

EXECUTIVE SUMMARY¹: INNOVATION IS NEEDED FOR THE TRANSITION TO ZERO-EMISSION FUELS IN INTERNATIONAL SHIPPING

Today, international shipping accounts for around 3 percent of global emissions of greenhouse gases (GHG). The decarbonization of the industry constitutes a particular challenge. Today the industry relies on the availability of and access to cheap, energy intensive fuels to transport heavy freight over long distances globally. However, the green, zero-emission fuels we see emerging as possible frontrunners for the transition of the industry are less price competitive and energy intensive. Moreover, the particular and sometimes hazardous properties of those fuels constitute significant risks around their transportation, storage, and onboard use.

To accelerate the decarbonization of shipping, innovation and regulatory measures are required. Further innovations are necessary to address some of the barriers to the wider efficiency, applicability, and uptake of green fuels in the industry. These barriers are both technological and market barriers. Regulatory measures are needed to secure and create the right incentives for innovation and the broader uptake of green fuels.

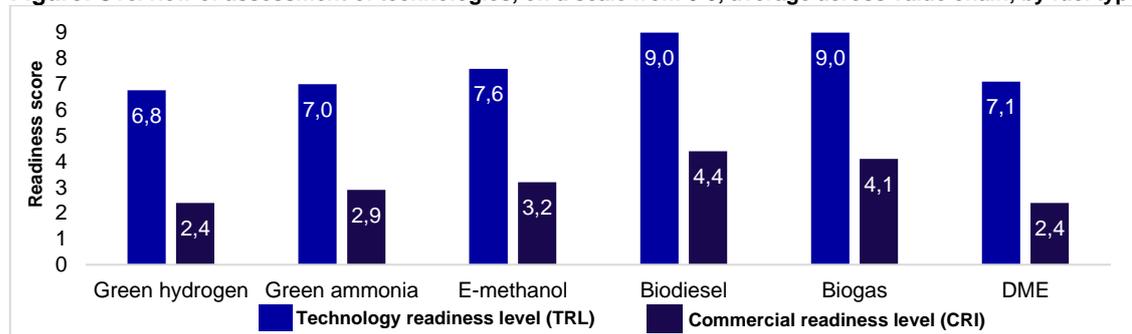
In the analysis of the innovation needs for the decarbonization of international shipping, we conclude that many green fuel technologies have already undergone considerable development and are being deployed through e.g., selected demonstration projects. Yet, despite the positive movement taking place, there remains significant obstacles and innovation needs to be addressed to support the decarbonization of international shipping.

FOUR MAIN CONCLUSIONS REGARDING READINESS AND INNOVATION NEEDS

1. The green fuel technologies are to a large extent technologically available but are in most instances not market ready. Innovations must accelerate their market readiness

According to our expert reviewed assessment, the overall technological readiness of the needed fuel technologies is moderate to high while their commercial readiness is in general low. The technological and commercial readiness of the six green fuel options assessed are summarized in figure 1. It was stressed by the expert panels that innovation, together with other market supporting measures, are needed to accelerate the readiness of technologies and support the commercialization of these technologies.

Figure: Overview of assessment of technologies, on a scale from 0-9, average across value chain, by fuel type



Note: A Technology Readiness Level (TRL) index and an adapted Commercial Readiness Index (CRI) has been applied to assess the readiness of technologies. The original CRI scores on a 0-6 scale have been recalculated on a 0-9 scale for the purpose of overall clarity.

¹ The executive summary highlights the results of an analysis of the innovation needs for the decarbonization of shipping to achieve commercially viable zero-emission shipping. The analysis has been conducted by Oxford Research, a Nordic consultancy, and Maritime DTU on behalf of the Danish Maritime Authority. The analysis has involved +30 global experts covering fuel production, bunkering infrastructure and vessel operations. The analysis will be used to guide the work of the international Zero-Emission Shipping Mission under the auspices of Mission Innovation. The Shipping Mission is co-lead by Denmark, USA, Norway, Global Maritime Forum and The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping.

2. A technology neutral approach must be applied to stimulate the further innovations of several fuel options

At this stage there is no clear green alternative fuel to marine fossil fuels. All six green fuels assessed have some limitations and challenges, which need to be addressed. Furthermore, several fuels may in the future emerge as the most commercially viable, suited to different industry needs and circumstances. Therefore, for the foreseeable future, it is important to favor a technology neutral approach in innovation.

3. Cross-cutting innovations are essential to address systemic gaps that affect all fuel types

To support the further development and scaling of green fuel technologies, three cross-cutting gaps and measures relevant for all fuels have been identified.

Firstly, **demonstration projects** of green fuels in real life settings and across the entire value chain in so-called “*green corridors*” are needed. This is to address a lack of knowledge around the applicability, safety and performance of the green fuels. Hence, integrated test and demonstration is suggested to gather knowledge on the performance and operation, which can guide further innovation and development efforts.

Secondly, **standards** are needed. While some standards exist, there is a need to further develop and update international standards to cover some new green fuel types (e.g., green ammonia, green ammonia). They should address safety management concerns related to bunkering and use and help provide consistency and certainty to the market around their validated green credentials to reduce the possible problem of fraudulent sales. Such standards would also generate a clearer framework for innovation.

Thirdly, there is both a need to **scale up supply of renewable energy and further develop the efficiency of equipment** used to produce renewable energy. It is recognized that there is a lack of supply of renewable energy and more efficient technologies are needed to produce the necessary volume of green fuels, especially electricity-based fuels.

4. Fuel specific innovations are needed in all three parts of the value chain

The innovations needed have the general aim of improving the cost efficiency, performance, safety and sustainability of the fuel value chains.

Concerning **fuel production**, the innovations suggested should address the common problems of high material cost and energy use of current technologies. These two items have a negative impact on the current capital and operational costs. This covers, for instance, electrolysis technologies used in the production of hydrogen. Furthermore, innovation of green desalination technologies is needed especially for countries with poor water supply, a key feedstock for hydrogen production. With respect to biomass fuels, further innovation is needed to improve access to a wider range of feedstock sources given that the current supply is perceived as limited.

Concerning **bunkering infrastructure**, innovations are called for to address the difficulties in transporting fuels efficiently and at scale, and in guaranteeing safe and efficient bunkering. Also, new innovative solutions are needed to address safety and maintenance concerns.

Concerning **vessel designs and fuel storage systems**, adaptations to enable the safe carriage of larger quantities of alternative fuels with lower energy density are needed. Moreover, new propulsion and emission control approaches would assist in ensuring good performance and the mitigation of negative environmental impacts from derived emissions. Gaps common to all fuels include commercially available green pilot fuels and zero emission auxiliary engines. An ‘innovation push’ is needed to enable vessel propulsion systems to meet zero carbon targets.