Nordic Innovation

NoGAPS: Nordic Green Ammonia Powered Ships

Phase 2 report: Commercialising early ammonia-powered vessels

2023

Prepared by Global Maritime Forum

Co-funding from Nordic Innovation, BW Epic Kosan and Yara Clean Ammonia

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Co-funded by: Nordic Innovation

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Ship Designer: Breeze Ship Design

Organisation logos from the NoGAPS consortium partners are shown. From top left, they are the Maersk Mc-Kinney Moller Center for Zero-Carbon Shipping, Yara Clean Ammonia, the Global Maritime Forum, BW Epic Kosan, DNV, MAN Energy Solutuions, Wartsila. Nordic Innovation, the Danish Maritime Authority, and Breeze Ship Design are captioned as co-funder, flag representative, and ship designer respectively.

This report was written by Joe Boyland at the Global Maritime Forum, with input from Anna Rosenberg and Ana Madalena Leitão at the Global Maritime Forum, and Thomas McKenney and Sara Åhlén Björk at the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. It draws on discussions within Work Package 2 of the project, which included Thomas Wøidemann of BW Epic Kosan and Eystein Leren of Yara Clean Ammonia. The report also draws on modelling inputs provided by the RMI (formerly Rocky Mountain Institute) Shipping Decarbonisation team.

Project members

- BW Epic Kosan: Thomas Wøidemann, Hans-Henrik Ahrenst, Michael Kure Larsen
- Yara Clean Ammonia: Eystein Leren, Ingvald Worren, Gunnhild Bækken, Naveed Qamar
- DNV: Monika Johannessen, Pål Spilleth, and Magnus Jordahl
- MAN Energy Solutions: Stefan Mayer, Dorthe Jacobsen
- Wärtsilä: Kent Åstrand, Fredrik Lindfors, Harald Øverland
- Global Maritime Forum: Jesse Fahnestock, Marieke Beckmann, Joe Boyland, Anna Rosenberg
- Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping: Claus Winter Graugaard, Thomas McKenney, Jun Kato, Koichi Sato, Martin Eriksen, Jun Ito, Peter Nerenst, Shinichi Iwamoto, Hiroyuki Yanagisawa

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This report is based on analytical work by the Global Maritime Forum and extensive interviews with external and consortium partners. The findings and conclusions reflect the view of the authors based on the data obtained and do not reflect the corporate views of Nordic Innovation or the consortium partners.

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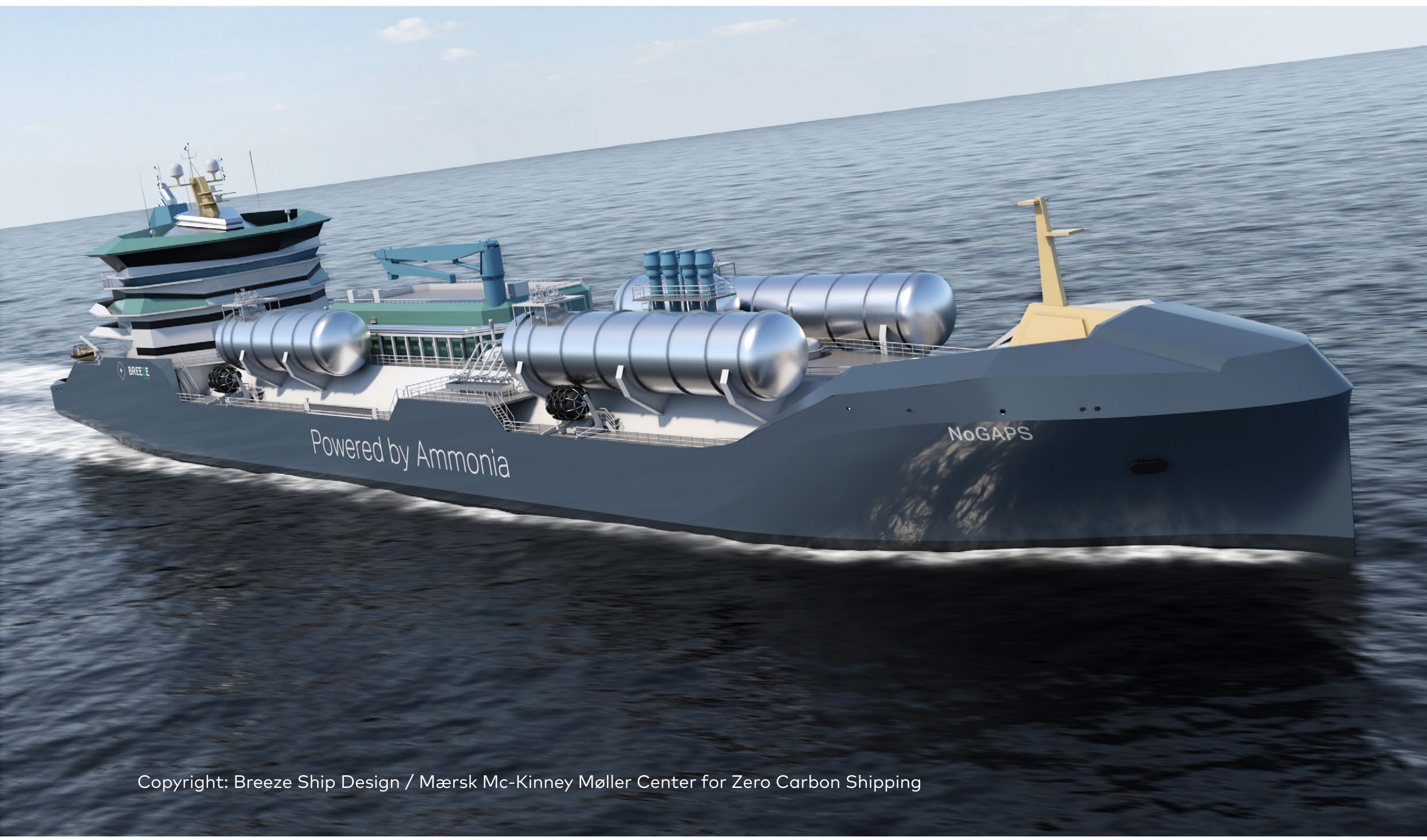
About Nordic Innovation

