



AUSTRALASIAN INSTITUTE
OF MARINE SURVEYORS

Shipshape

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**Bulk carrier safety, efficiency
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YEAR'S END A TIME TO REFLECT

Ammonia in shipping: tracing the emergence of a new fuel

DNV has released a White Paper discussing ammonia in shipping. The paper provides the context of ammonia as an emerging fuel type. References to sections in the White Paper have been identified and provided in footnotes to the paper.

Executive summary

In the maritime sector, ammonia has been identified as a future fuel to decarbonise shipping. Interest in ammonia as a fuel has increased significantly in recent years, following the International Maritime Organization's (IMO) approval of the Net-Zero Framework in April 2025, though its use also presents new safety challenges compared to conventional fuels – primarily due to its toxicity.

This paper assesses the current status of low greenhouse gas (GHG) ammonia as a ship fuel by considering 10 main barriers, with a specific focus on the changes between 2020 and 2025.

Across most barriers, significant advancements have been made in the last five years. Today, ammonia-fuelled engines are in the final stages of development for installation on 39 scheduled new-builds, and major ports are preparing for safe ammonia bunkering – a significant development compared to 2020, when such engines were only at the concept stage with no ammonia-capable newbuilds on order.

To effectively address the remaining challenges, accelerate the uptake of ammonia as fuel and achieve the widespread use of ammonia, two inter-linked objectives must be met.

Firstly, to build, fuel and

operate a “pioneering” ammonia-powered fleet (a few dozen vessels, crewed by a few hundred competent personnel, and bunkering a few million tonnes of ammonia from a dozen ports).

Secondly, to establish the necessary framework for further scaling (thousands of vessels, many thousands of crew, bunkering tens of millions of tonnes of fuel from ports across the globe).

For a pioneering fleet, we argue that it is not necessary to fully solve all barriers. Currently, many of the main barriers can be considered sufficiently low, making the realisation of this fleet feasible:

1. a functional risk-based framework for the safe application of ammonia as a ship fuel allows for statutory approval of the first ammonia-powered vessels;
2. the required technical solutions are shortly being installed on several deep-sea newbuilds in the orderbook, and first use have been demonstrated – in a tug and an offshore vessel;
3. the first ports and fuel producers are ready to safely supply first movers; and
4. sufficient competent crew can be trained for a limited number of vessels.

Nevertheless, fuel costs are currently excessively high. This stifles demand, consequently restricting investment in essential fuel production, distribution and bunkering infrastructure.

This barrier can be addressed through financial support mechanisms which reduce the cost gap between low-GHG

ammonia and fossil fuel oils. The scope and duration of such mechanisms may be quite limited.

For the upscaling phase, our barrier assessment changes: while the success of the limited pioneering fleet can rely on bespoke solutions and the willingness of first-movers to accept an increase in commercial risk, scaling up requires a framework of standardised solutions that can be easily adopted across the industry.

To achieve this:

1. the global GHG regulations must be tightened to create functional price-parity for new fuels, with no delay in the ongoing work at the IMO with the Net-Zero Framework;
2. ammonia's strong industrial platform for scaling can thus be leveraged to achieve scale for the fuel-production, distribution, and bunkering infrastructure; further
3. the risk-based approval framework must be replaced by prescriptive regulations mandated by the International Code of Safety for Ships using Gases or Other Low-flashpoint Fuels (IGF Code);
4. many more ports must be able to supply fuel, requiring harmonisation of port safety standards and dissemination of lessons learned; and, finally
5. standardised training must be in place to ensure enough competent crew.

These advances are within reach and show a path ahead for ammonia to fulfil its potential as a decarbonization option for deep-sea shipping¹.

¹ Executive Summary, DNV White Paper, pp.4-5.

Section 2: Why ammonia?

Those who regard ammonia as a promising option would highlight the many advantages of the fuel compared with its competitors – though, as we will see in Section 3, the use of ammonia as a marine fuel is not without difficulties. The barriers to its widespread adoption are several. In the following, we outline the most important advantages.

Ammonia is a fuel without carbon, which means it releases no carbon dioxide (CO₂) emissions when used in power generation devices, such as fuel cells, internal combustion engines and gas turbines.

Ammonia is a hydrogen-based fuel that is easier to store and transport than pure hydrogen. Its liquid volumetric density is 50 per cent higher than that of hydrogen², positioning it as a candidate for deep-sea shipping fuel. It is also less flammable and can be liquefied at lower pressures and higher temperatures than hydrogen, simplifying its onboard storage.

