NAVIGATE THE FUTURE WITH **CONFIDENCE**

Reducing GHG emissions from marine propulsion

WIN GD

Contents

Introduction

By 2050, the global merchant fleet will look very different to today. For the past 100 years ships have been powered mainly by marine engines burning fossil-derived liquid fuels. But over the coming decades many ships will run on fuels with no or minimal carbon content. Several will feature energy storage or power generation technologies that have not yet been deployed at any meaningful scale. Some may not even have engines.

Driving this change is the global demand to cut greenhouse gas emissions. But while the demand is clear – enshrined in the UN Paris Agreement and the IMO Initial Strategy on the Reduction of Greenhouse Gas Emissions from Ships – the route to low-carbon shipping is anything but. The regulation and policy required to facilitate complex planning has yet to be delivered. And the suitability of the future fuels and technologies that will enable decarbonisation remains uncertain.

The impact these changes will have on ship design and operation – and therefore on the commercial assumptions of shipping – is only just emerging. But with less than 30 years until IMO's ambitious target is to be met, ship owners have just one vessel lifetime to make the right choice for their fleet. Choosing the right technologies will be critical if companies are to keep their competitive edge as the market shifts rapidly.

As a leading designer of marine two-stroke engines with a history going back to the first Sulzer engines in 1898, WinGD can draw on experience gained over more than a century of evolution in marine propulsion. Our role, now as then, is to develop the technologies that allow vessels to be powered efficiently, reliably, safely and sustainably – whatever the future holds.

In this paper, we outline WinGD's approach to reducing GHG emissions in shipping. Our investment in research and innovation ensures that, although the future may be uncertain, ship owners and operators can continue to rely on WinGD to guarantee environmental compliance and exceptional performance.

All sustainable sources will have to be tapped into and we will see a wide variety of gaseous as well as liquid fuels enter the marine fuel market.

The WinGD approach

WinGD believes we need to make use of all options for further improving the efficiency of marine transportation systems. This starts from the optimisation of propulsion engines and all other equipment on board, as well as overall vessel and hull design. It includes the integration of on-board energy systems and the use of hybridisation on individual ships. Finally, smart shipping concepts will need to be adopted on a wide scale, with the aim of optimising the whole logistics chain through enhanced routing, fleet and cargo management.

The growing use of fossil LNG as a marine fuel is an important step in the right direction. But even combining this step with all the above measures, we will fall short of IMO's ambitious 2050 targets – to reduce total annual GHG emissions by at least 50% compared to 2008 whilst pursuing efforts towards phasing them out.

In view of typical fleet turnover times, the targeted reduction of GHG emissions from international shipping can only be achieved by means of massive decarbonisation; in other words, the early and massive adoption of net carbon-neutral fuels, either sustainably produced biofuels or synthetic fuels produced using excess renewable energy and an appropriate feedstock. No single fuel will do the job. Instead, all sustainable sources will have to be tapped into and we will see a wide variety of gaseous as well as liquid fuels enter the marine fuel market.

Fig. 1

LNG as fuel

Firing an engine with gas instead of traditional liquid fuels is associated with a natural CO2 emissions benefit due to the lower carbon content of the fuel. Even when counting in the effect of any methane slip on a 100-year time horizon, the balance is still clearly positive. This is specifically true for WinGD's X-DF engines, due to their very specific combustion system layout. In rigorous analysis on production and test engines [4], WinGD confirmed that the emissions of unburnt methane from X-DF engines are clearly lower than any other engine type using the same lean premixed combustion concept.

X-DF engines also provide a significant improvement in the overall emissions footprint as shown in Fig.2, specifically when compared to corresponding diesel engines running on customary residual fuel. The lean combustion process produces only very low NOx emissions, meaning these engines are inherently Tier III compliant in gas mode, with SOx and particulate matter emissions - largely determined by the pilot fuel - reduced considerably. This makes X-DF engines the most environmentally sustainable system for the combustion of any fossil fuel.

