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Clean, green ammonia
engines for maritime

Sponsored by: CIMAC International Council Power | Drives | Propulsion

Ammonia as a sustainable alternative marine fuel

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University of Birmingham
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Objectives and Knowledge Areas

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- **Overall objectives**
  - Paper 1: 'Educational' piece that will outline current state of the industry and outline why ammonia over alternatives. Will include some 'myth-busting elements'. Focus will be tailored to government.
  - Paper 2: Outline how to resolve problems and what will be needed in the future. Focus will be problem solving and future actions.

Any contributions?

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- **Key areas of knowledge**
  - Engineering
  - Economic
  - Production
  - Legislation
  - Social
  - Safety
  - Environment

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Engineering

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Key areas where improved understanding is required by 'lay-persons':

- Combustion
  - Production of higher levels of NOx offset carbon free advantage
  - Energy density
- Retrofit v dedicated ammonia engines
  - Pilot fuel requirement
  - Timelines of commercially available engines
- Safety

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Production

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Misconceptions:

- Ammonia requires fossil fuels
- Production presents risks to communities
- Requires difficult-to-acquire materials
- Cannot be produced in small facilities

Areas of clarification:

- Energy intensity
- Transport and infrastructure challenges

Hydrogen production by direct seawater electrolysis Xinghua Bay

Success!

- 130 ammonia-ready vessels on order,
- 240 dual-fuel engines entered service
- 30 ammonia-specific dual fuel engines delivered by MAN.
- 4-stroke ammonia engine commercially available through Wärtsilä
- Blue Point Complex Louisiana – CCUS
- Brazil, Oman Gigascale plants proposed
- Wyoming, Nebraska, Japan, Netherlands small-scale/modular proposals

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Environment

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- Well to Wake: Well to Tank + Tank to Wake
- Tank to Wake
  - carbon free, but fuel slip & N2O emissions
  - NOx emissions (6-500x that of NG)
- Well to Tank
  - Production method depends on source; green, blue, brown, grey or pink?
  - Transportation
- Energy consumption for compression/ liquefaction/re-gassification

Type	Source	Indicative Carbon Footprint
Brown	Coal/oil	90-140%x MDO
Blue	Fossil with CCS	43% reduction
Green	Solar	45% reduction
Green	Wind	79% reduction

- Few LCA studies with wide ranging results: more research needed

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Safety

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Toxicity

- Concentrations and duration of exposure impact on the severity of health effects
- Eye irritation and respiratory problems at 220ppm (only 0.022% air) for 30 minutes
- Fatal at 2,500ppm (0.25% air) and over
- Wind conditions / surrounding infrastructure
- Toxicity >3x conventional fuels diesel/methanol
- Requires new regulatory approaches for both toxicity and flammability

Flammability

- Hazard but lower risk than toxicity
- Narrow flammability range 15-28% by volume of air c.f. hydrogen 4-75%
- Has a higher auto-ignition threshold when compared with even methane (651degreesC vs 537degreesC)

Implications:

- Handling, storage and refuelling
- Leak detection and ventilation
- Emergency response plans

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Safety

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Corrosivity

- Corrosive properties especially metals and skin
- Interaction with aqueous environments produces ammonium hydroxide highly caustic
- Ammonia solutions can cause skin burns and eye damage that can develop over several days
- Stress Corrosion Cracking can lead to sudden failures in tanks & engine components
- Hydrogen presence risks hydrogen embrittlement and component failure

Implications:

- Material selection and mitigation strategies needed for long term integrity and safety

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Policy Instruments: headlines, but limited instructions…

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- Landscape pressure: International Maritime Organisation (IMO) near Net Zero by 2050, including well-to-wake (2023) penalty of 380 USD per tonne of non-compliant carbon (MEPC 83 2025).
- FuelEU Maritime carbon trading – onus rests with International Safety Management (ISM) company – data granularity, contractual burdens, documentation and verification.
- Market remains default mechanism continuing to prioritise the cheapest alternative fuel, MEPC 82 1% non-biological clause by 2031
- Limited regulation currently exists on the use of ammonia as an energy source (Crolius et al.,2021), cargo and passenger weighing 500gross+ permitted to use non-cargo ammonia as fuel (109th IMO Maritime Safety Committee, October 2024) - Vessel-by-vessel process remains
- MEPC82 broad agreement on the net-zero framework
- Carbon Intensity Indicator (CII) and Energy Efficiency Existing Ship Index (EEXI) review 2025; Onboard CCs by 2028.

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Economic

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Challenges: Cost - ‘Competing’ fuels - Speed to market

- Role of carbon taxation
- Multi-sector dependencies
  - Reducing cost of renewable electricity
  - Aligning Haber-Bosch process with intermittent energy or demand
  - Addressing risk and outlining the wider opportunity
- Bio-fuels currently favoured for their speed, but challenges for scale:
  - Land required
  - Price volatility
  - Impact on food prices
- Ammonia’s established supply chain
- Economic and cluster development opportunities

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Social

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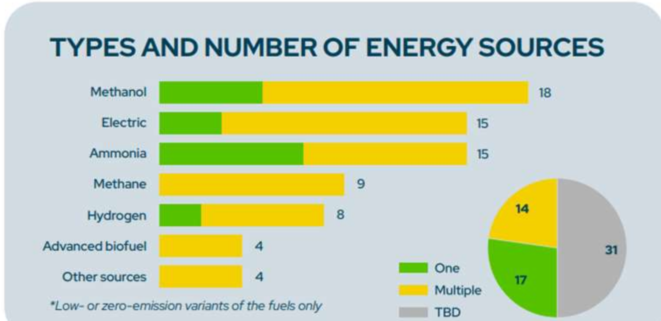
- Green Corridor progress
- Ports as sites of sustainable transition
- Danger to communities where production or bunkering takes place
- Public perception
- Chemical ports better positioned
- Geography and justice within industrial decarbonization
- Jurisdiction of responsibilities
- Training – on land and vessel



Source: Getting to Zero Coalition, 2024

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Success!

- EU, Alternative Fuels Infrastructure Regulation (AFIR)
- Holland, Australia vessel-to-vessel
- Singapore terminal-to-ship
- Singapore supply chain design
- SwitcH2 floating ammonia Portugal
- GHyGA 2W2NH3 retrofitting semi-submersible platforms
- Viking hydrogen cruise vessels
- Port of Milford Haven hydrogen community consultation
- Fortescue Green Pioneer
- ASPIRE
- UK Clean Maritime Research Hub
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