Ammonia is seen as a less costly option, with more energy-efficient production compared with competing e-fuels, such as e-methanol or e-methane. Most ammonia is produced by the Haber-Bosch process, which combines nitrogen gas (extracted from the air) and hydrogen gas at high pressures and elevated temperatures to form ammonia.

Ammonia production, being carbon-free, does not rely on renewable carbon sources, such as atmospheric CO₂ or sustainable biomass. Green ammonia is, in principle, scalable, since it only requires renewable electricity, water and air. Alternatively, blue hydrogen for ammonia production can be generated from fossil sources with close to

² The volumetric energy density of ammonia and liquefied hydrogen is 12.7 and 8.5 gigajoules per cubic metre (GJ/m³), respectively.

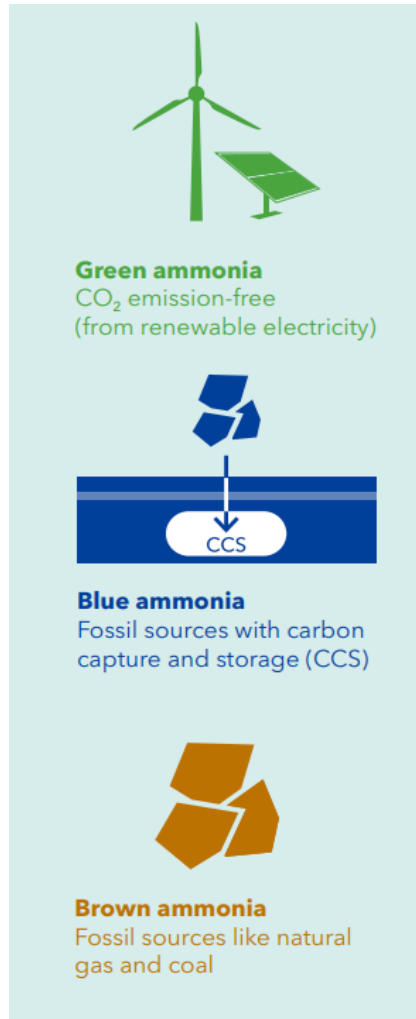


Figure 1.

complete carbon capture and permanent storage (CCS). See Figure 1. (This is Figure 2-1 in the original White Paper.)

Ammonia is one of the most widely produced chemical compounds, mainly due to fertiliser production. Although this ammonia production is almost entirely fossil (brown) today, the industry is developing green and blue production pathways for future supply. In 2024, ammonia's worldwide production reached approximately 200 million tonnes per annum (MTPA) and the successful decarbonisation of this production could lead to shipping benefiting from a well-established production and transportation infrastructure (DNV, 2024b).

Large ammonia storage facilities are typically situated at ports where ammonia is produced and distributed; 126 ports have



ammonia terminals ready to receive and ship this product from 550 ammonia plants (IRENA, 2022) (IEA, 2021). The geographical diversity of ammonia suppliers provides robust and secure supply chains.

The availability of sustainable green or blue ammonia for shipping depends on parallel developments across the complete value chain, including sustainable production, bunkering facilities and vessels, but the existing production and distribution infrastructure can largely be re-used, making scaling easier (Figure 2)³.

The use of existing infrastructure can be stimulated by a flexible chain of custody model that allows mixing of ammonia with different carbon intensity factors (DNV, 2024c⁴).

Ammonia is a substance well-known to the shipping industry, which already has extensive experience in handling and transporting ammonia as cargo at sea, with approximately 18 to 20 million tonnes of ammonia traded annually (some 10 per cent of the production). Ammonia is also used as a refrigerant in certain ship systems.

Despite these virtues, ammonia is at a significant disadvantage compared with conventional fossil fuels. Shipowners have always gravitated towards solutions that are cheaper, more available, more reliable, more efficient and need less space on board.

³ Figure 2 is presented as Figure 2-2 on page 9 of the White Paper.

⁴ DNV (2024c). Maritime Forecast to 2050 - Energy Transition Outlook 2024.