Nordic Innovation is an organisation under the Nordic Council of Ministers. Nordic Innovation aims to make the Nordics a pioneering region for sustainable growth and works to promote entrepreneurship, innovation, and competitiveness in Nordic business.

Executive summary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NoGAPS

The Nordic Green Ammonia Powered Ships (NoGAPS) project has brought together key players from the Nordic shipping and energy value chains to develop a first-of-a-kind ammonia-powered gas carrier, the M/S NoGAPS. Ammonia is increasingly seen as an important solution for decarbonising the shipping sector, as a zero-emission fuel with high scalability and the potential for use on long-distance routes. NoGAPS leverages the Nordic region's unique industrial position and the significant advantages of gas carriers as a starting point for introducing ammonia-powered vessels to demonstrate the potential of ammonia-powered shipping.

The first phase of the project, between 2020 and 2021, developed a holistic proof of concept for an ammonia-powered gas carrier, covering ship design and safety, the supply of clean ammonia, and commercial viability. It generated two main conclusions:

- Neither technical considerations nor regulatory approvals present major obstacles to putting an ammonia-powered gas carrier on the water.
- Rather, the most important challenge to be overcome is building a business model that is credible in the eyes of financiers and operators.

The second, and current, phase of the project has picked up where the first phase left off, examining the detailed design requirements, including producing an initial ship design for M/S NoGAPS with Approval in Principle[1], as well as pathways for commercialising the vessel.

This report provides a summary of the main outputs and findings from the second phase of NoGAPS. It begins with an overview of the vessel design for M/S NoGAPS, outlining the general arrangement of the vessel and key design decisions behind it. This is followed by a deep dive into the commercialisation of early ammonia-powered vessels, using NoGAPS as a case study. The topic is explored from two angles: ship financing and wider economic viability. The main findings of the assessment are presented below.

1 An Approval in Principle is a validation of a novel conceptual vessel design given by a classification society, confirming its technical feasibility.

Financing

Drawing on interviews with actors across the ship finance space including banks, funds, private equity firms, lessors, export credit agencies, and public investment banks, **the study finds that suitable finance should be available for early ammonia-powered vessels**.

While financiers acknowledge there are technical, operational and safety risks for early ammonia-powered vessels, these are not seen as a major barrier to investment. Rather, the key challenge is likely to be reducing the vessels' elevated costs and related commercial risks to acceptable levels. Without intervention, an ammonia-powered gas carrier is expected to be between 50-130% more expensive to own and operate than an equivalent gas carrier over the coming years. This creates significant commercial risks for both shipowners and lenders.

The study identifies four interlocking levers – different actions, contractual arrangements, and financial tools – that, if jointly pulled, could respond to this challenge and unlock suitable finance.

