

# MariNH<sub>3</sub>

Clean, green ammonia  
engines for maritime

## Ammonia as a Sustainable Marine Fuel: Policy challenges and recommendations

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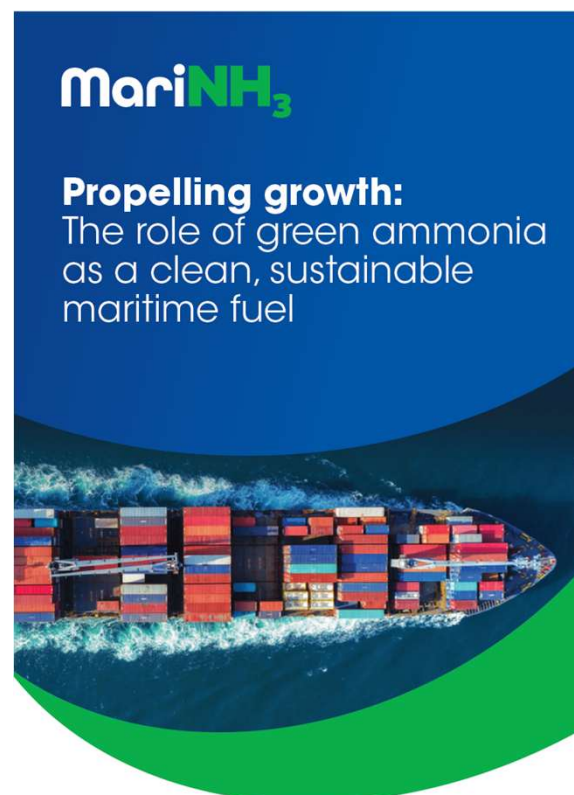
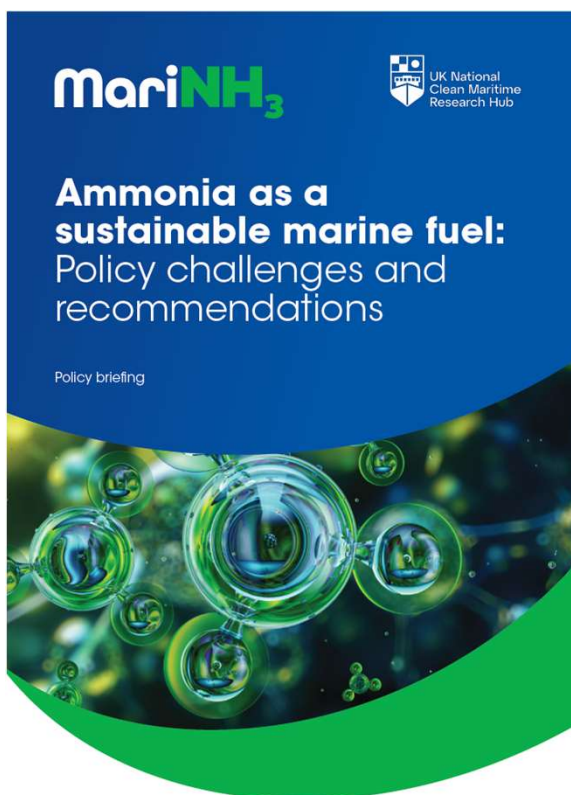
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# The Whitepaper Series

**MariNH<sub>3</sub>**  
Clean, green ammonia  
engines for maritime



## **Ammonia dual fuel marine engine technologies: Fundamentals, performance and emissions**

A technical overview of state-of-the-art ammonia dual fuel engine technologies. It outlines the rationale for ammonia in marine applications, examines key technical and acceptance challenges, and reviews performance, efficiency and emissions characteristics, alongside future development pathways.

**Issue date: September 2026**

## **Ammonia mono fuel marine engine technologies: Ultimate performance and emissions capabilities**

An examination of the performance and emissions potential of dedicated ammonia (mono fuel) engines. It explores the technical limits and opportunities of ammonia combustion and after-treatment systems, providing a comprehensive assessment of their capability to meet future maritime requirements.