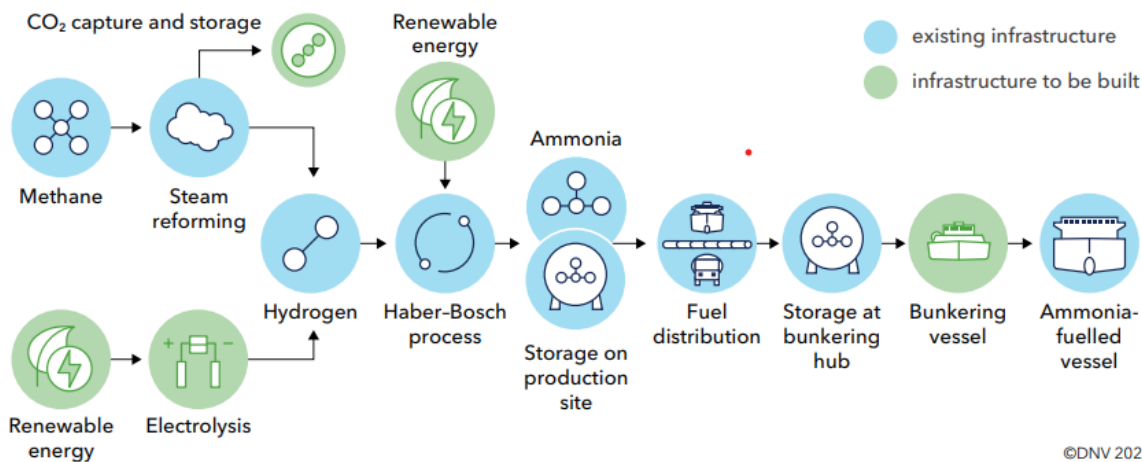


Figure 2: Sustainable ammonia value chain for shipping where the existing production and distribution infrastructure can largely be re-used. Green ammonia will require hydrogen produced by electrolysis with renewable energy, while blue ammonia needs the addition of CO₂ capture in the steam reforming process, including permanent storage.

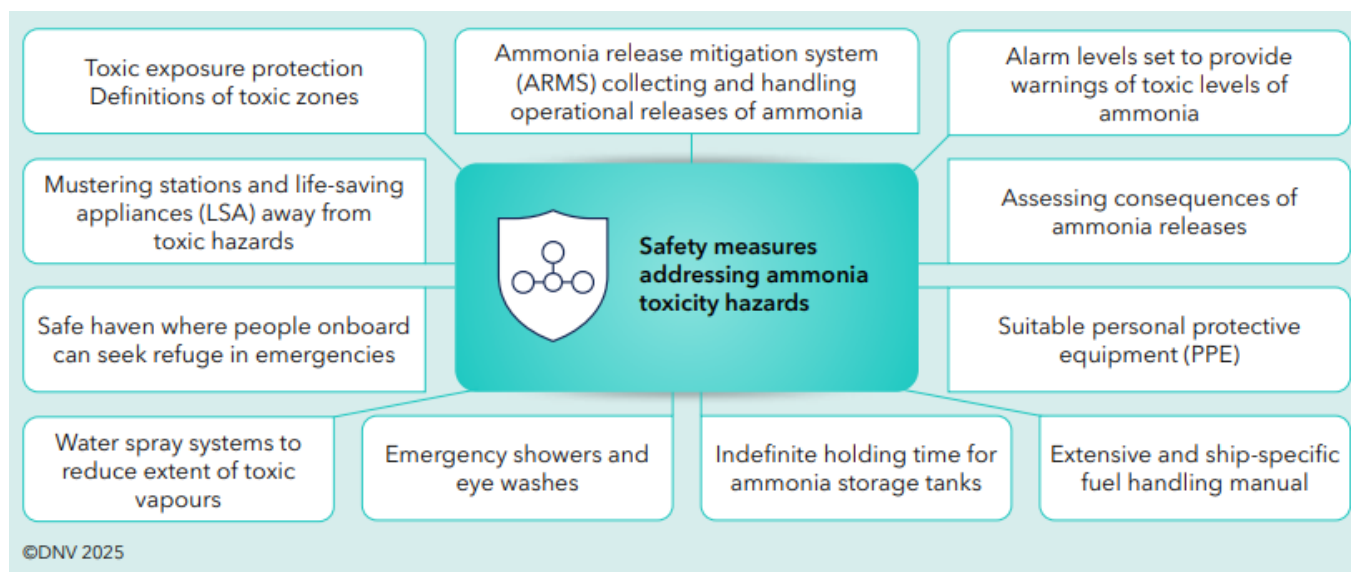


Figure 3: Additional safety measures are required to manage ammonia as a fuel onboard ships in a safe way. The safety principles in the IGF Code for natural gas serve as a foundation.

The challenge is that ammonia and other low or near-zero GHG fuels are typically more expensive, less available, less mature, less efficient, pose new safety challenges (toxicity challenges for ammonia, see below) and require more space on board. The next section explores this in more detail.