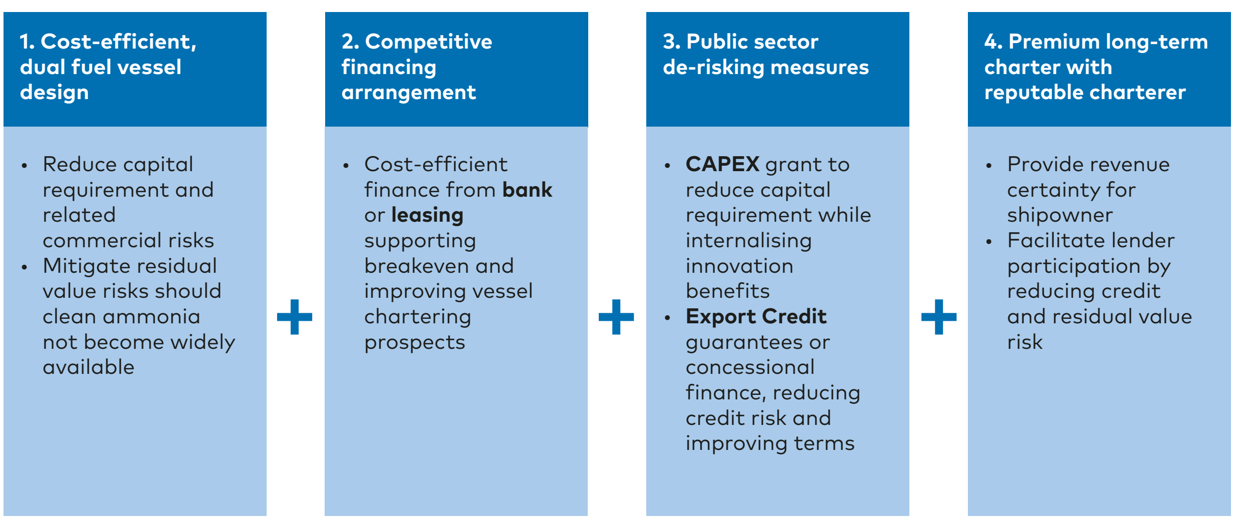


Figure 1: The four levers required to unlock competitive financing for NoGAPS. Source: Global Maritime Forum analysis, based on NoGAPS partner and financier insights.

Given the elevated costs, **a competitive financing arrangement will be important for the shipowner to obtain a financially viable investment case**. Two options are viewed as relevant for M/S NoGAPS, either a so-called "plain vanilla" deal consisting of a bank loan and portion of equity or a leasing arrangement in which the shipowner "rents" the ship from a third party. These arrangements are both familiar and, crucially, the most cost-effective sources of commercial financing. Based on input from banks and lessors, both options should not only be available, but be available on good terms, without a significant risk premium.

Both options will need to be complemented by de-risking measures to spread the cost and risks more evenly across the value chain. Support from an export credit agency (ECA) – either in the form of a loan guarantee or direct concessional lending – will be important to facilitate lender participation, by reducing credit risk. Meanwhile, access to a grant covering some of the additional capital expenditure (CAPEX) of the vessel will be essential for shipowners to reach breakeven and improve the vessel's chartering prospects. While ECA backing is expected to be available, the study reveals that there is a shortfall in the CAPEX support available for first movers globally. Norway's Enova and the EU's research, development, and demonstration (RD&D) schemes represent best practice in this space and could potentially provide funding opportunities for M/S NoGAPS.

The availability of a competitive financing arrangement and de-risking measures will depend on the strength of a project's underlying business case. As shown by NoGAPS, **shipowners can play a role in facilitating a viable case through the vessel design**, with several no-regrets measures available to reduce cost and residual value risk "at source" in this way. But the key lever will be securing a **premium long-term chartering agreement with a creditworthy charterer**, with consensus among financiers that this is the single most important requirement for investment.

Economic viability

Although the wider outlook for financing is positive, securing long-term chartering agreements is expected to be a significant challenge for early ammonia-powered vessels. Charterers will bear much of the additional cost of operating the vessel, including the fuel cost. To facilitate a long-term chartering agreement, this premium must be substantially reduced.

The study examines whether and how the premium can be tackled, using a new framework of "commercial model archetypes" – different combinations of public sector and industry actions to reduce the cost gap. Four archetypes and their impact on the cost of ownership for M/S NoGAPS in 2026 and 2030 are explored:

1. **The Base case archetype**, which represents a business-as-usual action scenario
2. **The Industry leadership archetype**, which represents a scenario with strong industry action
3. **The Policy pull archetype**, which represents a scenario with strong public sector action
4. **The Strategic opportunity archetype**, which represents a scenario with both strong industry and public sector action.

