Potential for dual-fuel conversions of marine engines

MAN Energy Solutions
Future in the making

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Engine designer MAN Energy Solutions and classification society DNV jointly argue that the main challenges of decarbonisation for the existing fleet are fuel price and availability, capacity challenges at repair yards and risk of conversion-budget overshoot, and current IMO NO_X regulation. Proposals for addressing these bottlenecks include promoting the uptake of low-and zero carbon fuels in a well-to-wake perspective, legal frameworks that allow planning and build-up of capacity, and developing new guidelines or amending IMO's technical regulation.

The primary driver for dual-fuel conversion/retrofit of marine engines is the reduction of greenhouse gas emissions. In addition to the benefits for the climate, economic benefits can also be achieved through a retrofit to a dual-fuel engine. A single-fuel engine can be retrofitted to dual-fuel, which enables the engine to run on a second fuel with a small pilot injection of conventional fuel. The pilot fuel can also be sustainable biofuel or a synthetic fuel. Dual-fuel conversions have historically been centred on converting the engines of energy carriers to run on the fuel carried, such as methane conversions of LNG tankers and LPG conversions of LPG tankers. However, with a view to stricter global GHG regulations from the International Maritime Organization (IMO) and regional regulations from the European Union, for example, the interest in retrofitting to other fuels has recently risen.

Ships currently retrofitted to operate on LNG result in approx. 20% fewer CO_2 exhaust emissions, compared to a single-fuel engine running on heavy fuel oil. Fuels such as methanol and ammonia can be produced to emit zero well-to-wake CO_2, or close to zero, during operation. We expect that GHG regulations in the future will be based on a lifecycle approach to emissions from marine fuels, also known as a well-to-wake emission perspective. If only emissions out of the ship's funnel were considered, what is known as tank-to-wake, there is a high risk that emissions would simply be pushed upstream to the production of the fuel. To properly assess the emissions associated with shipping, a lifecycle perspective of fuels is therefore a necessity. It is in a lifecycle perspective that the advantages of bio- and e-fuels compared to fossil fuels become apparent (see Table 1). Whilst biodiesel and e-diesel can be used in existing single-fuel engines, ammonia and methanol require dual-fuel engines.

To accelerate decarbonisation of shipping to limit the expected global temperature increase to a maximum of 1.5°C (Paris Agreement), well-to-wake zero-CO_2-capable technologies are required for newbuilds as well as for retrofitting the existing fleet. Whereas two-stroke newbuilds, i.e. +2,000 deadweight tonnes or +2,000 gross tonnes, concerns approx. 1,500–2,000 ships per year for the merchant marine fleet, the existing total fleet contains some 55,000 ships. For four-stroke, newbuilds amount to approx. 750 per year for engine units larger than 1 MW and the existing fleet is around 30,000 ships. This highlights the importance of implementing decarbonisation action for the existing fleet that is driven largely by fossil-based single-fuel engines. One way to reduce GHG emissions would be to run the single-fuel engines on sustainable biofuel; however, that would lead to a global shortage. As the availability of biofuel is expected to be limited, it is not a scalable GHG reduction option for shipping. This emphasises the need for retrofitting to other fuels.

Retrofitting to dual-fuel becomes attractive in view of upcoming GHG regulations for some ships with certain characteristics. According to our assessment, such characteristics for two-stroke engines are: ships having an electronically controlled engine, a bore size of at least 50 cm, a sea trial conducted after 1 January 2015, a newbuild price above 50 million USD, where the retrofit cost does not exceed 25% of the newbuild value and being a certain size ship for the retrofit to make sense commercially. The threshold for the newbuild price is suggested at 50 million USD because the cost of a dual-fuel conversion is around 12 million USD, including the fuel storage and fuel supply system, corresponding to a quarter of the newbuild price. Ship types matching the criteria are:

- Tankers >50,000 DWT
- Bulkers >160,000 DWT
- Containers >7,000 TEU
- PCTC >6,000 CEU
- VLGC >35,000 cbm

For four-stroke engines, the ships with the highest potential for a dual-fuel conversion are ships with sea trial 8–15 years ago. An outstanding major engine overhaul and the largest bore sizes in particular will give the best business case.

IMO is currently revising its GHG strategy including strengthening the GHG reduction ambitions for international shipping. A large number of member states calls for an ambition to reduce lifecycle GHG emissions to zero in 2050 in order for shipping to play its part in achieving the 1.5°C temperature goal of the Paris Agreement. However the current technical IMO regulations present a challenge for fast implementation of retrofitting to dual-fuel at scale. The issue is that a parent engine test of exactly the same electronically controlled engine type is required for a dual-fuel conversion to be NO_X compliant. This is a problem for the pace and cost of decarbonisation. Imagine relatively new engine technologies such as methanol and ammonia that are not available for all bore sizes. Today shipping needs to wait for a newbuild test before the new technology can be implemented as retrofit. But certain historical engine types are not made for newbuilds anymore. So there are engines in operation running on HFO where shipowners want to retrofit to dual-fuel based on a positive business case, but where a test of a newbuild engine – a parent engine test – is not possible.