Addressing toxicity

Ammonia is toxic to humans, and exposure must be maintained within safe limits to safeguard personnel onboard or in proximity to the vessel. Even at low concentrations, it can irritate the eyes, lungs and skin. However, at higher concentrations or through direct contact, it can

present an immediate life-threatening hazard⁵. Ammonia is also hygroscopic, meaning it draws water from nearby sources, including the human body.

Mucous membranes, such as the eyes, respiratory system and skin, contain high moisture levels and are particularly vulnerable. Additionally, contact with liquefied ammonia can immediately cause frostbite, along with caustic burns.

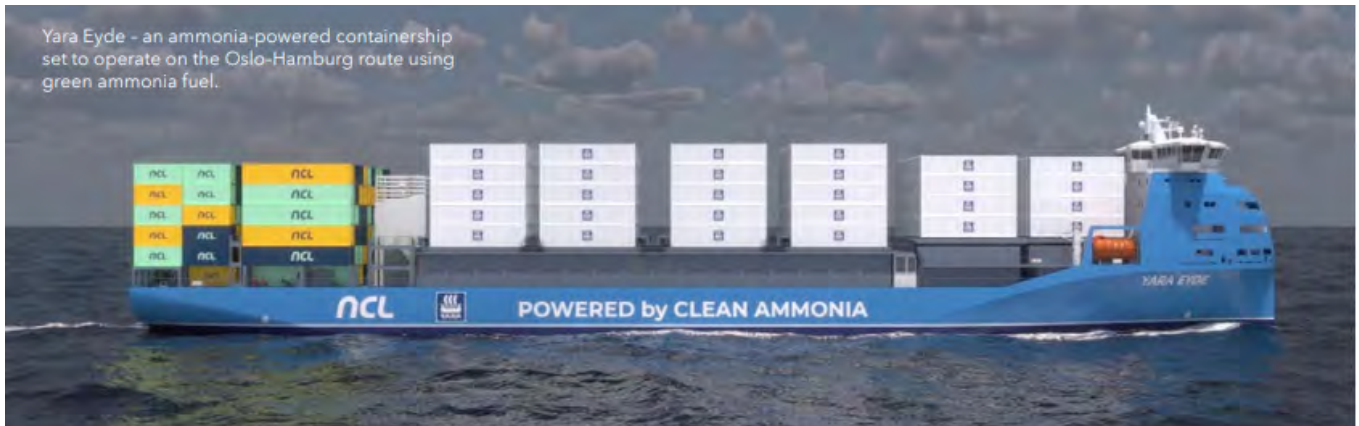
Since the consequences of direct exposure to ammonia

⁵ <https://www.gov.uk/government/publications/ammonia-properties-incident-management-and-toxicology/ammonia-toxicological-overview#health-effects-of-acute-or-single-exposure>

can be severe, technical safety measures integrated into ship design, as well as operational procedures, should aim to minimise and control ammonia releases. Although the safety principles in the IGF Code (segregation from external events, system integrity, double barriers, leakage detection and automatic isolation of leakages) serve as a foundation, additional measures are necessary for ammonia (Figure 3⁶) (DNV, 2022c⁷).

⁶ Figure 3 is resented as Figure 2-3 on page 10 of the White Paper.

⁷ DNV (2022c). Fuel properties and their consequences for safety and operability. DNV report no. 2022-1163, Nordic Roadmap publication no.1-B/2/2022.



These include implementing systems to prevent operational releases of ammonia, providing safe havens for people onboard where they can seek refuge, and having plans in place for safe evacuation in case of accidental ammonia release. Additionally, it is crucial to ensure that suitable protective equipment, depending on duties, is available.

Ensuring that the crew is familiar with the specific hazards related to ammonia is a prerequisite for safe operation – this will require new competencies on board and ashore.

Fuel transfer to a ship always poses a risk and a thorough risk assessment should be conducted to assess the consequences of a worst-case accident during bunkering.

To ensure the safety of society and personnel near a proposed bunkering site, the suitability of the geographical location for bunkering specific fuels must be evaluated by dispersion analysis, considering accidental release scenarios and weather conditions. This is especially important for ammonia bunkering, where potential evaporation of leaked fuel will necessitate considerable safety distances.

Many of the barriers to the uptake of ammonia as marine fuel (see Sections 3 and 4), both on board and ashore, are linked to the toxicity of ammonia.