**Issue date: October 2026**

## **Ammonia beyond marine: The application of ammonia in off-highway and stationary genset sectors**

An exploration of the wider application of ammonia beyond shipping. It compares the techno-economic performance of ammonia and hydrogen across off-highway and stationary power generation sectors, highlighting opportunities, constraints and potential deployment pathways.

**Issue date: October 2026**

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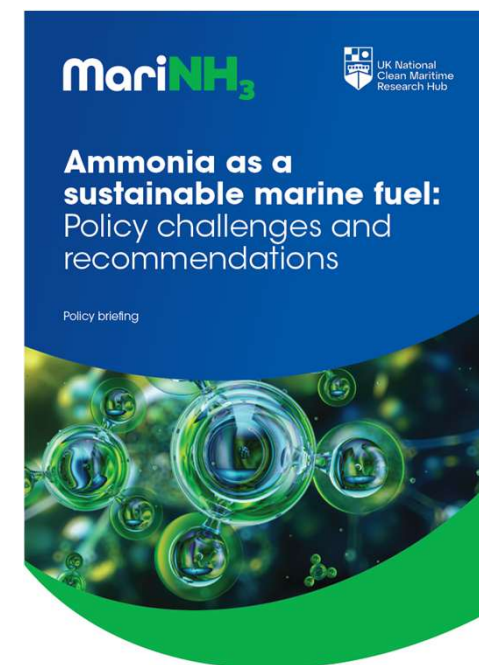
# Policy briefing

- MariNH<sub>3</sub> and UK National Clean Maritime Research Hub collaboration
- Support from Department of Transport, Maritime and Coastguard Agency, the Department for Energy Security and Net Zero

**Challenge #1** Ammonia as a fuel

**Challenge #2** Green ammonia supply

**Challenge #3** Safety management



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# Policy and safety regulations

Attribute	IMO	EU	UK
<b>Ambition</b>	<ul style="list-style-type: none"> <li>Net zero by 2050 – interim targets to be agreed</li> </ul>	<ul style="list-style-type: none"> <li>2030: 55% reduction</li> <li>2050: Net zero</li> </ul>	<ul style="list-style-type: none"> <li>2030: 30% reduction</li> <li>2040: 80% reduction</li> <li>2050: Zero emissions</li> <li>No out-of-sector offset</li> <li>WtW basis</li> </ul>
<b>Greenhouse gas (GHG) pricing &amp; emissions trading schemes (ETS)</b>	<ul style="list-style-type: none"> <li>Market based measures under negotiation</li> </ul>	<ul style="list-style-type: none"> <li>EU ETS includes shipping from 1 January 2024 phase-in</li> <li>100% from 1 January 2026 (intra-EU &amp; 50% extra-EU voyages)</li> </ul>	<ul style="list-style-type: none"> <li>UK ETS includes shipping from 1 July 2026 (UK to UK voyages and at port emissions)</li> </ul>
<b>Energy efficiency &amp; fuel standards</b>	<ul style="list-style-type: none"> <li>EEDI &amp; EEXI for (new &amp; existing) vessel design</li> <li>Carbon Intensity Indicator (CII), CO<sub>2</sub> only, TtW basis</li> <li>Global fuel standard under negotiation</li> </ul>	<ul style="list-style-type: none"> <li>IMO plus FuelEU Maritime</li> <li>GHG intensity with penalties for non-compliance, CO<sub>2</sub> + CH<sub>4</sub> + N<sub>2</sub>O, WtW basis</li> </ul>	<ul style="list-style-type: none"> <li>IMO only. No additional UK specific measures</li> <li>Fuel Standard consultation expected in 2026</li> </ul>

**Table 2 notes:**

EEDI = Energy Efficiency Design Index (for new ships)

EEXI = Energy Efficiency Existing Index (for existing ships)

WtW = Well-to-Wake – whole life cycle consideration from extraction through production processes and distribution to consumption