The results suggest that the cost gap can be closed on M/S NoGAPS' potential route between the US Gulf and Northwestern Europe.

Were M/S NoGAPS to bunker US ammonia, the gap could be closed by as early as 2026. This applies to both blue ammonia - produced by conventional means with applied carbon capture and storage - and green ammonia - produced with electrolytic hydrogen -, which could reach a premium of just 2% and 3% already by this point. The vessel could also approach cost parity by 2030, with a premium of no more than 10%, in other scenarios, including if it were to bunker with more expensive ammonia produced in Northwestern Europe.

These results are primarily driven by the significant policy progress made over the last two years. It is shown that the hydrogen production credits under the US Inflation Reduction Act and EU Fit for 55 package would reduce the cost of NoGAPS by ~20% and ~10% each. While these policy measures would greatly support the business case, they would not be sufficient to close the cost gap on their own. Rather, **a combination of both public sector and industry action will be required to close the gap this decade**. Among the industry actions assessed, sourcing lowest cost clean ammonia and slow steaming would make the largest contribution.

Overall, the results point to at least three potential pathways for commercialising M/S NoGAPS.

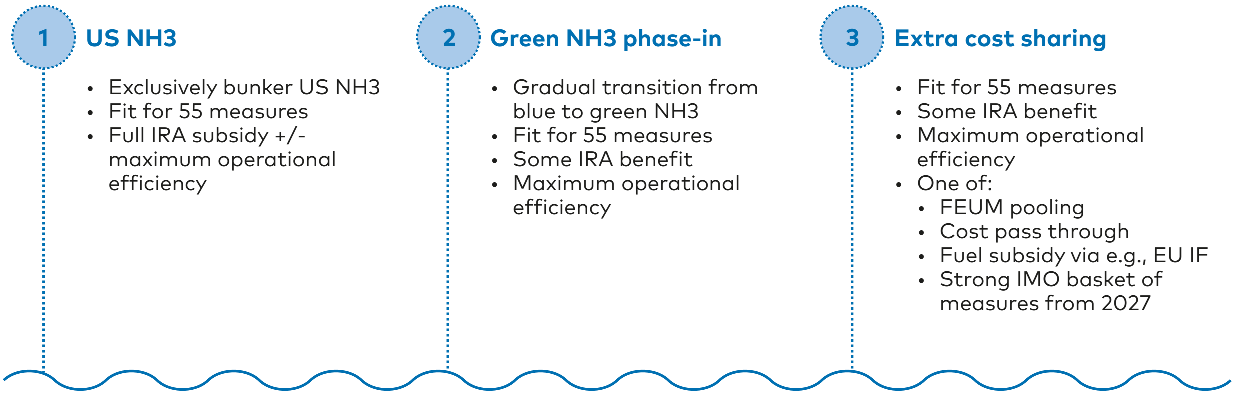


Figure 2: Three anticipated pathways for commercialising M/S NoGAPS.

- Pathway 1: **The simplest pathway would be for the vessel to bunker in the US**, where the highly competitive cost of ammonia created by the IRA could make using either blue or green ammonia viable if suitable action is also taken within the value chain.

  Bunkering in Northwestern Europe would be more expensive than the US, leading to a cost premium until the early 2030s. Were M/S NoGAPS to also bunker in Europe, it would, therefore, need to:

- Pathway 2: **Pull all the cost reduction levers examined and use blue ammonia during its initial years of operation**, before transitioning to green ammonia once the cost is reduced, or

- Pathway 3: **Pull all the cost reduction levers examined as well as an extra lever, to close the remaining gap**. Several possible extra levers exist which could do so, including a fuel subsidy, such as Contracts for Difference, which is being considered under the EU Innovation Fund; offsetting the remaining cost through the FuelEU Maritime pooling mechanism; passing the remaining cost on to the end-customer as a small green premium; or the International Maritime Organisation (IMO) introducing a basket of strong mid-term policy measures in a timely fashion, by no later than 2027.

NoGAPS

The analysis provides a positive outlook for commercialising M/S NoGAPS. It suggests that it should be feasible to close the cost gap facing the vessel if suitable action is taken within the value chain and sources of public sector support can be accessed. When combined with the remaining contractual and financial levers, this should make the project bankable, activating lender interest.

The deep-dive, therefore, confirms the core conclusions of the first NoGAPS report, that the project has a strong strategic business case, with the potential to be among the first clean ammonia-powered vessels deployed internationally.

