Work Group #4: Sustainable Marine Fuels

Deliverable 3.1 Report Review Template

1. Report title	**How to decarbonize international shipping: options for fuels, technologies and policies**
2. Publication date	2019-02-15
3. Author	Paul Balcombe, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes and Iain Staffell Authors are with Imperial College London and the consultancy E4tech
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	n/a (Academic publication)
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)	47
7. Link (or where to get if not available online)	Energy Conversion and Management, Volume 182, 15 February 2019, Pages 72-88 https://sustainableworldports.org/wp-content/uploads/Balcombe-et-al._2019_How-to-decarbonise-international-shipping-report.pdf
8. Sector coverage	Maritime shipping

9. Main aim of the study	The study gives the emission reduction potential of LNG, of some alternative fuels and of some energy efficiency measures, as well as combinations thereof. The probability of meeting the 50% GHG reduction target of the IMO is assessed for different alternative fuel options in combination with efficiency measures. Alternative policy measures are assessed on a high-level.
10. Methodology	Mainly based on a literature review.
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?*	The following topics are covered: • current emissions of vessels – *a high-level overview of current GHG emissions of maritime shipping* • emission reduction targets – *an overview of global emission reduction policies and targets for shipping* • fuel costs – *for LNG historical fuel costs and for FAME and HFO one estimation of current costs are given* • capital costs – *LNG related capital costs are specified* • vessel efficiency improvements – *a small number of energy efficiency measures are discussed on a high-level* • decarbonisation potential – *a comparison of carbon emissions reduction potential of the fuel types* • decarbonisation policies – *a high-level discussion of possible future policy changes which benefit the adoption of low carbon fuels*
12. What are the main conclusions from the report?	For some fuel types it holds that their use has to be complemented by energy efficiency measures to be able to meet IMO's 2050 emission reduction target. A combination of policy measures (one overarching measure + different specific measures) is required for the sector to decarbonize.
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	In the quantitative, core analysis of the study, the following (alternative) fuel types/technologies are considered: • LNG • Methanol • Bio-liquids • Bio-methanol • Hydrogen • Electricity

	• Nuclear energy For these fuels, the following characteristics are discussed without much detail: • required engine changes on vessels For these fuels (except for electricity and nuclear energy), the following characteristics are discussed: • CO_2 emissions
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 focus of the report is on greenhouse gas emissions. Air quality emissions are also considered to some extent. Only for hydrogen, noise is mentioned.
15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?	Literature estimates of the life-cycle GHG emissions of the different fuel types are given (Figure 7).
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.	Emission rates in terms of gCO_2e/kWh for the different fuel types are presented in Figures 7 and for specific biofuels in Figure 8 of the report. For NO_x and SO_x the reduction of emissions are presented in the text expressed as a percentage decrease compared to conventional fuels. [The reference emission values used and whether life-cycle or exhaust emissions are considered is not always clear in the study.]
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?	The report does mention barriers for ships to use specific low-carbon fuels. These barriers are: • cost and availability (biofuels) • large storage volume (hydrogen) • safety concerns (nuclear)

	The opportunities mentioned in the study are: - policies to incentivize the use of new fuels The report does not directly identify the maturity level of the fuel on a global scale with respect to the use by vessels. However, examples of ships already implementing the different technologies are identified.
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?	The report does not focus on ports. Related to this topic, the following comments are made: • the cost of adding LNG port infrastructure may be significant • capital costs for new infrastructure could be a barrier for global commercialization of hydrogen. • an example of a nuclear marine propulsion ship which is restricted in its access to ports due to safety concerns.
19. Does the report include capital and operating cost estimates for the ship and/or land-side?	For LNG the capital costs for the ship (retrofit and new-built) are included in the report in Table 1. For the other fuel sources, no specific numbers are given.
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)*	Not specified in report.

21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?	Not specified in the report.
22. Does the report identify/discuss potential issues around community acceptance for this fuel, or potential social/community impacts associated with the system?	For nuclear fuel community acceptance due to safety concerns is mentioned.