TtW = Tank-to-Wake – consumption of fuel only

Country	Summary
<b>UK</b>	<p><b>Control of Substances Hazardous to Health (COSHH) Regulations:</b> Under COSHH 2002, employers must assess the risks from hazardous substances such as ammonia, ensure proper handling, provide personal protective equipment (PPE), and implement health surveillance.</p> <p><b>COMAH Regulations:</b> The Control of Major Accident Hazards (COMAH) Regulations 2015 require high-risk industrial sites to prepare safety reports, conduct risk assessments, and establish both on-site and off-site emergency plans. [Aligns with the EU Seveso III Directive]</p> <p><b>Marine Guidance Notes Certification:</b> For vessels using innovative technologies.</p>
<b>EU</b>	<p><b>Seveso III Directive (2012/18/EU):</b> Prevents and limits the consequences of major industrial accidents involving dangerous substances.</p> <p><b>Industrial Emissions Directive (IED) 2010/75/EU (EU):</b> IED ensures that NH<sub>3</sub> plants minimise air and water emissions using Best Available Techniques (BAT), thereby reducing the environmental and safety risks from accidental releases.</p>
<b>USA</b>	<p><b>National Fire Protection Association (NFPA) 55 &amp; American Petroleum Institute (API) 751:</b> These codes provide guidelines for the storage, handling, and piping of anhydrous ammonia, with emphasis on containment, leak detection, and fire protection measures.</p> <p><b>Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) – 29 Code of Federal Regulations (CFR) 1910.119:</b> These standards mandates hazard identification, risk analysis, operating procedures, maintenance of critical equipment, employee training, emergency response plans, and management of change (MoC) for highly hazardous chemicals like ammonia.</p>

# Challenge 1: Ammonia as a fuel

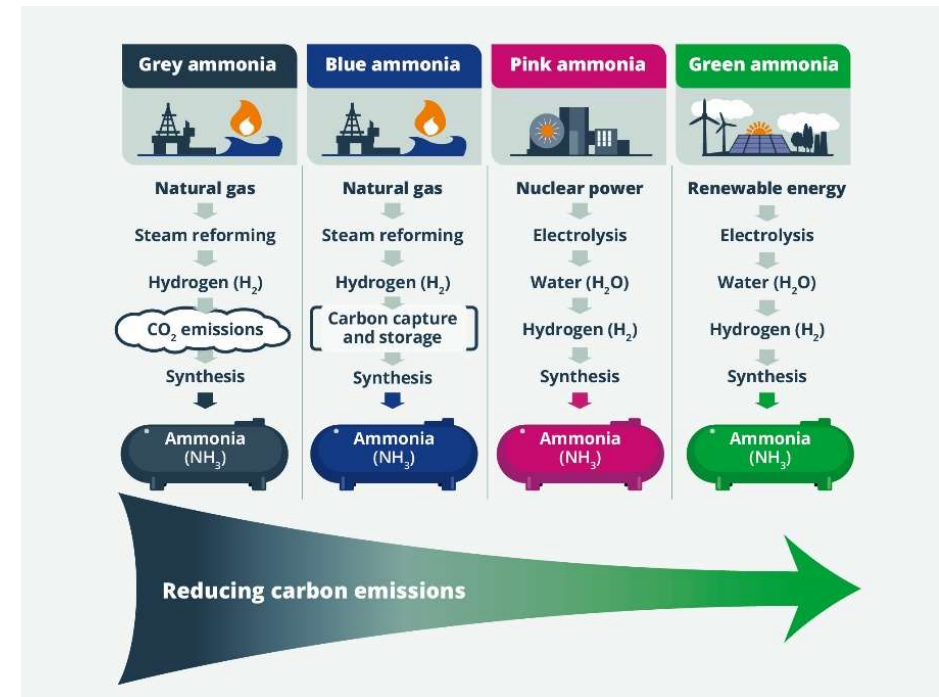
- Use as a fuel is at the heart of the adoption challenges.
- Not unique to ammonia
- Engineering technicalities well addressed
  - Storage,
  - Ignition,
  - Flame stability,
  - Environmental impact
- Remaining issues are sociotechnical

