Work Group #4: Sustainable Marine Fuels

Deliverable 3.1 Report Review Template

1. Report title	Maritime Forecast to 2050 – Energy Transition Outlook 2019
2. Publication date	September 2019
3. Author	DNV-GL (Maritime and their central R&D unit)
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	DNV-GL
5. Context of study (e.g. project in the context of which report is published or titles of other reports if part of a series)	
6. Length (pages)	118
7. Link (or where to get if not available online)	https://sustainableworldports.org/wp-content/uploads/DNV-GL_2019_Maritime-forecast-to-2050-Energy-transition-Outlook-2019-report.pdf
8. Sector coverage	
9. Main aim of the study	
10. Methodology	

11. Topic(s) and indication of the level of detail For example: • System Description - *A description of the full marine energy system.* • System Components - *A description of all the components.* • Infrastructure requirements for new fuels • Applicability - *which of the new fuels are expected to replace existing fuels?*	• Alternative fuels: World fleet energy mix (2018-2050; and 2050); alternative fuel technologies; and boosting uptake of alternative fuels by ships in operation and on order. • Emissions: World fleet CO2 emissions 2013-2018 and towards 2050; Shipping emissions reduction by measure (Fuel, Energy efficiency, Speed reduction, Logistics). • Fuel flexibility: energy converters; storage tanks; fuel switching onboard systems; shore-side flexible fuel infrastructure. • Fuel converters: Internal combustion engines (ICE); Fuel Cells; and Electric motors. • Share of fuels: % of energy bunkered for new buildings (2018-2050). • Storage: capacity barrier to alternative fuels. • Bunkering: intervals for different types of fuel. • Timeline of LNG as ship fuel: Technical maturity; Rules and regulations; Fuel availability; Infrastructure, CAPEX; Energy cost.
12. What are the main conclusions from the report?	• Ammonia is the most promising fuel if not relying on drop-in fuels compatible with current fuel converters. • In all modelled pathways, there is a prevalent use of liquefied methane (40%–80%), but the primary energy source for this methane varies between fossil, biomass and other renewables. • There is a significant risk that for a vessel built in 2020, the most competitive fuel in the ship's early life will not necessarily be the same as when it is scrapped. Moreover, fuel availability and bunkering infrastructure are issues to consider carefully. • Case study undertaken for a very large crude carrier (VLCC) running model simulations with 9 selected design combinations in 16 scenarios spanning the commercial, regulatory and technology opportunity areas. The results of the case study show that to remain competitive throughout the operating lifetime of a vessel, investing in energy efficiency is paramount. This is because a VLCC built today will compete with vessels built in five, 10, 15 years' time, and must consider future standards to remain competitive. • Unless prices for alternative fuels move to the same level as those for fossil fuels, introducing policy measures is a key to addressing GHG emissions in shipping. Without further incentives for alternative fuels, the current fuel mix will prevail, but with LNG taking a greater share of it. • Further modelling can be useful for policymakers and the maritime industry to anticipate the need for scaling up the supply of alternative fuels to satisfy the demand generated by new regulations.

	• Large-scale investments today will only be made in technologies that are currently commercially available and competitive. However, a robust investment strategy should also include the available technologies offering the best hedge for adopting future alternative fuels emitting lower or no greenhouse gases (GHGs) at minimum retrofit costs. • Economics will be the main driver of fuel shifts in shipping in the future, though environmental regulations will also have a significant impact on choices of fuel and energy. • Regulators should be mindful of the complex maritime ecosystem when considering new regulations or incentives. • Identifying and stimulating the right parties to reduce key barriers is essential. Focusing solely on the ship owners will not work.
13. What fuel/energy type(s) are discussed in the report and in what level of detail? For example: • Fuel description e.g. type, energy density, specific energy density, flash point, boiling point, fire point, flammability limits, hazards	• HFO • HVO (*) • LSFO • LPG • LNG (*) • NH3(*) • Liquefied methane • H2 (*) • Advanced biodiesel • Electricity (batteries*) (*) Qualitative analysis of key barriers for selected alternative fuels: Technical maturity; Fuel availability; Infrastructure; Rules; CAPEX; Energy cost; Volumetric energy density; and current development status. Gravimetric and volumetric storage energy density for conventional and alternative fuels (MJ/L and MJ/kg respectively)
14. What environmental aspects does the report consider? E.g. Air quality emissions, climate change emissions (GHG + BC), other (for example terrestrial or underwater noise, water quality, emergency releases, fugitive emissions, odour, water resources, mining)	• CO2 emissions and carbon-intensity from 2013 to 2018; and projections of CO2 emissions and fuel mix. • LNG emissions reduction potential (GHG, N0x, S0x, PM) for four gas-engine concept ships for short-sea and deep-sea applications.