A list of recommended further

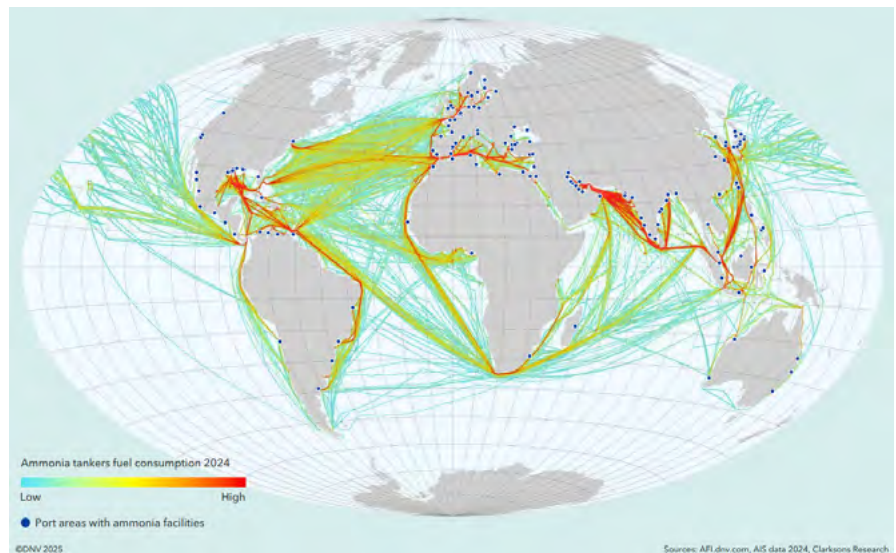


Figure 4 Geographical distribution of fuel consumption for a fleet of 274 ammonia carriers and location of around 140 port areas with ammonia facilities. This overlaps major trade routes for global shipping, indicating that this ammonia network could form a useful steppingstone for further scaling.

reading on the safe introduction of ammonia as fuel is provided at the end of this paper⁸.

Section 3.2.1: Energy cost

Some front-runners decide to move ahead independently: *Yara Eyde*, an ammonia-powered container ship being constructed to serve the Oslo-Hamburg trade carrying fertilisers for Yara, has received CAPEX support from Enova.¹⁹ Yara, a major ammonia producer, plans to fuel the vessel with green ammonia from its production, absorbing the additional cost to showcase the feasibility of ammonia as a fuel and cultivate a potential market for its product.

Fortescue, a major mining company with plans to produce low-GHG ammonia, has similar

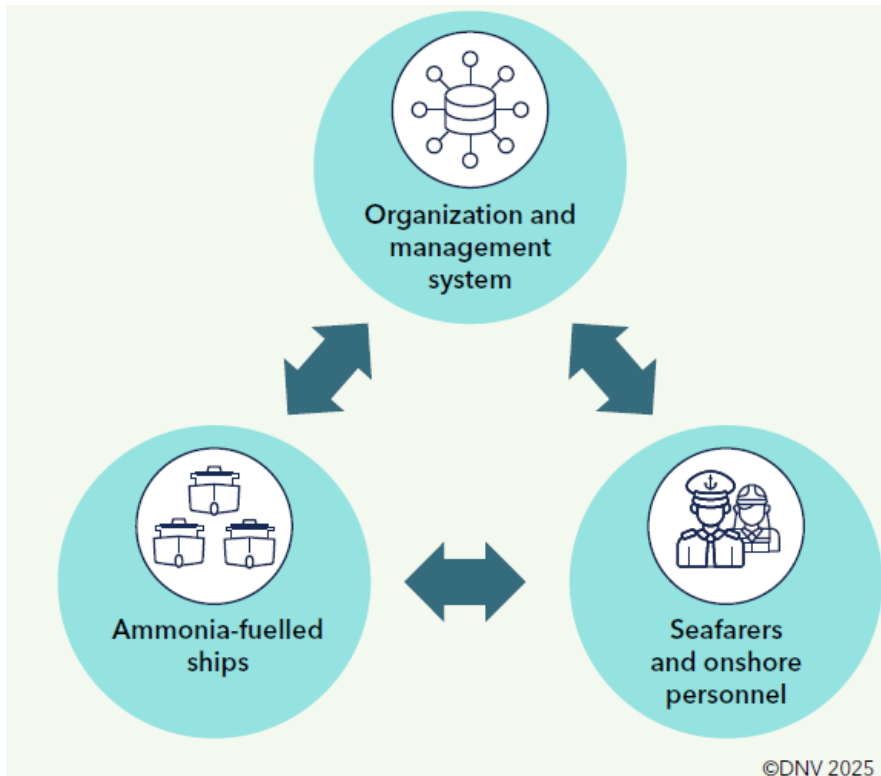
plans to use ammonia to help decarbonise its operations. Others, such as car carrier owner Höegh, plan to build ammonia-powered ships to be in a position to offer transport to carbon-conscious customers from 2027, while Skarv Shipping Solutions, a joint venture between Grieg Edge and Peak Shipping, has placed an order for a dual-fuel ammonia general cargo ship to be delivered in 2027⁹.

