Work Group #4: Sustainable Marine Fuels

Deliverable 3.1 Report Review Template

1. Report title	**Perspectives for the Use of Hydrogen as Fuel in Inland Shipping**
2. Publication date	October 2018
3. Author	MARIKO GmbH, FME, RWTH Aachen University MARIKO GmbH is a private company aiming at connecting science and the maritime economy in a specific region in Germany. FME is a Dutch employers' organisation in the technology industry. RWTH Aachen University is a public, non-commercial entity.
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	The MariGreen project is co-financed under the INTERREG V A program Germany-Netherlands with funds from the European Regional Development Fund (ERDF), the Dutch Ministry of Economic Affairs, the German State of Lower Saxony, the North Rhine-Westphalian Ministry of Economic Affairs, Energy, Industry, SMEs and Crafts in Germany and the Dutch provinces of Drenthe, Flevoland, Friesland, Gelderland, Groningen, Noord-Brabant and Overijssel. It is supported by the program management INTERREG at the Ems Dollart Region (EDR).
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)	The report is part of the MariGreen project
6. Length (pages)	123
7. Link (or where to get if not available online)	https://sustainableworldports.org/wp-content/uploads/MARIKO-et-al_2018_Perspectives-for-the-use-of-hydrogen-report.pdf
8. Sector coverage	Inland shipping

9. Main aim of the study	Main aim of the study is to compare and contrast the use of hydrogen as alternative fuel with the special requirements in inland shipping.
10. Methodology	Hydrogen as alternative fuel for inland navigation is assessed for four vessel types (cargo vessel, pushed convoy, cabin vessel, river ferry) which are considered representative for their respective kind.
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?*	In this study, the use of hydrogen as alternative fuel is compared and contrasted with the special requirements in inland shipping: • Various ways of hydrogen production • Local distribution of the production sites and transport to the harbor • Hydrogen storage technologies • Conversion of hydrogen on board of the vessel • The combinations of the selected energy storage and conversion technologies are evaluated systematically for four vessel types based on typical operational profiles. • Relevant legal situation including identified gaps • Strategies how hydrogen technologies can be established in inland shipping
12. What are the main conclusions from the report?	It is expected that emission standards for inland shipping will further be tightened in the future. Since the use of hydrogen reduces emissions significantly, the use of it could be a compliance option. To this end it should be produced from renewable energy sources. In ports, the hydrogen should preferably be stored in the form in which it is delivered and provided to the consumer: due to additional energy losses, conversion between the various forms of storage should be avoided. The conventional ways of bunkering, namely by bunker boat, truck or pipeline can also be used for hydrogen. On board the vessels, the chemical energy stored in the hydrogen can be converted to electricity and mechanical propulsion energy by means of internal combustion engines or fuel cells and electric motors. Combustion engines are considered more advantageouss for cargo vessels and pushed convoys whereas fuel cells for cabin vessels and inland water ferries.

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	The use of hydrogen as fuel for inland shipping is discussed in the report on a detailed level: • Chemical properties (Table 3.2 in the report) • Technological feasibility - Options to produce hydrogen - Infrastructure and supply - Ecological and economical assessment - Transport and storage in the harbor - On board storage and bunkering - Comparison of energy conversion technologies (internal combustion engine and fuel cell) - Application cases (cargo vessel, pushed convoy, cabin vessel, river ferry) - Legal frame conditions
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)	The report considers the following environmental aspects: • Air quality emissions (SOx, NOx, HC, PM) • Climate change emissions (CO_2, CO) • Noise per fuel conversion technology
15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?	The report considers both lifecycle and exhaust emissions: the evaluation of energy efficiency is usually carried out by the well-to-tank (WTT) approach for power generation and the tank-to-wheel (TTW) approach for implementation in the vehicle. Combined, this results in a well-to-wheel (WTW) view of the entire process.
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.	The emission rates are dependent on the fuel type and conversion technology. The emission rate for hydrogen as fuel is not specified. However, the following information regarding emissions is provided in the report: • The CO_2 emissions of shipping compared to global emissions (Figure 2.5) • The emission limit value (for CO, HC, NOx and PN) for IWT (inland waterway transport) engines > 130 kW (Figure 2.6) • The GHG emissions in g CO_2eq. / km (Figure 4.5) • The emission limit value for CCNR Stage I engines (Table 5.1) • The emission limit value for CCNR Stage II engines (Table 5.2)

	• The regulations (emission limit) of the European Parliament regarding stage V engines (Table 5.3)
17. Does the report discuss barriers and opportunities for <u>ships</u> 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?	The report discusses barriers and opportunities to/of the use of hydrogen by inland vessels and identifies the maturity level of hydrogen on a regional scale.
18. Does the report discuss barriers and opportunities for <u>ports</u> 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?	The report discusses barriers and opportunities for inland navigation ports to provide hydrogen. Focus is thereby on different types of storage and bunker options. The maturity level of the provision of hydrogen by ports is assessed on a regional scale. It is analyzed how ports in the Rhine-Ruhr area could profit from the existing chemical infrastructure in this area.
19. Does the report include capital and operating cost estimates for the ship and/or land-side?	The report includes an estimation of the capital and operating costs for ships for various hydrogen conversion technologies. It also includes information about the production costs of hydrogen, but does not provide information about the storage costs ashore.
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)*	• No timeline for the commercial availability of hydrogen as fuel for inland shipping is provided. • The technology readiness level of hydrogen is provided per fuel conversion technology. • The report does not provide information regarding the on board and external safety readiness level of hydrogen and the conversion technologies. However, the report gives information regarding regulations and guidelines for low flashpoint fuels and fuel cells.

21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?	The operational profile of the four different ship types (cargo vessel, pushed convoy, cabin vessel, Rhine ferry) is taken into account for the assessment of the hydrogen conversion technologies (internal combustion engine/fuel cell).
22. Does the report identify/discuss potential issues around community acceptance for this fuel, or potential social/community impacts associated with the system?	Since crews on board inland waterway vessels (and seagoing vessels) do not have experience with hydrogen as fuel, training is required.