As immediate next steps, the project partners should consider actions to:

- Optimise the fuel strategy for M/S NoGAPS, based on the opportunities afforded by the Inflation Reduction Act, including the expected availability of IRA-subsidised blue and green ammonia.
- Explore the requirements and timelines for bidding for relevant CAPEX and fuel subsidies.
- Reach out to ECAs, especially in North Asia, to confirm the potential to access a loan guarantee for the vessel.

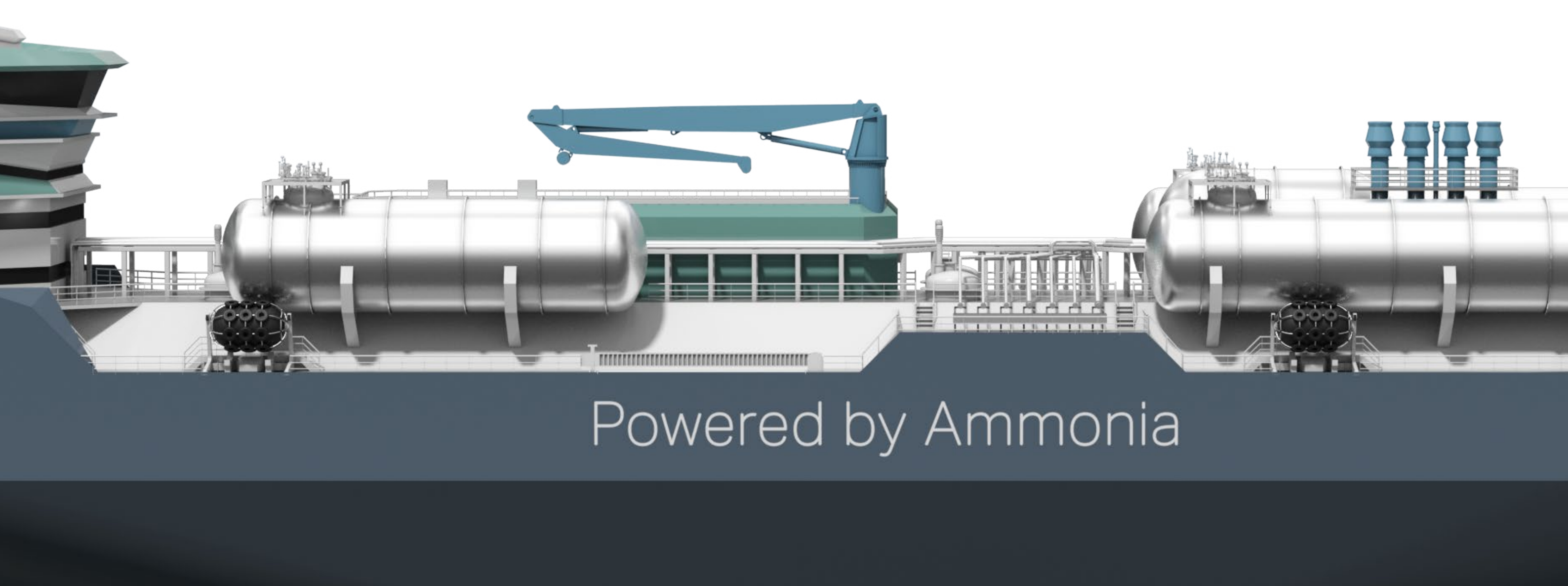
Sector-wide

The analysis also has implications for action in the sector at large.

Shipping will require a policy-rich transition, with a strong policy framework that supports the economic viability of zero-emission vessels. The analysis suggests that such a framework is now coming into place between the US and Europe, after the agreement of the Inflation Reduction Act and Fit for 55 package. Routes between the two continents therefore have unique conditions for first mover action, with the potential for zero-emission shipping to be viable well within this decade.

This underlines the importance of national and regional policy action as a driver of zero-emission shipping's emergence phase. It highlights the opportunity for other national and regional governments to implement policies that push the envelope for zero-emission shipping this decade. This would lay the groundwork for and maximise the impact of eventual mid-term measures from the International Maritime Organisation, while establishing leadership in the maritime transition and hydrogen economy. Impactful policy measures include CAPEX grants which, given the long lead times for building ships, must be expanded as a priority in the coming years if 2030 targets are to be achieved, and, even more crucially, subsidies for production/use of clean hydrogen-based fuels, like clean ammonia.

