



## Work Group #4: Sustainable Marine Fuels

### Deliverable 3.1 Report Review Template

1. Report title	Setting the Course to Low Carbon Shipping: Pathways to Sustainable Shipping
2. Publication date	April 2020
3. Author	ABS (in collaboration with Maritime Strategies International and Herbert Engineering)
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	n/a (Outlook seems to be financed by the classification society itself)
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)	This report is part two of an ABS series called 'Setting the course to low carbon shipping'. The first report has the subtitle '2030 Outlook, 2050 Vision' and was published in June 2019 (ABS refers to the report as 'The 2019 ABS low carbon shipping outlook')
6. Length (pages)	107
7. Link (or where to get if not available online)	<a href="https://sustainableworldports.org/wp-content/uploads/ABS_2020_Pathways-to-sustainable-shipping-report.pdf">https://sustainableworldports.org/wp-content/uploads/ABS_2020_Pathways-to-sustainable-shipping-report.pdf</a>
8. Sector coverage	Maritime shipping
9. Main aim of the study	Industry stakeholders will have to make choices between new fuels, energy sources and emissions control systems in the transition towards low-carbon operations and zero-carbon shipping. The report intends to inform the stakeholders' decision making process.
10. Methodology	The report builds on the expertise of ABS as a classification society as well as on current literature.

<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 following topics are covered in detail in the study:</p> <ul style="list-style-type: none"> <li>• Emissions regulations – <i>an overview of the current global regulations and IMO’s reduction targets</i></li> <li>• Energy market forecast – <i>forecast of the future global energy market</i></li> <li>• Trade and technology choices – <i>explanation of the link between technological developments and the shipping sector</i></li> <li>• Carbon capture – <i>the possibilities and role of carbon capture</i></li> <li>• Fuel pathways – <i>three pathways towards low-carbon maritime shipping</i></li> <li>• Hybrid electric power – <i>hybrid electric power for maritime shipping</i></li> <li>• Fuel cells – <i>fuel cells for maritime shipping</i></li> <li>• DC systems – <i>DC systems for maritime shipping</i></li> <li>• Just in time versus optimal shipping route – <i>discussion of these two approaches to shipping</i></li> <li>• Design of future vessels – <i>future vessel designs for low-carbon fuels</i></li> </ul> <p>With regards to alternative fuels for maritime shipping, the following topics are discussed in detail for each of the three pathways:</p> <ul style="list-style-type: none"> <li>• Current state of the art – <i>specifications of different fuel types, available engines and storage technologies</i></li> <li>• Developments – <i>future (medium- and long-term) developments with respect to the fuel types</i></li> <li>• Challenges – <i>challenges (including regulatory and bunkering challenges) for the use of the fuel in maritime shipping</i></li> </ul>
<p>12. What are the main conclusions from the report?</p>	<p>Three fuel pathways to carbon-neutral and zero-carbon shipping are identified: ‘Light gas pathway’, ‘Heavy gas and alcohol pathway’ and ‘Bio/synthetic fuel pathway’. All three pathways start with fuels that can be used in existing power generation and propulsion systems.</p> <p>Further important conclusions are:</p> <ul style="list-style-type: none"> <li>• Fuels with low volumetric energy content may require holistic redesigns of vessels</li> <li>• Hybrid fuel systems have significant potential to reduce emissions</li> <li>• Petroleum-based fuels are expected to still have a considerable market share in 2050 (up to 40%)</li> <li>• New safety regulations will be required</li> <li>• The transition to low carbon fuels is likely to increase the costs of vessels and their operation</li> </ul>

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 report discusses the following fuels:

- LNG
- Biomethane/electromethane
- Hydrogen
- LPG
- Methanol
- Biofuels
- Ammonia
- Biodiesel/renewable diesel
- HVO
- HFO
- MGO
- Hydro-treated vegetable oil
- FAME
- Ethanol
- DME

These fuels are divided in three 'pathways' (1: light gas, 2: heavy gas and alcohol and 3: bio/synthetic fuel). For the different pathways the different specifications are given per fuel.

For pathway 1 the following specifications are stated:

- Liquid density
- Lower heating value
- Energy density
- Air/fuel stoichiometry
- Research octane number

- Oxygen content
- Aromatics content
- Sulfur content

For pathway 2 the following details are provided per fuel:

- Lower heating value
- Heat of vaporization
- Auto-ignition Temperature
- Liquid Density
- Cetane number
- Octane number
- Flash point
- A/F ratio
- Adiabatic flame temperature at 1 bar
- Greenhouse gas emissions

For pathway 3 the following details are provided per fuel:

- Density
- Lower heating value
- Viscosity
- Surface tension
- Cetane number
- Stoichiometric air/fuel ratio
- Oxygen content
- Sulfur content

<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>The report mainly considers greenhouse gas emissions.</p>
<p>15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?</p>	<p>For some fuels, the report gives both well-to-tank and tank-to-propeller GHG emissions and for others only the well-to-tank GHG emissions.</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>For fossil bunker fuels (HFO, MGO, LPG and LNG) life cycle greenhouse gas emissions (kg CO<sub>2</sub> eq./GJ) are presented in Table 2 of the chapter 'Heavy Gas and Alcohol Pathway' (p. 25)  The well-to-tank GHG emissions (g CO<sub>2</sub> eq./MJ) for ammonia production, transmission and distribution are presented in Table 5 of the same chapter (p. 31), differentiating four electricity sources (municipal waste, hydropower, nuclear power, biomass).  For FAME and HVO, the well-to-tank GHG emissions (g CO<sub>2</sub> eq./MJ) are presented in Table 4 of the chapter 'Bio/Synthetic Fuel Pathways' (p. 38), differentiating three different feedstocks.</p>
<p>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?</p>	<p>The report discusses the barriers for ships to use the different fuels/energies. These discussions are presented under the 'challenges' part at the end of some chapters. Technical barriers as well as regulatory barriers specific to the fuel type are discussed.</p> <p>The report does identify the maturity level of the fuels on a global scale, which translates into the distinction between fuels which are suitable for the 'short-term', 'mid-term' and 'long-term'.</p>
<p>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?</p>	<p>Some barriers with respect to bunkering and regulation for the port side are mentioned in the challenges paragraph of the 'light gas pathway' chapter.</p> <p>The maturity level of the fuel with respect to provisions in ports is not explicitly considered.</p>

<p>19. Does the report include capital and operating cost estimates for the ship and/or land-side?</p>	<p>Not specified in report.</p>
<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>• Technology Readiness Level of the system - <i>Estimated maturity of the system technology</i></li> <li>• 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>• 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 report distinguishes ‘short-term’, ‘mid-term’ and ‘long-term’ fuel options as part of pathways to carbon-neutral and zero-carbon shipping:</p> <ul style="list-style-type: none"> <li>• In the short-run, LNG, bio-diesel, HVO and alcohol are considered viable alternative fuels.</li> <li>• In the mid-run, methane, gas-to-liquid fuels and bio/electro fuels are considered viable alternative fuels</li> <li>• In the long-run, hydrogen, 2<sup>nd</sup> and 3<sup>th</sup> generation carbon neutral fuels and ammonia are considered viable alternative fuels.</li> </ul> <p>The pathways are visually presented in Figure 1 of the chapter ‘How Taxonomies Lead to Fuel Pathways’ (p. 12).</p>
<p>21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?</p>	<p>Not specified in the report.</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 specified in the report.</p>