Property	Ammonia (Liquid)	Liquefied Hydrogen	Liquefied Natural Gas	Diesel
Storage temperature (°C)	25	-253	-162	25
Storage pressure (kPa)	1,030	101.3	101.3	101.3
Autoignition temperature (°C)	924	844	538	503
Fuel density (kg/m <sup>3</sup> )	602.8	70.8	422.6	838.8
Energy density (volumetric) (MJ/m <sup>3</sup> )	11,333	8,539	20,825	36,403

# Challenge 2: Green Ammonia Supply

## - Production

- Supply and demand co-ordination issues – shipping industry has long-term supply agreements
- Marketplace challenges are being faced by all the renewable electricity derived synthetic fuels
- Increasing deployment will reduce costs
- Production – energy store and transportation
- Electrolyser capacity and renewable energy infrastructure
- Modular Supply



# Challenge 2: Green Ammonia Supply

## - Economics



- e-fuel production electricity cost – UK reliance on natural gas and associated charging structure
- Energy store potential can mitigate seasonality or other demand-supply challenges
- Blue ammonia cost parity 2030, green ammonia in the early 2030s
- Green ammonia enables compliance with tightening emissions standards typically linked with carbon taxation measures
- Co-locating ammonia production and bunkering facilities offers co-ordination advantages and regional economic development benefits

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# Challenge 3: Safety Management

	Toxicity	Flammability & reactivity	Corrosion & material degradation	Training & operational safety
<b>Key risks</b>	<ul style="list-style-type: none"> <li>Small leaks can cause acute harms</li> <li>Releases can disperse hundreds of metres</li> <li>Accumulation risk in enclosed spaces</li> </ul>	<ul style="list-style-type: none"> <li>Lower ignition risk but hazards increase in confined spaces or when mixed with hydrogen or hydrocarbons</li> </ul>	<ul style="list-style-type: none"> <li>Caustic burns</li> <li>Corrosion of metals</li> <li>Stress corrosion cracking</li> <li>Hydrogen embrittlement</li> </ul>	<ul style="list-style-type: none"> <li>New skills required</li> <li>Uncertainties due to limited experimental data</li> <li>Increased public proximity</li> </ul>
<b>Typical maritime context</b>	<ul style="list-style-type: none"> <li>Shipboard tanks</li> <li>Machinery spaces</li> <li>Bunkering areas</li> <li>Enclosed compartments</li> </ul>	<ul style="list-style-type: none"> <li>Engine rooms</li> <li>Mixed-fuel systems</li> <li>Maintenance scenarios</li> </ul>	<ul style="list-style-type: none"> <li>Bunkering spills</li> <li>Long-term tank and piping integrity</li> <li>Stressed components</li> </ul>	<ul style="list-style-type: none"> <li>Ship-to-ship and shore-to-ship bunkering</li> <li>Emergency response</li> <li>Routine operations</li> </ul>

