MariNH3

Clean, green ammonia
engines for maritime

Pathways to technology acceptance

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MariNH3 Conference
28th June 2023

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Ammonia market challenges

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- Opportunities:
  - Existing infrastructure (Elishav et al., 2021)
  - International Maritime Organisation's (IMO) dedication to cut shipping industry emissions by a minimum of 50% by 2050.

- Challenges:
  - Cost: 200-300% times more costly; global investment of 6 trillion USD to decarbonise 40% (Ash and Scarborough, 2019); higher level of upfront investment needed than other potential fuels (Nayak-Luke et al., p31); retrofitting a vessel to run on ammonia is around >50% of the vessel's market value (Grieg Star, 2023, p8)
  - Supply/demand dilemma (Grieg Star, 2023, p8) with 3 times current production required. Around 20% redundancy in current system – additional production capacity could be realised in 30 years (Alfa Laval et al., 2020).
  - Renewable energy costs and availability - 400 GW power is needed to meet 30 % of future marine fuel demand (Alfa Laval et al., 2020) = 330 more of the biggest offshore windfarm in the world
  - Demand from other sectors: refrigeration, farming and potentially other sectors not yet identified...

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Regulatory challenges

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- How can innovation be encouraged and economic incentives created to unlock investment in green ammonia technologies?
- Policies need to ensure that new fuels are sustainable, and all emissions are accounted for throughout the lifecycle (Ash and Scarborough, 2019)
- Policymaker capacity:
  - Multi-fuel future dependent on the size vessel, cargo and type of journey
  - Multi-sector legislation for use of ammonia: transportation, shipbuilding, vessel class, international shipping regulations, port regulations, refrigeration, farming, and renewable energy.
  - Multi-level governance challenge for an international industry

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Current Status of Legislation...

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The 'Pacing Problem'

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- The emergence of numerous new net-zero technologies has created a ‘pacing problem’ (Worthington, 1982)
- Challenges with pacing occur when the new technology fails to fit with existing regulatory frameworks and the rapid pace of innovation outstrips the development of legislation (Marchant, 2011)
- However, to ensure that the ammonia fuel innovation system provides the maximum benefit to society and economy, good governance with an appropriate regulatory framework is essential (Fegerber and Srholec, 2008)

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Challenges in current legislation

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- Vessel-by-vessel process requires extensive certification – passing risk to first movers
  - ‘Alternative design approach’ : Safety of Life at Sea (SOLAS) and the International Code of Safety for Ship Using Gases of Other Low-flashpoint Fuels (IGF code)
  - 'Plan-Do-Check-Act approach': MCN 664 (M+F) Certification process
  - MARPOL, the control of Volatile Organic Compounds (VOCs) at tanker terminals. 18 months for registration
- Raft of UK, European and international regulations for environmental protection – although impacts are less than other fuels and have greater potential to be cleaned effectively from the environment (Environmental Defence Fund, 2022)
- USA Standard 1910.1000 also limits the number of hours employees can be exposed to an air contamination of 50ppm

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Future framework

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- Energy Efficiency Design Index (EEDI) which requires ships to comply with mandatory minimums of energy efficiency performance
- Ship Energy Efficiency Plan (SEEMP) that establishes mechanisms for the improvement of new and existing ships by shipowners. These measures are included in MARPOL Annex VI and are the first mandatory GHG reduction initiatives for the global shipping industry (Alfa Laval et al., 2022).
- The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI, does not regulate other combustion products such as N2O so is considered to have low regulatory readiness – subject to revision by the IMO, with guidelines expected to be completed in 2024

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"Green ammonia is well positioned to become a leading net-zero fuel for the shipping industry, yet the current lack of visibility of future effects of regulation are problematic.

The current legislative horizon ends in 2026, where new metrics must be introduced that provide stimulus for the rollout of green ammonia as a maritime fuel.

Pathways already being established for the governing of marine fuels such as methanol and ethanol. Through **collaboration**, the green ammonia industry is poised to pave a pathway to a well-functioning net-zero industry.

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