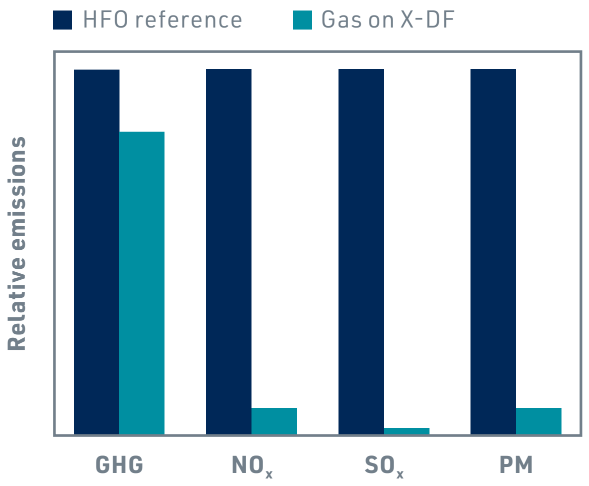

Fig. 2

The second generation of X-DF engine technologies, introduced in 2020, enhance GHG performance even further. The main building block of X-DF2.0 consists in Intelligent Control by Exhaust Recycling (iCER), which allows increasing the percentage of inert gas in the combustion chamber, thus delivering enhanced combustion control. The technology reduces the reactivity of gas/air-mixture by replacing oxygen in suction air with carbon dioxide, improving gas consumption, levelling firing pressure fluctuations, reducing emissions and allowing an increase of power density.

The result is a reduction in methane slip emissions of up to 50% when using LNG and a significant reduction of fuel consumption, of 3% in gas mode and 5% in diesel mode (see fig.4). The compound effect of using less gas fuel and reducing methane slip is an improvement in overall GHG emissions of nearly 10% in gas mode compared to first-generation X-DF engines.

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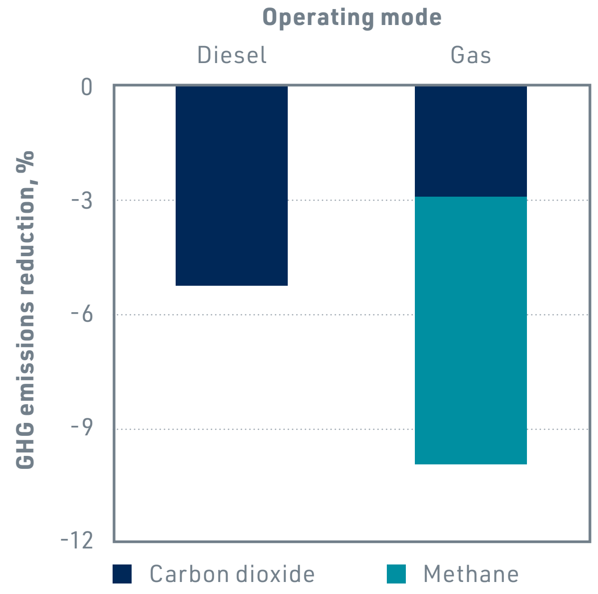

Fig. 4

This second-generation X-DF technology offers further potential for emission reductions by enabling operators to blend either fossil or renewable LNG with sustainable hydrogen. The increased combustion reactivity that hydrogen brings to the fuel-air mix can be controlled by increasing the exhaust recirculation rate through the iCER system which, unlike high-pressure exhaust gas recirculation, does not carry extra auxiliary equipment requirements or limit exhaust scavenge strategies. Consequently, the X-DF 2.0 is not only the most sustainable system for burning LNG today; it also provides an excellent base for meeting future emission demands without requiring expensive retrofits.

Integration and hybridisation

To date, conventional shipboard energy systems show only a very limited degree of integration between different subsystems. The main propulsion and the electrical power systems are often completely independent: propulsion power is delivered to the propeller directly and exclusively by the main engine, while generator sets provide electrical power for the hotel load and other regular consumers, including cargo handling equipment and auxiliary propulsion system components such as thrusters.