	Toxicity	Flammability & reactivity	Corrosion & material degradation	Training & operational safety
<b>Mitigations &amp; controls</b>	<ul style="list-style-type: none"> <li>Containment</li> <li>Ventilation</li> <li>Gas detection</li> <li>Emergency procedures</li> <li>Personal protective equipment (PPE)</li> <li>Trained personnel</li> </ul>	<ul style="list-style-type: none"> <li>Ignition control</li> <li>Ventilation</li> <li>Leak prevention</li> <li>Compatible materials</li> <li>Fire detection and suppression</li> </ul>	<ul style="list-style-type: none"> <li>Material selection</li> <li>Corrosion monitoring</li> <li>Coatings</li> <li>Moisture/oxygen control</li> <li>Personal protective equipment (PPE)</li> <li>First-aid facilities</li> </ul>	<ul style="list-style-type: none"> <li>Training and certification</li> <li>Standard Operating Procedures</li> <li>Drills</li> <li>Coordinated safety management systems</li> </ul>
<b>Regulatory &amp; standards</b>	<ul style="list-style-type: none"> <li>Rules for design</li> <li>Containment</li> <li>Detection</li> <li>Bunkering</li> <li>Crew training</li> <li>Personal protective equipment (PPE)</li> </ul>	<ul style="list-style-type: none"> <li>Guidance on ammonia fire/explosion behaviour</li> <li>Detection &amp; protection standards</li> </ul>	<ul style="list-style-type: none"> <li>Material standards</li> <li>Inspection intervals</li> <li>Decontamination requirements</li> </ul>	<ul style="list-style-type: none"> <li>Training standards</li> <li>Harmonised bunkering requirements</li> <li>Toxicity-focused risk frameworks</li> </ul>
<b>Evidence gaps, further work</b>	<ul style="list-style-type: none"> <li>Better dispersion &amp; consequence data</li> <li>Model validation</li> <li>Community risk guidance</li> </ul>	<ul style="list-style-type: none"> <li>Research on ignition behaviour</li> <li>Mixed-fuel effects</li> <li>Explosion characteristics</li> </ul>	<ul style="list-style-type: none"> <li>Long-term integrity data</li> <li>Stress corrosion cracking thresholds</li> <li>Embrittlement guidance</li> </ul>	<ul style="list-style-type: none"> <li>Validated datasets for modelling</li> <li>Emergency planning</li> <li>Regulatory development</li> </ul>

# Challenge 3: Safety Management

- Fuel agnostic approach can exacerbate knowledge gaps for safe use and market restructuring
- Holistic approach that addresses the interlinked innovation systems to embrace opportunity whilst minimizing the risks of new fuel adoption
- Further research in: containment systems, bunkering and handling protocols, sensing and ventilation technologies, and other measures needed to prevent, detect and manage incidents effectively
- A robust technical foundation is necessary for regulatory approval and public trust

# Policy recommendations

- Market measures
- Bunkering hub development funding
- Support development of green ammonia corridors
- Accelerate adoption of safety regulations and crew training programs
- Mandate the full life GHG emissions
- Public information and communication

Ammonia as a fuel	Green ammonia supply	Safety management
Carbon pricing with ratchet thresholds to encourage shift to zero carbon fuels	Capitalise on ammonia and hydrogen's shared infrastructure requirement	Government support for skills and safety training in the new use of ammonia
Fuel standards based on whole life cycle (Well-to-Wake) and additional greenhouse gases (not just CO <sub>2</sub> )	Green Shipping Corridors with ammonia fuel could encourage development of supply	World class safety standards should be maintained
R&D for nitrous oxide and ammonia leakage mitigation technologies	Strategic planning around which ports to provide incentives for development of ammonia bunkering facilities	Communications campaign for public acceptability of ammonia as a fuel

# Propelling Growth: The role of ammonia as a clean, sustainable maritime fuel

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### 1. Establish effective market incentives

- Implement meaningful carbon pricing, including progression on the currently stalled IMO mechanisms.
- Create clear market signals that reward low carbon fuels such as green ammonia.

### 2. Enable port side ammonia ecosystems

- Support regulatory frameworks that allow ports to build integrated ammonia infrastructure.
- Facilitate development of production, import/export facilities, bunkering systems, and connections to renewable energy and hydrogen networks.

### 3. Build training and skills capacity

- Develop specialised training for seafarers, port workers, regulators, and emergency responders.
- Ensure that skills development keeps pace with technology deployment.

### 4. Improve public and stakeholder understanding

- Communicate clearly that the benefits of ammonia outweigh the manageable risks.
- Apply lessons from the mixed success of hydrogen projects, particularly around community engagement.

### 5. Continue research and innovation

- Sustain research into engine combustion, after treatment systems, and emissions control.
- Support innovation in safe storage, fuel handling and leakage prevention.
- Strengthen understanding of environmental and social impacts.
- Expand research into effective pathways for transitioning the maritime sector.

Thank you! Diolch!

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