Meanwhile, first movers in the industry should explore opportunities to access lower cost fuel, including whether they can benefit from emerging hydrogen subsidies, like those provided by the IRA. The analysis shows that getting zero-emission vessels on the water will require multiple actions from both industry and policymakers to enable economic viability and obtain financing; ambitious actors in the industry should explore the opportunities they have to contribute within these collaborations.



Nordic region

Finally, the analysis highlights several opportunities for the Nordic region. Nordic companies are at the forefront of technological innovation in zero-emission shipping and continue to play a significant role in areas like ship finance. There are clear opportunities to lean into these strengths to accelerate shipping decarbonisation, not only regionally but globally, while securing market share in emerging zero-emission shipping technologies and fuels, including clean ammonia.

To seize these opportunities, policymakers in the region should consider:

- Accelerating the development of policies to close the cost gap and increase the availability of clean ammonia for shipping in the region, following the example set by the US. Contracts for Difference are being advanced by Nordic governments, which could be effective means of doing so. To support the sector's target of at least 5% uptake of zero-emission fuels by 2030, policy action should be taken as soon as possible.
- Increasing the availability of CAPEX subsidies for demonstration and early deployment of ammonia-powered vessels and infrastructure by applying best practices from Enova across the wider region. This should include consideration of how such funding can complement EU funding and promote the decarbonisation of deep-sea shipping.
- Exploring how Nordic ship finance, including national export credit agencies, can be best mobilised to support first-mover projects.

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1. Introduction

The Nordic Green Ammonia Powered Ships (NoGAPS) project was initiated as a response to the urgency of understanding and demonstrating the viability of clean ammonia-powered shipping. Ammonia is seen as a high-potential fuel in the transition to zero-emission shipping, as it is zero-carbon, applicable for long-distance routes, and highly scalable. While the technological feasibility of powering vessels using ammonia has been established, a number of barriers still need to be solved before ammonia-powered ships can operate on the water. These barriers include having ship designs and engines approved and available, establishing protocols for the safe handling and use of ammonia, developing the required regulatory framework, and ensuring the commercial viability of using ammonia as a maritime fuel.

With its unique position to pioneer ammonia-powered shipping, the NoGAPS project brings together key players with complementary expertise and strategic interests from across the Nordic shipping value chain to drive this transition forward. The objective of the project is to develop M/S NoGAPS, an ocean-going clean ammonia-powered gas carrier.

The **first phase** of NoGAPS (2020-2021) elaborated a concept for M/S NoGAPS. During this phase, barriers for putting the ship on the water and options for addressing them were identified. The results were published in the NoGAPS phase 1 project report. The report concluded that neither technical nor the regulatory considerations surrounding ammonia-powered shipping should present major obstacles for putting M/S NoGAPS on water. Rather, the biggest challenge facing green ammonia powered shipping is the development of a credible business model to secure the necessary investments. Initial options for strengthening the business case, including forms of public support, were suggested.

The **second phase** of NoGAPS (2022-2023) builds on the first phase. It brings together an industry consortium consisting of shipowner BW Epic Kosan, charterer/fuel producer Yara Clean Ammonia, original equipment manufacturers MAN Energy Solutions and Wärtsilä, classification society DNV, and non-profit facilitators the Maersk McKinney Moller Center for Zero Carbon Shipping (MMMCZCS) and the Global Maritime Forum. It has two objectives – to produce a design for M/S NoGAPS that can lay the foundation for a shipyard tender and eventual construction of the vessel, and to further explore options for commercialising ammonia-powered shipping, based on the experience in the project.

The vessel design workstream published a feasibility assessment in May 2023, summarising the learnings and approach of the initial vessel design process. The initial design for M/S NoGAPS then received an Approval in Principle (AiP) from DNV, in June 2023. A specification and drawing package has now been prepared to initiate a shipyard tender and potential vessel construction.

The following report provides a high-level overview of the vessel design outcomes followed by an exploration of the options for commercialising ammonia-powered shipping, using M/S NoGAPS as a case study. The objective of the report is to provide financiers, policymakers, and other stakeholders with information on the challenges, opportunities, and emerging pathways for commercialising ammonia-powered shipping, based on experience from NoGAPS.

2. Vessel design

The NoGAPS consortium has produced an initial vessel design for the ammonia-powered gas carrier M/S NoGAPS (Figure 1). M/S NoGAPS is a Handysize ammonia-powered gas carrier with 22,000 m3 cargo capacity optimised for commercial operation in the North Atlantic and Northwestern European waters. The MMMCZCS has led the vessel design work with support from the external ship designer Breeze Ship Design. This has been done in close collaboration with project partners BWEK and Yara to reflect the design requirements from the potential ship operator and charterer, OEMs MAN Energy Solutions and Wärtsilä supporting on the relevant design components, and DNV, streamlining the design process towards an Approval in Principle (AiP).