	• Pure/dual-fuel gas engines burning LNG; Dual-fuel engines burning LPG and other low-flashpoint liquids; Dual-fuel engines burning ammonia; Battery electric power systems (Nickel Manganese Cobalt Oxide - NMC; Lithium Iron Phosphate - LFP, Lithium Titanate Oxide - LTO). • Fuel cells (PEM, HT-PEM, SOFC). • Brief mention to noise and vibrations for battery and fuel cell systems.
15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?	• Exhaust gas recirculation (EGC) only
16. If determined in the report, what are the emission rates/factors by pollutant? NOx, SOx, PM10, PM2.5, ultra fine PM, VOC, NH3, GHGs, Black carbon, and any others e.g. that may be unique to the fuel/energy.	• Emissions reduction potential for LNG, Battery systems and Fuel Cells in GHG, NOx, SOx, and PM (%).
17. Does the report discuss barriers and opportunities for ships to use the fuel(s)/energy? Does the report identify the maturity level of the fuel on a regional or global scale with respect to use by vessels?	• Analysis of LNG status of key barriers and key players in Technical maturity; Fuel availability; Infrastructure; Rules and regulations; CAPEX; Energy cost. • Brief summary of these barriers and key players for selected alternative fuels (HVO; LNG; H2; NH3; Battery).
18. Does the report discuss barriers and opportunities for ports to provide the fuel(s)/energy? Does the report identify the maturity level of the fuel on a regional or global scale with respect to provision by ports?	• Distributing methanol to ships can be by truck or bunker vessel. Stena Line has created a dedicated area in the Swedish port of Gothenburg for bunkering the vessel Stena Germanica. • In Germany, the first methanol infrastructure supply chain – from production using renewable energy, to trucking and ship bunkering through to consumption in a fuel-cell system on the inland passenger vessel MS Innogy – was launched in August 2017. • Today more than 320 hybrid/plug-in ships are in operation or on order. Limited shore-based infrastructure is available for charging, but progress is being made in certain regions and it is expected that almost every new build vessel will use batteries in some way in the short near term.

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	• Flexible shore-side fuel infrastructure is needed to supply ships in port with alternative fuels. Some carbon-neutral fuels produced by electrofuel processes and bio-refining have potential to use existing infrastructure for marine fuels.
19. Does the report include capital and operating cost estimates for the ship and/or land-side?	• The cost of retrofitting a ship to switch from diesel to a dual-fuel methanol/diesel fuel has been estimated to be EUR 250–350 per kilowatt for large, 10–25 megawatt engines. • The costs of installing battery systems onboard, including replacing them after typically eight to 10 years, is significantly higher than for traditional diesel engines. In addition, investment in on-shore infrastructure is needed to provide electricity. • Electricity production from hydropower is reported to be price-competitive with MGO.
20. When are the fuel(s)/energy expected to be at a demonstration stage vs. commercialization? For example: • Technology Readiness Level of the system - *Estimated maturity of the system technology* • On Board Safety Readiness Level of the system - *Estimated maturity of the risk mitigations on board (on a scale of 1-9)* • External Safety Readiness Level of the system - *Estimated maturity of the risk mitigations for bunker operations (on a scale of 1-9)*	• Technical maturity and fuel availability for selected alternative fuels (HVO, LNG, H2, NH3, Battery). • Hydrogen and ammonia are still on the first steps of the stairway, while HVO and battery electric power have seen their first commercial short-sea applications.
21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?	• Four gas-engine concepts for short-sea and deep-sea applications described in terms of fuel flexibility for fossil (LNG, MGO/HFO) and non-fossil fuels (LBG, synthetic methane, biodiesel, synthetic diesel); and current uptake of LNG in ships in operation and on order. • Storage of most alternative fuels will require more space onboard compared with traditional fuels, due to reduced energy density and/or space required for high pressure/low temperature storage systems. For many ship types, this fact translates to loss of cargo carrying capacity, i.e. potential loss of income. Land-based demand and infrastructure development are also critical for the success of introducing alternative fuels in shipping.

22. Does the report identify/discuss potential issues around community acceptance for this fuel, or potential social/community impacts associated with the system?	• No mention of community acceptance of social/community impacts associated with alternative fuels and technologies.