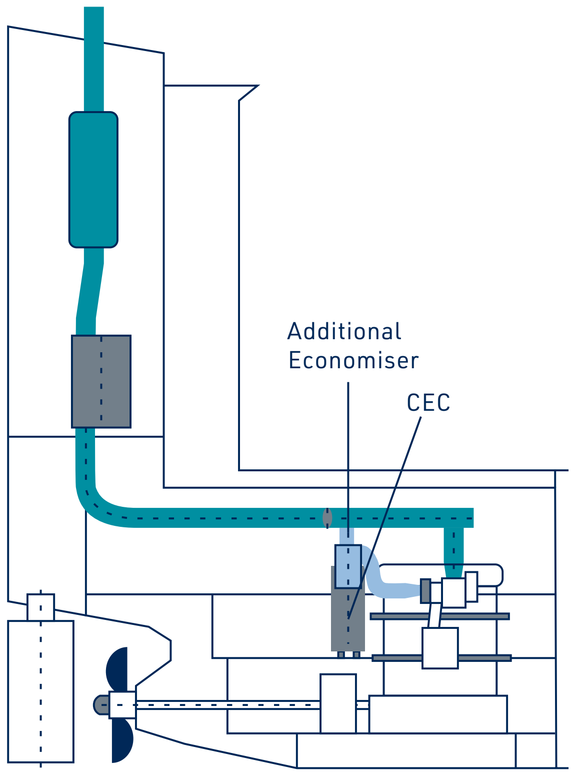

Fig. 3

Electric propulsion is an interesting alternative for short-route voyage applications where ports have adequate recharging capacities. But in view of the very low power density of even the most advanced battery technologies - and the unrivalled efficiency of two-stroke engines - it will be difficult to realise solutions that are economically competitive for long-distance shipping.

Nonetheless, there is potential for more integrated energy solutions on deep-sea ships that do include battery storage options. One such concept is shown in the lower part of Fig. 5. By using a power take-out/power take-in (PTO/PTI) unit connected to the main engine, operators can choose to either feed electrical energy into the on-board grid or draw extra propulsion power from the grid.

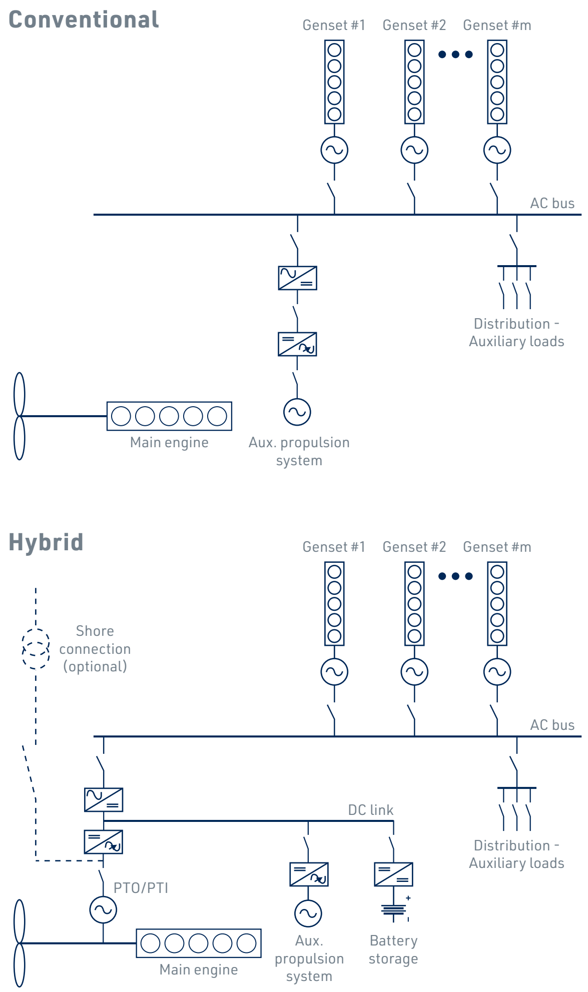

Fig. 5

WinGD has developed a comprehensive **full-hybrid-system simulation platform** to study hybridisation

This on-board grid can include a suitably sized battery storage and can be split into alternating current (AC) and direct current (DC) sections. Optionally, a connection to shore-side power supply can be foreseen to profit from increasing cold-ironing opportunities at ports.

WinGD has developed a comprehensive full-hybrid-system simulation platform to study the potential of hybridisation options for all kinds of applications. The platform includes dedicated tools for the optimisation of complex systems, such as ensuring optimal energy production from the various sources and power flow among the components.

In the first stage, the simulation platform determines the optimum selection of components. It then assesses the performance of the complete system during the envisaged operation, drawing on detailed physical models of main components such as the main engine as well as the auxiliary engines and any battery storage. In the final stage, the platform can be integrated with the overall energy management system of the completed vessel to ensure continuous optimisation in service.