Section 3.2.3: Infrastructure

Figure 4 shows the geographical distribution of fuel consumption for a fleet of 274 ammonia carriers and location of around 140 port areas with ammonia

⁹ First Out with Timber Transport on Zero-Emission Vessels: <https://skarvshipping.com/first-out-with-timber-transport-on-zero-emission-vessels/>. Section 3, DNV White Paper, p.20.

⁸ Section 2, DNV White Paper, pp.8-10.



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Figure 5: Operating ammonia-fuelled ships will impact the organisation and management system and require seafarers and onshore personnel to acquire new competencies (DNV, 2025a)

facilities¹⁰. This overlaps with major trade routes for global shipping, indicating that this ammonia network could form a useful steppingstone for further scaling.

Section 4.1: People and organisation

Compared with traditional fuels, ammonia's characteristics introduce added complexities to bunkering operations and ship operations relating to on-board fuel storage, fuel distribution and energy conversion, as well as maintenance and emergencies.

While the most effective risk-control measures are incorporated during the ship design and construction phases through technical solutions, it is vital to establish comprehensive training, operating procedures and a robust safety culture to ensure the ship's safe operation. This will require changes to the safety management system, generate the need for new competencies on board and

ashore, and may also affect the organization (Figure 5¹¹).

Organisational factors supporting safe operation encompass various aspects, including working practices, safety culture, manning philosophy, and roles and responsibilities. In this context, we focus on three formal pillars related to training, procedures and management systems.

Hence, for this barrier to be considered resolved, ammonia-specific training courses, procedures and management systems as required by the IMO should be established and implemented to a level where the shipping organisations operate ammonia-fuelled vessels as part of their standard procedures and competent personnel are available to crew and support the operation of these ships.

Organisation and management system

Recognising that organisational factors related



to the safe operation of an ammonia-fuelled ship comprise more than the management system and organisational chart, the following framework is formally required by the IMO.

The International Safety Management (ISM) Code sets clear objectives and requirements for shipboard operations. The entire ship safety management system required by the ISM Code will be influenced by the use of ammonia as fuel, encompassing normal operations, maintenance and emergency preparedness.

The IMO interim guidelines for ammonia refer to the operational requirements outlined in the parts of the IGF Code applicable to natural gas, which state that specific procedures must be provided on board the ship for normal operations, including bunkering, as well as for maintenance and emergencies.

It also requires drills and emergency exercises to be carried out on board at regular intervals.

The ISM Code places obligations on ship operators to ensure that both the master and crew are well informed about the

¹⁰ Figure 4 is presented as Figure 3-6 on page 23 of the White Paper.

¹¹ Figure 5 is presented as Figure 4-1 on page 24 of the White Paper.

risks associated with the ship's operations.

Additionally, training in using ammonia as fuel must be established and overseen, as mandated in the safety management system. This is further elaborated in "Guidelines for developing and implementing a Safety Management System for ammonia-fuelled ships" (MTF, 2025¹²).

The adoption of ammonia fuel, along with the related technologies, may also require changes within the ship operator's organisation, potentially resulting in the establishment of new roles and responsibilities on board and ashore.

Seafarers and onshore personnel

The availability of seafarers with ammonia competence will be critical for the widespread use of ammonia fuel. Additionally, competence is required for all stakeholders onshore, including shipowners, ship management representatives, port operators and fuel suppliers.

While relevant competencies gained through decades of operating gas carriers will be valuable in training for other shipping segments, individuals with this competence are a limited resource, considering the small number of ships and seafarers in this segment compared to the world fleet.

Similarly, experience with operating tankers carrying ammonia as cargo will be valuable – but represents an even more limited resource pool. This means that there is an urgent need for training, which will in turn influence the crewing cost and the competition in the industry for qualified crew.

¹² MTF (2025). Guidelines for developing and implementing a Safety Management System for ammonia-fuelled ships. Maritime Technologies Forum.