Copyright: Breeze Ship Design / Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Figure 1: NoGAPS design concept.

The design objectives for M/S NoGAPS were defined based on the conclusions from the first phase of the project, which were:

- The vessel design should confirm that there are no major technical or regulatory obstacles to putting M/S NoGAPS on water.
- The vessel design should demonstrate a credible business model, focusing on reducing risk and cost while maintaining acceptable safety levels and fulfilling design requirements.

The design process has followed design requirements, based on defined capabilities and findings from the first phase of the project and input from consortium partners. Some of these requirements are unique to ammonia-powered vessels, while others are standard for gas carriers. The main requirements can be found in the fact box below.

Cargo

- 22,000 m3 cargo capacity
- Flexible design that can carry multiple gas cargoes, but the main intended cargo is ammonia
- Semi-refrigerated cargo tanks

Operation

- Capable of operating with net-zero carbon equivalent emissions on a lifecycle basis
- Optimised for commercial operation in North Atlantic and Northwestern European waters
    - Intended route: Gulf of Mexico to Northern Europe
    - Range on ammonia: 12,000 nautical miles
    - Range on secondary fuel: 6,000 nm
    - Length overall (LOA) port restriction of 160 metres
- Maximum service speed of 16 knots at design laden condition with a full load of cargo
- An operational profile with 75% of the time at sea (average around 13.5 knots) and 25% of the time in port
- Semi-refrigerated fuel tanks (8 bar, -33.2°C)
- Crew complement of 27, plus 6 Suez crew

Ammonia bunkering capability (optional)

- Capable of being used as an ammonia bunker vessel to bunker other ammonia-powered vessels
- Bunkering system including capacity, manifolds and reliquification
- Bunkering hose handling
- Mooring fenders
- Increased manoeuvrability

The group ran an open innovation process to capture the best engineering practices in configuring the design for ammonia fuel, and best practices in safety standards and safeguards, energy efficiency, and technology. Because of the novelty of ammonia as a marine fuel, there is currently no prescriptive regulatory framework in place for designing and constructing a ship using ammonia as fuel. The partners, therefore, used their collective understanding of the risks associated with ammonia (- fuel storage, supply systems, and engine room design) and applied these as part of a risk-based alternative design process to establish new guidance on safeguards and operational procedures.

Considerations in vessel design

Several considerations have been made in the design of M/S NoGAPS to ensure it qualifies as a safe, capable, energy, and cost-efficient ammonia-powered gas carrier. They include considerations around the general arrangement, machinery configuration, safety concept and bunkering capability. Key decisions and the reasoning behind them are described below.

General arrangement

The general arrangement of the final design concept (Figure 2) consists of aft accommodation and engine room, three main cargo tanks below deck, three fuel tanks on deck and a deckhouse that includes fuel reliquification and handling rooms. The pros and cons of forward versus aft accommodation were discussed, and it was concluded that a sufficiently safe design could be achieved with an aft configuration.