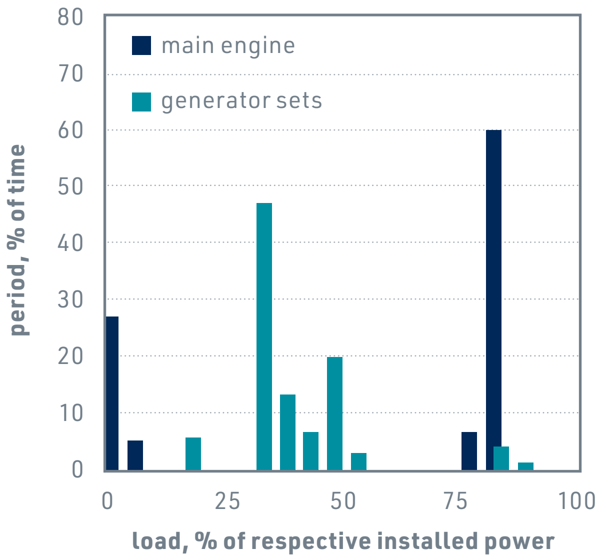

Fig. 6

Fig. 6 shows the typical operating pattern of a pure car and truck carrier (PCTC) using a conventional system layout. The respective relative loads have been determined by referencing to the main engine design power and the total installed generator power. In this setup, the main engine operating pattern is almost bimodal. While at open sea, it runs in a very narrow range defined by the vessel's service speed. Otherwise it operates at very low loads while approaching or departing from ports and is taken out of operation when the vessel is at berth.

The full capacity of the generators is hardly ever used and the simultaneous operation of all engines occurs only for a very limited time. The generators mainly operate at low relative load, resulting in low efficiency and high specific emissions. Much of this can be accounted for by the the need for spinning reserve during manoeuvring, to avoid power outages.

A more integrated concept with a hybrid energy system – with the possibility to provide power to the electric consumers by PTO/PTI from the main engine and a battery as well as the gensets – would offer many benefits:

1) Energy is produced more efficiently as the main engine has a much lower fuel consumption than the gensets – reducing both fuel cost and emissions;

2) The battery and PTO/PTI can be used as spinning reserve rather than gensets, meaning gensets can be used less often and at higher power (and consequently better fuel efficiency);

3) As genset operation is significantly reduced, there is potential to reduce the number of gensets on board if the electric components are sized suitably - minimising capital investment and offering highly attractive return on investment.

Fig. 7 shows GHG emissions for two application cases: a container vessel and the same PCTC case referred to in Fig. 6. Reduction levels are in the high single-digit percentage range, resulting from the higher efficiency of the X-DF main engine and its distinctly lower methane slip compared to typical dual-fuel genset engines.

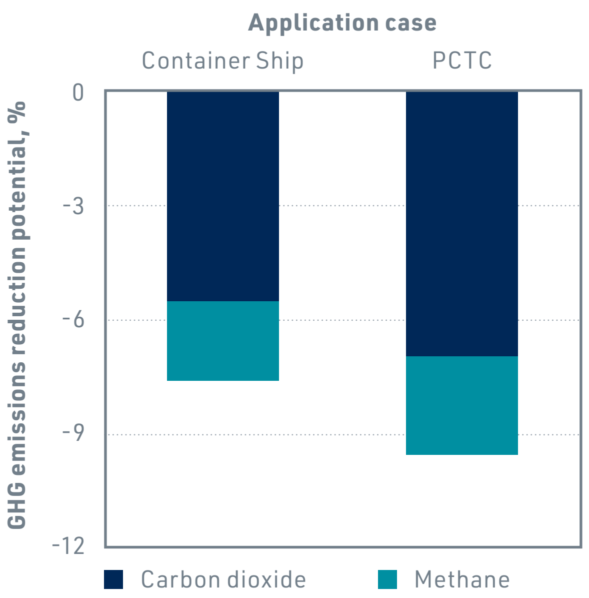

Fig. 7

Alternative fuels

There is considerable promise for decarbonisation through the suite of emerging alternate fuels and the significant investment in the infrastructure to scale these fuels is a very positive sign. WinGD has several years of research into the combustion characteristics of methanol as well as a number of lignin-based bio-fuels. Deep understanding of how these fuels interface with the engine in varying conditions is critical to ensuring the safety and stability of the fuel to then further understand how to optimise its energy efficiency.

Working with Ammonia in slow-speed two-stroke applications confirms the promising combustion results within existing engine technology. As with many of the potential future fuels, the interface with the engine technology is not the greatest hurdle for the industry to overcome in the pursuit of the decarbonisation goal. For alternative fuels to be viable net carbon-neutral fuels, the feedstock used as well as any energy involved in their production needs to come from renewable sources.

Fig. 8 illustrates, in generic form, all aspects to be considered here. The chart is specifically applicable to potential future synthetic fuels requiring multiple processing steps but can be considered equally valid for any process related to the production of future fuels requiring at least one processing stage.

