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**On the Way towards Decarbonization – Green Fuels,
Hybridization and Digitalization in Large Engine Applications**

Decarbonizing Large Bore Engines

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Global marine transport is responsible for approx. 2,5% of global CO₂ emissions and, driven by IMO- and additional regional regulations, needs to improve its greenhouse gas footprint. For coastal short distance shipping an uptake of battery hybrid propulsion systems supplementing the traditional combustion engine will be one part of the solution. However, for long range deep sea shipping alternative carbon-neutral fuels are the only viable option providing the necessary energy and power density. A number of different Power-to-X fuels are possible, ranging from green hydrogen to ammonia, methanol, methane and also synthetic e-diesel. Engine technology either can or will soon be able to cope with all of these alternative fuel types, but the (carbon neutral) fuel production cost as well as the respective storage and handling cost will be of crucial importance for the fuel selection. From today's point of view it is very likely, that there will be different optimum fuels for different applications, trade routes and geographic regions.

Consequently, a modular and flexible architecture of dual fuel engines, enabling various fuel adaptations and also retrofits of existing engines with the least possible effort, are of utmost importance to provide ship owners with the necessary flexibility they need to operate and potentially also re-sell their vessels in an economic viable way. MAN Energy Solutions does provide and is further expanding such a flexible and modular engine program for both 2-stroke and 4-stroke engines. While methane, LPG, ethane and methanol can already be burned today in addition to conventional diesel as backup fuel, MAN is currently developing ammonia and hydrogen combustion technologies to extend its carbon-neutral engine portfolio. And the market demand for these future-proof alternative fuel solutions is steadily increasing, having taken a substantial share of the newbuilding market and also a number of successful retrofit projects to existing vessels. Last but not least, a globally harmonized regulation including a greenhouse gas pricing is necessary, in order to support and accelerate the maritime energy transition.