Drivers of retrofitting to dual-fuel include:

1. The expected EU regulations in well-to-wake GHG intensity of marine fuels (FuelEU Maritime). FuelEU Maritime may allow for pooled compliance for a fleet of ships, which will help drive decarbonisation. Having one state-of-the-art zero well-to-wake CO_2 vessel is more financially attractive than 10 sub-optimized vessels. Thus, FuelEU Maritime with pooled compliance will have a positive, scalable effect on decarbonisation.

Feedstock	Fuel type	Well-to-tank	Tank-to-wake	Well-to-wake
Fossil	**Hydrogen (natural gas)[a]**	132.0	0.0	132.0
Fossil	**Ammonia (natural gas)[a]**	121.0	0.0	121.0
Fossil	**Methanol (natural gas)[a]**	31.3	69.1	100.2
Fossil	**HFO[a]**	13.5	78.1	91.6
Fossil	**LNG (medium Otto)[a]**	18.5	72.6	91.1
Fossil	**LNG (large Otto)[a]**	18.5	65.4	83.9
Fossil	**LNG (large Diesel)[a]**	18.5	57.7	76.2
Fossil	**LPG[a]**	7.8	65.5	73.3
Liquid biofuels	**Bio diesel (waste mix)[b]**	-26.1	77.5	51.4
e-fuels	**e-Methane (large Diesel)[c]**	-52.1	57.7	5.6
e-fuels	**e-Methanol[b]**	-67.1	71.6	4.5
e-fuels	**e-Hydrogen[a]**	3.6	0.0	3.6
e-fuels	**e-Ammonia[a]**	0.0	0.0	0.0

Table 1: CO_2 emission factors in gCO_2eq/MJ
[a] FuelEU Maritime
[b] IMO, "Development of draft lifecycle GHG and carbon intensity guidelines for maritime fuels (draft LCA guidelines). ISWG-GHG 11/2/3," 2022
[c] Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

2. Customers, particularly those in the business-to-consumer (B2C) market and the cruise and ferry market, are demanding lower CO_2 emissions and are willing to accept the distributed cost increase. Ship types especially used in the B2C market are container carriers, roll-on/roll-off ships (ro/ro), and pure car, truck carriers (PCTC). Additionally, some vessels for dredging in coastal areas and wind turbine installation already demonstrate the requirement for reduced GHG emissions.
3. Shipowners may face an issue when refinancing fossil-fuelled ships where they may find that refinancing a fossil-fuelled ship is harder than refinancing a green ship. Here, retrofitting to dual-fuel may make the ship eligible for green funding schemes.

Issues	Bottlenecks of retrofitting/converting to dual-fuel	Proposals for addressing the bottlenecks
Fuel price and availability	Coming from a century with fuel hegemony for diesel fuels, we are about to enter a period marked by fuel diversity. Fuel diversity requires availability of fuels and infrastructure in ports including bunkering facilities to be scalable. The fuel price of, for example, green methanol and ammonia is expected to be higher than conventional marine fuels.	Drivers should be introduced to promote the uptake of low- and zero-carbon fuels, based on a well-to-wake perspective. For example, a carbon pricing scheme may equalize the price difference of fossil versus green fuels until production capacities and fuel infrastructure is in place.
Capacity challenges and risk of budget overshoot	The implementation of all the dual-fuel conversions is expected to be carried out by a limited number of shipyards, which poses a challenge both in terms of capacity and engineering/naval architect competences due to the number and scale of conversions. Furthermore, shipowners' ability to make solid retrofit budgets with repair yards as subcontractors on a large, complex project such as a conversion may lead to a too high risk of budget overshoot.	The legal framework must allow sufficient time for planning and building up of capacity for both shipowners, yards, classes and engine manufacturers.
Current IMO NO_x regulation	Current IMO NO_x regulation is an obstacle for dual-fuel converting engines in service.	To remove the current obstacle for NO_x certification of retrofitted engines, new guidelines or amendment of IMO's technical regulations should be developed.
Challenges to technical organizations	The technical organisation of some shipowners may be challenged by fuel diversity.	To reduce the technical challenges, regulations and guidelines on the use of new fuels must be clear and technically feasible. Furthermore, equipment manufacturers should give special consideration to the "user friendliness" of technologies for new fuels whilst shipowners should prioritize training of technical personnel and seafarers to handle new technologies in a safe manner.
B2B	In the business-to-business (B2B) market of tankers and bulkers, it is relatively difficult to pass on the cost to the final consumers, contrary to the B2C container trade.	Mandatory regulations to reduce GHG emissions will require shipowners in all segments to take measures to stay compliant.

Table 2: Bottlenecks of retrofitting/converting to dual-fuel and proposals for addressing them

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