The IGF Code outlines crew members' training and competence requirements, referencing the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). Depending on their duties on board, the crew shall hold certificates in basic or advanced training for service on ships subject to the IGF Code.

The STCW specifies additional training and qualification requirements for masters, officers, ratings and other personnel on ships subject to the IGF Code, and there are associated STCW courses for LNG fuel. However, existing training frameworks do not address the distinct properties and handling requirements of ammonia, and no specific STCW training courses are currently available for ammonia fuel.

Together with industry partners, DNV has developed a recommended practice (RP) that provides a clear roadmap for developing concrete ammonia-specific training courses.

The RP can also be used as input to competence planning

and operational manuals as well as for reviewing safety management systems.

It can also be used by third parties for certifying training programmes.^{40,41} The Maritime Technologies Forum (MTF) has developed guidelines for safety management systems specifically for ammonia-fuelled ships, and these can provide further guidance in updating the safety management system (MTF, 2025).

The current availability of trained crew and personnel ashore, operational procedures and organizational structures is considered to represent a high barrier to the uptake of ammonia as fuel.

There is no experience from ships operating with ammonia fuel apart from the vessels demonstrating first-use, and no ammonia-specific STCW courses are available. However, extensive experience of operating gas tankers that carry ammonia as cargo can serve as a starting point for developing similar approaches for ammonia-fuelled ships and this is reflected in the barrier level (see below).

The above international framework and developments in guidance documents represent a good foundation for further reducing the “people and organisation” barrier. It will also be important to learn from early adopters, including the vessels already demonstrating the first use of ammonia as ship fuel.

Moving forward, the IMO is expected to initiate the development of training programs for seafarers on ships utilising ammonia as fuel this year.

Until STCW courses for seafarers on ships using ammonia as fuel are in place, training should be developed based on existing resources, including DNV’s RP, in consultation with the Flag Administration.

This may involve incorporating relevant sections of the IGF and STCW, employing risk assessments from the design phase to enhance understanding of risks, raising awareness, and devising emergency training scenarios (DNV, 2025a)¹³.

Selected DNV projects

Green Shipping Programme (GSP)

A public-private partnership initiated in 2015 with 120+ partners from industry and government, managed by DNV. By May 2025, the GSP has initiated 60 green pilot projects, several of which have considered the feasibility of using alternative fuels for various ship types and trades.

<https://greenshippingprogramme.com/>

Equinor ammonia powered tanker

GSP pilot study facilitated by DNV, investigating the technical and economical applicability of implementing ammonia-eligible

¹³ Section 4, DNV White Paper, pp.24-26.

engines and fuel and bunkering systems in a large generic tank ship design. With participation from 18 GSP partners covering the entire value chain, including Wärtsilä, Brevik Engineering, and Altera.

Grieg Star ammonia powered bulk carrier

GSP pilot study facilitated by DNV, investigating the technical and commercial feasibility of retrofitting an open hatch bulk carrier for green ammonia operations in a trans-Atlantic route. With participation from 21 GSP partners covering the entire value chain, including Yara, NMA, and G2 Ocean.

Lerøy Havfisk ammonia powered trawler

GSP pilot study facilitated by DNV, investigating if it is possible to implement an ammonia-fuelled system on a newbuild with similar performance as the current modern trawlers in their fleet. With participation from 13 GSP partners covering the entire value chain, including Wärtsilä, Skipsteknisk, and Grieg Maritime.

Color Line ammonia as fuel

GSP pilot study facilitated by DNV to shed light on potential barriers, such as the environmental footprint, security aspects, technological solutions, cost and possible private and public financing solutions. Includes an ammonia bunkering quantitative risk assessment (DNV, 2021c¹⁴). With participation from 24 GSP partners across the entire value chain, including the Port of Oslo, Yara, DSB, and NMA.

Blåvinge ammonia-fuelled AHTS

GSP pilot study facilitated by DNV, investigating the technical

¹⁴ DNV (2021c). Ammonia Bunkering of Passenger Vessel – Concept Quantitative Risk Assessment. Green Shipping Programme. DNV report no. 2021-0205, Rev.0.

and economic feasibility of developing an ammonia-battery-hybrid anchor handling newbuild for the installation and operation of floating offshore wind turbines. With participation from 11 GSP partners across the entire value chain, including Vard, Yara, and DNB.

Nordic Roadmap for Future Fuels

A Nordic collaboration project with 70 partners, managed by DNV and funded by the Nordic Council of Ministers. The project presented the Fuel Transition Roadmap for Nordic Shipping, with a focus on ammonia, hydrogen, and methanol, in 2024. The project has developed a complete proposal for ammonia fuel guidelines submitted to the IMO in 2023 from the Nordic countries.

