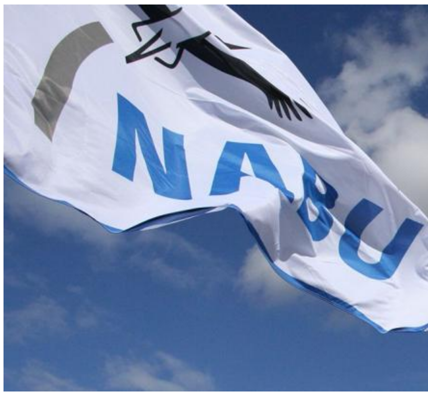
STUDY SHIPPING

Ammonia as Marine Fuel

Risks and perspectives - Summary



The decarbonisation of the shipping sector ultimately requires the switch to alternative post-fossil fuels. Ammonia has recently received increasing attention as a potential marine fuel that could drive this decarbonisation. In the context of a growing hydrogen economy, ammonia is also interesting as the cheapest form in which to transport hydrogen over long distances and in large volumes. It is a basic chemical which is globally traded and produced; it has mainly been used for fertilizer production to date. However, ammonia has hitherto not been used as a marine fuel. It is a carbon-free energy-carrier but also toxic. If ammonia were to be used in shipping, it needs to be safe for humans and the (marine) environment. While decarbonising the sector, ammonia should not result in higher emissions or environmental risks.

This study assesses whether these potential risks and challenges of ammonia have been sufficiently considered and whether this impacts ammonia's suitability as a future marine fuel. The study summarises the state of the art and focuses on ammonia's impact on marine ecosystems as well as the environmental impact of combusting ammonia.

Toxicity

Considering its toxicity, various studies show that the acute ecotoxicity of ammonia to fish and aquatic invertebrates is very high and has a similar order of magnitude to the acute toxicity of Heavy Fuel Oil (HFO). Ammonia also has long-term toxic effects on fish and aquatic invertebrates. However, under real environmental conditions, ammonia concentrations are expected to decrease more rapidly after a spill than with HFO. At the same time, a huge influx of ammonia into a water body can lead to eutrophication because ammonia is a nitrogen source for algae and microorganisms. If ammonia is spilled into water, it floats on the water surface and rapidly dissolves within the water body into ammonium hydroxide while concurrently boiling into the atmosphere as gaseous ammonia. The ratio of ammonia dissolved in the water versus its release to the atmosphere as vapour depends on the dynamics of the release.

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Climate impact and air pollution

Ammonia can be used as a marine fuel in both internal combustion engines and fuel cells. The combustion of ammonia or ammonia mixtures can lead to emissions of nitrogen oxides (NO_x), nitrous oxide (N_2O) and to the direct slip of ammonia (NH_3). There have been no marine ammonia engines to date, either in the testbed or in pilot projects. Sufficient empirical data on the emissions from combusting ammonia does not exist yet. Further research is thus necessary to clarify the quantity of emissions and to develop technologies for reducing or avoiding them.

The application of exhaust gas aftertreatment systems seems to be a promising solution for NO_x emissions and ammonia slip. To ensure the climate benefit of green ammonia, issues with N_2O emissions must be solved as N_2O has a high global warming potential. The elimination of N_2O emissions (or their reduction to a negligible minimum) needs to be proven in typical marine engines. Stringent N_2O emissions regulations could ensure that ammonia engines are designed in a way which guarantees fulfilment of the long-term goal of climate-neutral maritime shipping. To incentivize the development of suitable marine machinery, N_2O could, for example, be covered by maritime carbon pricing policies or limited to tolerable levels through stringent emission standards based on carbon dioxide equivalents. Ammonia combustion will likely require a pilot fuel to facilitate combustion. Dual fuel engines will thus be a promising pathway for ammonia to enter the maritime sector. Ammonia engines are expected by 2024. First pilot projects might start shortly thereafter with a potential commercial scale-up starting in the late 2020s.

Fuel cells could circumvent the problem of emissions from combustion engines but their commercial use in deep sea shipping is even further away than ammonia internal combustion engines (ICEs). The use of ammonia in fuel cells should thus be pursued alongside the development of ammonia engines.

Comparison of the fuels

The table compares ammonia with other fuels when used in ICEs based on key environmental criteria. The comaparison is done horizontally across fuels. The higher the given number, the better the performance of the fuel. Ammonia's potential to reduce greenhouse gas (GHG) emissions compared to other fuels needs to be evaluated with uncertainties in terms of N_2O emissions. Since we apply a well-to-wake approach, methanol is considered climate-neutral even though it is a carbon-based post-fossil fuel.

Table 1: Comparison of post-fossil fuels and fossil heavy fuel oil (HFO) based on key environmental criteria

Criterium	Ammonia	Hydrogen	Methanol	HFO
GHG reduction potential	4*	5	5**	1
Air pollutants	3	5	4	1
Aquatic ecotoxicity	2	5	5	1
Human toxicity	2	5	3	3
Flammability	2	1	2	5
Explosion risks	4	2	5	5

Notes: Ranking: 1= high risk/ low performance to 5=low risk/ high performance, *uncertainty about N_2O emissions, **well-to-wake
Source: Authors' own compilation

Ammonia is a future fuel candidate as it is a carbon-free energy carrier and thus likely to be cheaper than other post-fossil fuels. Robust safety guidelines will be necessary for the safe handling of ammonia onboard ships. Due to its risk profile, its use may not be applicable in all segments of the maritime sector, for example in passenger ships. The maritime sector will likely rely on different post-fossil fuels in future depending on the market segment. In addition, stringent well-to-wake regulation including all GHG emissions will be required from the outset to prevent that decarbonization through ammonia is undermined by significant N_2O emissions.

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