



## Work Group #4: Sustainable Marine Fuels

### Deliverable 3.1 Report Review Template

1. Report title	<b>Zero-Emission Vessels: Transition Pathways.</b>
2. Publication date	January 2019
3. Author	Lloyd's Register and UMAS  Lloyd's Register is a marine classification society and private entity. UMAS is a consultancy and set up as a partnership between the University College London (UCL) Energy Institute and MATRANS Ltd. and thus a private/public entity.
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	No third party client is mentioned.
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 'Low carbon pathway 2050 series' published by Lloyds Register (and UMAS), consisting of: 1.A) Zero-Emission Vessels: Transition Pathways. as published 2019, with the following two directly related reports B) Safety considerations for the use of zero-carbon fuels and technologies. C) Fuel production cost estimates and assumptions. 2. Zero Emission Vessels 2030. How do we get there? as published 2017 3. Low carbon pathways 2050 as published 2016.
6. Length (pages)	30

7. Link (or where to get if not available online)	<a href="https://sustainableworldports.org/wp-content/uploads/Lloyds-Register-and-UMAS_2019_Zero-emission-vessels-transition-pathways-report.pdf">https://sustainableworldports.org/wp-content/uploads/Lloyds-Register-and-UMAS_2019_Zero-emission-vessels-transition-pathways-report.pdf</a>
8. Sector coverage	Maritime shipping
9. Main aim of the study	<p>The report develops potential transition pathways for the decarbonisation of shipping. Looking at the milestones and enablers over the required timeframe and considering cost implications, operating profile and how policy measures could influence this, the report aims to show what is required to enable the transition on both a ship and supply infrastructure.</p> <p>The authors also intend showing what is needed to support the development of an action plan to achieve the IMO's 2050 goal and to demonstrate to all industry stakeholders that action can be taken now.</p>
10. Methodology	Backcasting: Assuming that in 2050, the fuel mix in shipping will be dominated by zero-carbon fuels, milestones and enablers are identified that connect the specified future to the present.
<p>11. Topic(s) and indication of the level of detail For example:</p> <ul style="list-style-type: none"> <li>• System Description - <i>A description of the full marine energy system.</i></li> <li>• System Components - <i>A description of all the components.</i></li> <li>• Infrastructure requirements for new fuels</li> <li>• Applicability - <i>which of the new fuels are expected to replace existing fuels?</i></li> </ul>	<p>The report describes the following pathways towards decarbonisation:</p> <p>Pathway 1: Renewable dominate Pathway 2: Bio-energy dominate Pathway 3: Equal mix</p> <p>On all pathways a transition to zero-carbon fuels will be achieved by 2050. This means that fossil fuel-based marine fuels (such as Heavy Fuel Oil (HFO), Low Sulphur Heavy Fuel Oil (LSHFO), Marine Diesel Oil (MDO) and Liquefied Natural Gas (LNG)) will be completely phased out or will take a small share (~10%) of the total fuel mix in 2050.</p> <p>There is consideration of how cost, operating profile and policy measures could influence the pathways. Milestones are identified over time with regards to the safety, technical, social, economic and environmental aspects of the potential zero-emission vessels (ZEVs) and the associated supply of the zero-carbon fuel options.</p>

	<p>At this point in time, there is too much uncertainty to decide on one route, one fuel and one technology for the future transition of the shipping industry. So all key primary energy sources that would allow zero-carbon fuels to enter the shipping fuel market are considered: renewable energy, bio-energy and fossil fuels with carbon capture and storage (CCS).</p>
<p>12. What are the main conclusions from the report?</p>	<p>All pathways will achieve the IMO's level of ambition of at least 50% reduction in GHGs by 2050 and go beyond to show that zero emission is possible. All paths lead to a mix of fuels, but with different dominant fuels. Although it is difficult at this stage to decide on one route, fuel or technology, there is a need to better understand what the interactions are over time between the applications on board ships and the production and supply in order to take early action.</p>
<p>13. What fuel/energy type(s) are discussed in the report and in what level of detail? For example: a. Fuel description e.g. type, energy density, specific energy density, flash point, boiling point, fire point, flammability limits, hazards</p>	<p>Zero-carbon fuels/energy discussed in the report:</p> <ul style="list-style-type: none"> <li>- Methanol</li> <li>- Gas oil</li> <li>- Hydrogen</li> <li>- Ammonia</li> <li>- Electricity</li> </ul> <p>Energy sources related to the zero-carbon fuels:</p> <ul style="list-style-type: none"> <li>- Natural gas CCS</li> <li>- Biomass</li> <li>- Renewable electricity</li> </ul> <p>Physicochemical parameters of these zero-carbon fuels are not discussed in the report.</p>
<p>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)</p>	<p>It is briefly described that air quality emissions (NO<sub>x</sub>, SO<sub>x</sub>) and greenhouse gas emissions (CO<sub>2</sub>) need to be reduced in the coming decades to achieve the IMO's level of ambition. The amount of emissions per fuel/energy type is not specified in the report.</p>

<p>15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?</p>	<p>It is briefly discussed that the emissions are not only related to the exhaust during operation, but also to the production phase.</p>
<p>16. If determined in the report, what are the emission rates/factors by pollutant? NO<sub>x</sub>, SO<sub>x</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, ultra fine PM, VOC, NH<sub>3</sub>, GHGs, Black carbon, and any others e.g. that may be unique to the fuel/energy.</p>	<p>Not determined in report.</p>
<p>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?</p>	<p>It is briefly discussed which type of fuel(s)/energy has opportunities in the maritime industry and which has more opportunities in other sectors. It is discussed how zero-emission fuels can be adopted in the maritime sector. Opportunities and barriers are discussed globally, but not identified per fuel/energy type. The report identifies per pathway per fuel type globally which actions need to be taken to make the fuel/energy type commercially available in the maritime sector and to reach the IMO's level of ambition to reduce the emissions.</p>
<p>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?</p>	<p>No.</p>
<p>19. Does the report include capital and operating cost estimates for the ship and/or land-side?</p>	<p>The following costs are discussed in the report per fuel/energy type and source:</p> <ul style="list-style-type: none"> <li>• Production costs</li> <li>• Storage costs</li> <li>• Engine costs</li> <li>• Voyage costs</li> <li>• Revenue loss</li> </ul>

<p>20. When are the fuel(s)/energy expected to be at a demonstration stage vs. commercialization? For example:</p> <ul style="list-style-type: none"> <li>b. Technology Readiness Level of the system - <i>Estimated maturity of the system technology</i></li> <li>c. On Board Safety Readiness Level of the system - <i>Estimated maturity of the risk mitigations on board (on a scale of 1-9)</i></li> <li>d. External Safety Readiness Level of the system - <i>Estimated maturity of the risk mitigations for bunker operations (on a scale of 1-9)</i></li> </ul>	<p>The following three items are shortly discussed per transition pathway:</p> <ul style="list-style-type: none"> <li>• Technology Readiness Level of the system</li> <li>• On board safety readiness level of the system</li> <li>• External safety readiness level of the system</li> </ul> <p>Per transition pathway necessary developments, including a timeline, to realize the IMO’s level of ambition to reduce 50% of the GHG emissions in 2050 are discussed.</p>
<p>21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?</p>	<p>Not discussed</p>
<p>22. Does the report identify/discuss potential issues around community acceptance for this fuel, or potential social/community impacts associated with the system?</p>	<p>Not discussed</p>