a conversion kit for the vessel. Also, Stena managed to secure a supply agreement with a methanol producer. At this time no rules and regulations were in place for methanol so the company conducted a fuel related risk analysis. In parallel, seeking classification rules to run on methanol, Stena collaborated with Class to develop rules and regulation and create a regulatory framework.
- 2015: the shipyard based in Poland was converted to perform the retrofitting. At the same time a bunkering station was built on a quayside in Gothenburg.
- 2016: the retrofitting was starting and was one of the first such retrofits in Europe.

a. *The pathways for retrofitting by Euronav*

A presentation from Lampros Nikolopoulos, Projects & Dry Docking Engineer at Euronav, provided a glimpse at a methodological approach to vessel retrofitting and the optionality that comes with such decision making. The timeframe of a retrofit is a very important element to consider in light of the availability of future fuels in the market and lining up the shipyard to perform the retrofit. From this point, different pathways can be considered and will depend on the original fuel combusted by the engine.

There are some logical options that involve less extensive retrofitting as some of the infrastructure, e.g.fuel containment system. Overall, there are a number potential pathways, for example:

- Very Low Sulphur Fuel Oil (VLSFO) designed with certain structural provisions for later retrofit to ammonia or liquified natural gas (LNG), can eventually run on biofuels now with no retrofitting needed.
- Very Low Sulphur Fuel Oil (VLSFO) designed with certain structural provisions for later retrofit to ammonia or liquified natural gas (LNG), needs large scale retrofit of Main Engine (M/E), fuel gas supply system (FGSS) and fuel tanks to run on ammonia.
- Very Low Sulphur Fuel Oil (VLSFO) vessels designed with provisions to be retrofitted later to methanol, need relatively small scale engine retrofits but also the installation of a new FGSS.
- Liquified petroleum gas (LPG) fueled vessel will certain design provisions to be able to run on ammonia will need mainly a rather small retrofit of the FGSS and Engine to run effectively on ammonia.

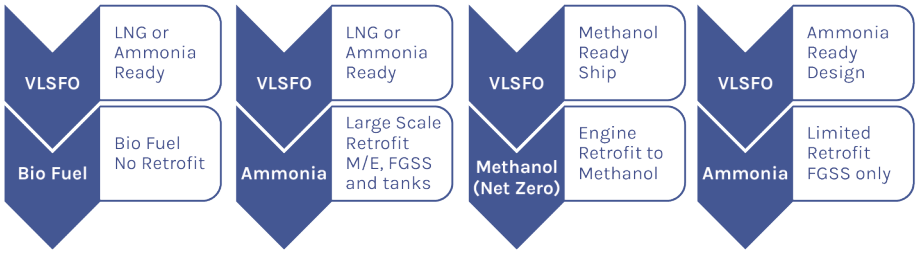


Exhibit 3: *Some potential pathways for retrofitting*

Source: *EURONAV (2021)*

The age of a vessel and its remaining life are the main parameters to retrofitting decision making. Obviously it makes much more sense to invest more in a newer vessel than one closer to its end of life. For example, Euronav classifies the potential for retrofit to zero emissions in the following blocks:

- New builds (2025-2030) must be zero emission by design.
- 0-5 year old vessels are strong candidates for retrofit.
- 5-10 year old - candidates for less costly retrofits (mainly methanol).
- 10-15 year old vessels - no major retrofit should be considered but the potential use of "drop -in" fuels.

For Lampros Nikolopoulos at Euronav, "zero ready" vessels should be deployed by design to allow retrofit options with optimised costs. The first criterion for retrofitting is the commercial life expectancy of the vessel. Then the level of fuel consumption is quite an important parameter, especially in view of carbon taxation. The availability of fuels options in the market is also a key consideration. Finally, funding opportunities need to be considered in the balance.

b. "Retrofit ready"

If the industry accepts that a large quantity of vessels will need to be retrofit, then consideration should be given to how to reduce the cost of retrofitting a vessel by initially building vessels with features that make future conversions easier and less costly . Vessels that are yet to be built could be future-proofed by adopting design changes that enable future modular retrofits with a limited cost. Preparing a vessel for retrofitting may also include design elements such as leaving free space for additional storage and pipe routing, preparing an engine to be easily retrofit, readying containment systems for zero-emission fuels, carbon capture devices, and structural reinforcement for future loads. Classification societies will play a key role in assessing what attributes will enable a vessel to be considered "retrofit- ready" and identify readiness levels that will enable the ship owners to decide what is the feasible upfront investment, for allowing the ship to be retrofitted economically in the future, with vessels that adhere to these principles being considered at a clearly defined level of being zero-ready.

As mentioned by Ulrik Frorup, Special Project & External Affairs Director at Bureau Veritas, the class societies can play a role in developing technical rules to ensure safety onboard is maintained. In the process of developing new rules, an iterative process with industry input is developed. The class society designs alternative

pathways for decarbonization to issue tentative rules, to finally issue a certification. In this context, Bureau Veritas has developed a partnership with the shipbroker Barry Rogliano Salles (BRS) and Deltamarin assesses the operational and retrofit solutions required by shipowners to reach their decarbonisation and performance targets. These will include assessments of engine power limitations, propulsion optimisation, and energy saving devices, use of new fuels, wind propulsion and other options.

One of the lessons learned by Euronav is that some actions can already be taken today. To move forward the development of zero-emission ready vessels, the company has decided to increase the level of preparedness for retrofitting, breaking down the level into two categories.

- The first category designs are the ones which provide infrastructure preparation. That is meant for vessels that already have the space and appropriate structural reinforcements for accommodating the future retrofit of a Containment and Fuel Gas Supply System. Through this approach, the space for the fuel gas supply system, relevant pipe routing and engines future components are provided in the ship's design.
- The second category - dual fuel, zero ready vessels - entails more advanced readiness level. For vessels running on dual fuel engines it is easier to encompass zero emission fuels. In this case, the containment system is compatible to run on dual fuel engines with the proper auxiliary systems adjusted for zero emission ready vessels. The Fuel Gas Supply System can be also sized to the future fuels needs limiting the future retrofit needs to the Engine and its components.

Conclusion

Retrofitting offers flexibility on the transition pathway. Indeed, as explained during the webinar a vessel can be retrofitted to different types of engines to meet the different global standards and to adapt to fuel availability. In doing so, considerable challenges, mostly related to the cost of retrofitting and shipyard availability, need to be overcome. The decision of retrofitting can emerge from identifying and analysing the cost benefit of retrofitting existing vessels or acquiring new build vessels. Taking actions now to have "retrofit ready" vessels and planning are key to accelerate retrofitting and the transition to zero emission fleets more broadly. Panellists concluded there is a need to develop a common view on what retrofitting is and to engage more stakeholders along the value chain in this dialogue.