Each production process involves feedstock, i.e. raw materials/reactants, which need to be sourced and prepared as well as transported to and stored at the production site. The same applies to any energy required in the production process, which may yield a (usable) by-product on top of the fuel produced in this processing stage, which in turn, if to be used as is, again requires appropriate transport and storage before being consumed.

Every process associated with the preparation, transport and storage of feedstock and energy, as well as the actual production, transport and storage of any fuel produced, is associated with losses which have an impact on the overall efficiency. Further, each process may generate emissions of GHG and/or pollutants. The more stages in the production process, the higher the impact on overall efficiency and the higher the risk of well-to-tank emissions annihilating any potential benefit from using it.

To identify truly net carbon-neutral fuels, we need to assess not only all aspects related to the application of such fuels to our engines but also how these fuels can be produced and brought to the shipping market in the most sustainable way. WinGD is conducting extensive studies into fuel manufacturing processes and their further development, first results of which have just become available [7]:

Fig. 9 shows typical data for potential future fuels requiring one stage, such as hydrogen, or two stages, such as ammonia, methanol and methane (considering only synthesis and biomass-based production in the case of methane).

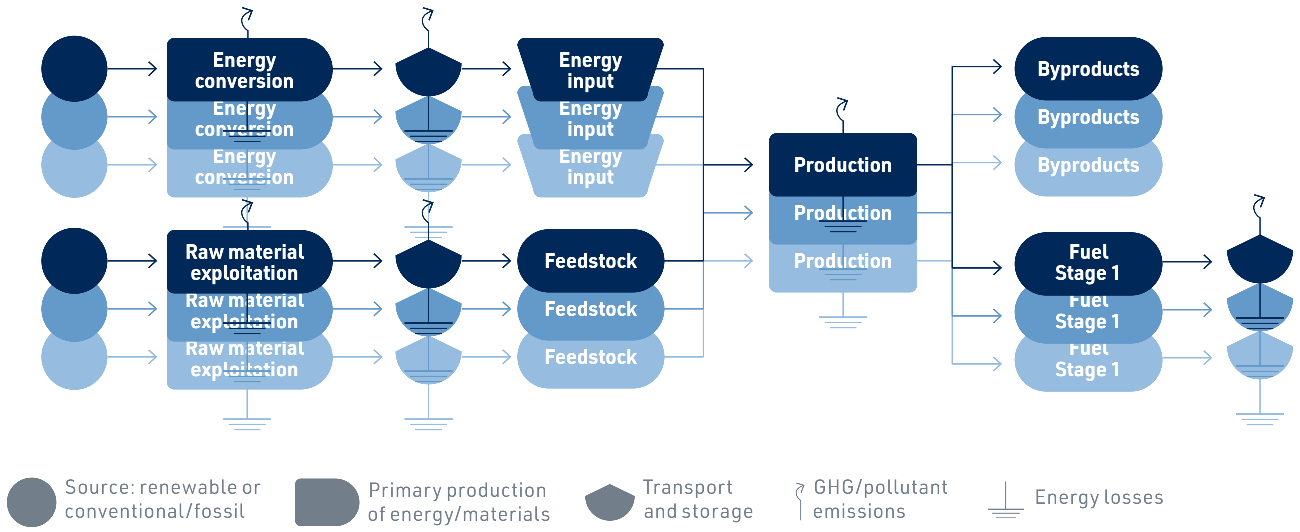

Fig. 8

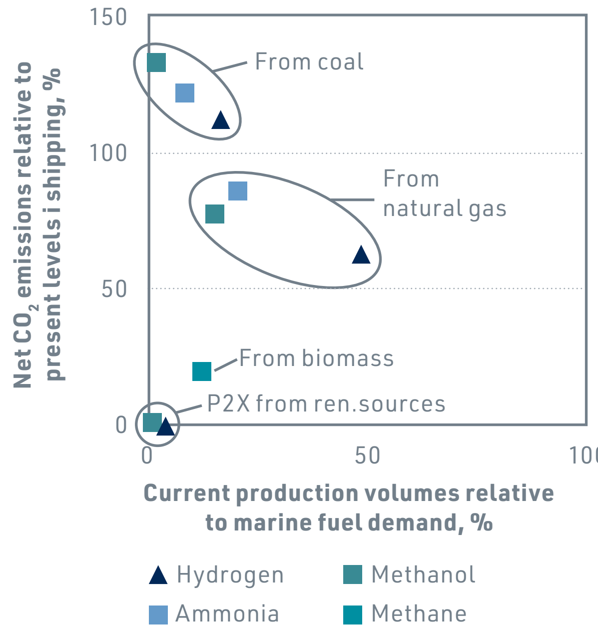

Fig. 9

Production of any of these fuels from completely renewable sources is still at close to zero levels and nowhere near the fuel volumes consumed by the shipping industry. Hydrogen, ammonia and methanol are produced today, but with the exception of some very special cases, are not being used as a fuel and, more importantly, are produced almost exclusively using fossil fuel as feedstock.