<https://futurefuelsnordic.com/>

Ammonia as a Marine Fuel Safety Handbook

Provides practical guidance on safety aspects of ship design in the development of ammonia-fuelled ships for shipowners, yards, and designers. Developed by DNV on behalf of GSP with input from the Norwegian Maritime Administration, the Nordic roadmap project and other industry partners.

<https://greenshippingprogramme.com/wp-content/uploads/2021/03/Ammonia-as-a-Marine-Fuel-Safety-Handbook-Rev.02.pdf>

AEngine

A consortium led by Everllence to develop a two-stroke, ammonia-fuelled engine for maritime shipping with funding from Innovation Fund Denmark. DNV is among the consortium members.

<https://www.man-es.com/company/press-releases/press-details/2020/10/21/>

man-energy-solutions-to-lead-danish-consortium-developing-ammonia-fuelled-engine-for-maritime-sector

Ammonia 2-4

An EU-funded project led by Wärtsilä where the overall aim is to demonstrate at full scale both a two-stroke and a four-stroke dual-fuel marine engine running on ammonia as the main fuel. DNV is among the partners.

<https://www.ammonia2-4.eu/>

ARISE

A research partnership for controlled ammonia release at sea, where DNV is among the sponsors. ARISE aims to fill knowledge gaps by conducting experiments, thereby enhancing the quality and consistency of risk assessments.

<https://www.arise-partnership.org/>

NoGaps

A collaboration project supported by Nordic Innovation and led by the Global Maritime Forum with partners including DNV, Wärtsilä, Yara, and Everllence. Aims to produce a detailed ship design for an ammonia-powered ammonia carrier.

<https://www.nordicinnovation.org/programs/nordic-green-ammonia-powered-ships-nogaps>

Eidesvik's *Viking Energy*

The DNV-classed platform supply vessel (PSV) *Viking Energy* will be equipped with an ammonia dual-fuel engine. In 2026, the vessel is planned to operate on ammonia for Equinor.

<https://eidesvik.no/viking-energy-makes-history-as-first-ammonia-powered-offshore-vessel/>



Maritime Technologies Forum (MTF)

A collaborative effort between Flag States and classification societies which includes DNV, working to bridge the gap between technological progress and regulatory process across the maritime sector.

The MTF has published several reports, such as “Guidelines for Developing and Implementing a Safety Management System for Ammonia-fuelled Ships” and “Safety Considerations for Establishing Green Shipping Corridors”.

<https://www.maritimetechnologiesforum.com/>

Fortescue Green Pioneer

A converted supply vessel which became the first oceangoing vessel to be fuelled by ammonia after completing a set of trials in Singapore in May 2024. Gas-fuelled ammonia notation from DNV.

Höegh Autoliners' Aurora Class car carriers

The first Aurora Class vessel entered into commercial operations in August 2024 with DNV's ammonia ready notation. By 2027, the last four vessels of the series are planned to be

delivered, able to run net zero on ammonia directly from the yard.

<https://www.hoeghautoliners.com/aurora-class>

https://www.dnv.com/expert-story/maritime-impact/from-forecast-to-fleet-lessons-from-hoeghs-ammonia-transition/?utm_campaign=website&utm_medium=email&utm_source=newsletter

CMB.TECH's Yara Eyd

This 1,400 TEU ice-class containership is planned to be delivered by mid-2026 with DNV's gas-fuelled ammonia notation and will serve routes between Norway and Germany.

<https://cmb.tech/news/cmbtech-to-build-worlds-first-ammonia-powered-container-ship-in-partnership-with-ncl-and-yara>

Energy sector

Several dozen industry projects in the energy sector for ports and terminals, producers of ammonia, producers of equipment, and others. Projects include qualitative safety studies, technology qualification, GHG emission assessment,

LCA studies and assistance on market strategy and regulations¹⁵.

Authors: Linda Sigrid Hammer, Magnus Strandmyr Eide, Marius Leisner and Øyvind Endresen. **Reviewers:** Håkon Hustad, Christoffer Böhmer, Jason Stefanatos and Jan Kvålsvold.

White Paper link: <https://www.dnv.com/maritime/publications/ammonia-in-shipping-download/>

DNV White Paper
“Ammonia in Shipping: Tracing the emergence of a new fuel”

¹⁵ Selected DNV projects, DNV White Paper, pp.38-41.