The very low volumetric power density of hydrogen means that the fuel variants requiring two processing stages are potentially better candidates for global shipping. Fig. 10 compares the overall production efficiencies for synthesising these from renewable sources. Overall production efficiencies are relatively similar, with synthetic methane ranking highest – although at the same time data for methane are characterised by the largest spread. This suggests that researchers expect quite some room for optimisation.

If the differences between the fuel types in terms of efficiency are confirmed to be minor, and if other key criteria do not turn out to be prohibitive, there are good arguments for promoting the synthesis of methane over the other fuels. Methane could easily be used as a drop-in fuel, while application of the other two would require significant investments in new supply and distribution infrastructure, as well as updating the regulatory framework for marine fuels. Safe handling of ammonia and methanol would be critical due to toxicity issues.

Net carbon-neutral fuels are widely known as X-fuels. The 'X' indicates that similar processes (the application of renewable energy and the use of biomass as an energy source) can be used to develop several fuels. In the case of shipping, it further suggests that the fuel of the future has yet to be decided – and that no single fuel is likely to satisfy all applications. For WinGD, the X-fuel is the future source of power for the dual fuel X-DF engine. Indeed the engines can already use synthetic and biomass-produced methane in the field without modification – and will be able to be retrofitted for ammonia and methanol when these fuels become commercially available.

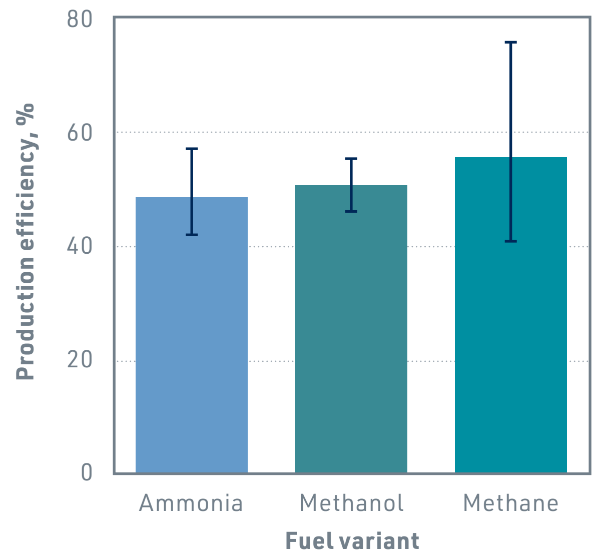

Fig. 10

Conclusion

Minimising GHG emissions from marine propulsion requires a coordinated effort from all stakeholders and WinGD is well-prepared to contribute a vital share, not only through the traditional further development of its engines but also by bringing relevant new technologies to the market as demonstrated with the introduction of X-DF technology.

The recent release of X-DF2.0 is an important milestone in this quest for more sustainable solutions, while more integrated, hybrid systems hold the promise of further improving environmental footprint. In parallel, WinGD is carrying out extensive investigations into all aspects related to emerging alternative fuels in order to evaluate their potential future role in shipping.

Biomass-derived methane and synthetic methane – delivered as liquified biogas or liquefied synthetic gas – have been initially identified as the first X-fuels that can be applied today, using existing supply infrastructure and X-DF engines already in service. But the search for other alternatives continues and WinGD's engines will be ready for these fuels too.
By preparing for these future scenarios, WinGD is taking the risk out of engine investments for shipowners and operators. These may be uncertain times, but our extensive research programme aims to place the future performance and compliance of WinGD engines beyond doubt.

References

[4] "Greenhouse Gas (GHG) Emissions from LNG Engines, Review of the Two-Stroke Engine Emission Footprint", Weisser, G, Nylund, I., Schneiter, D, 29th CIMAC Congress, Vancouver, (2019)

[7] "Future fuels production pathways – A study of relevant literature", Pancaldi-Giubbini, B., WinGD report, (2020)

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