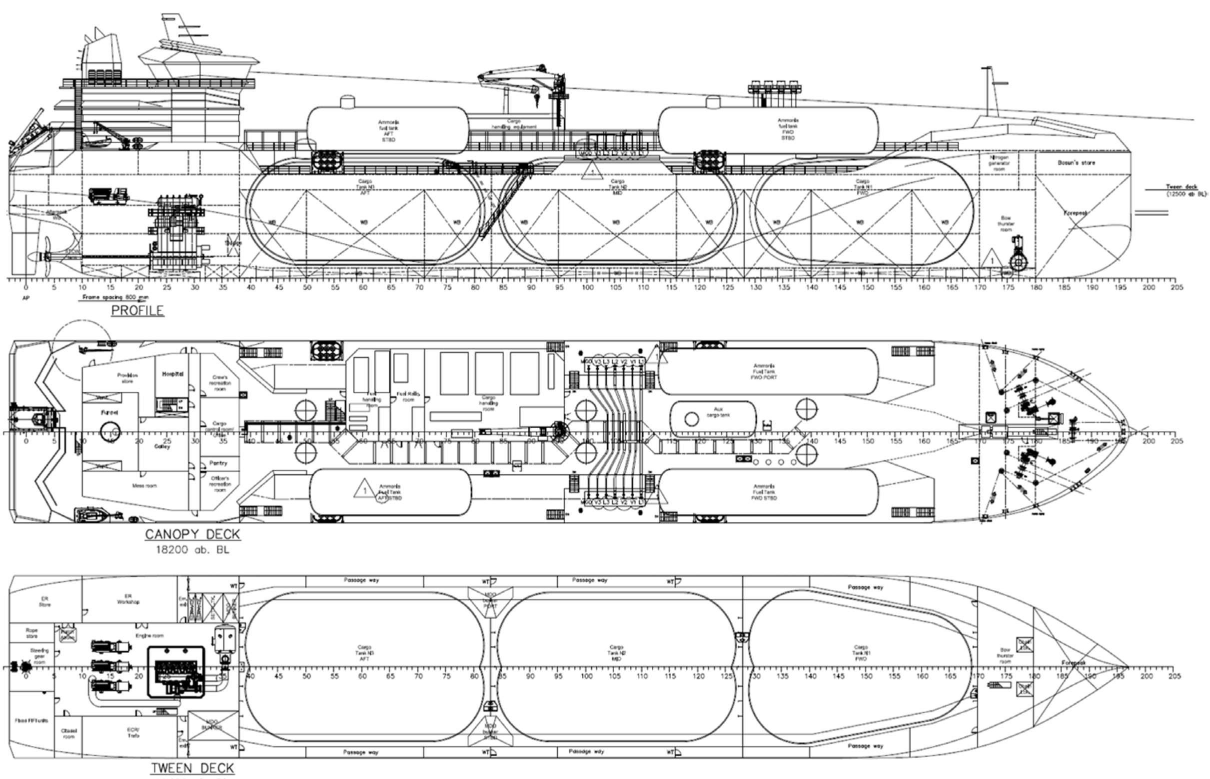
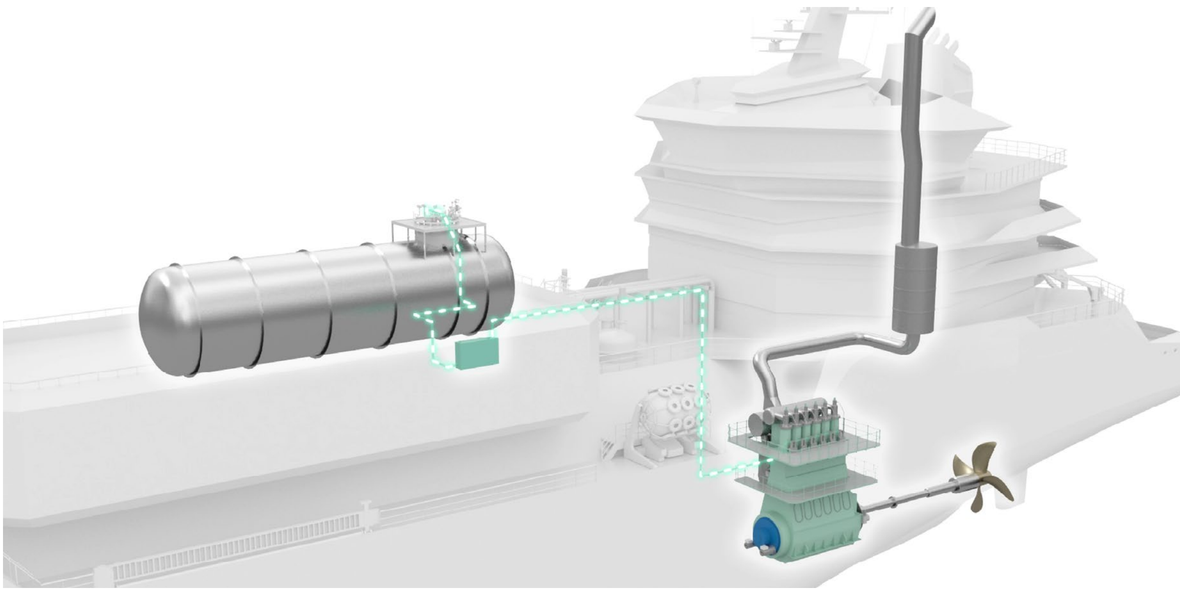


Figure 2: General arrangement of final design concept.

Ammonia bunkering is received through the open-air bunker station and manifolds located on the canopy deck midship. The ammonia fuel is then stored in three semi-refrigerated Type-C deck tanks with a total capacity of around 2,700 m3. The fuel reliquification and handling rooms are in the deckhouse on portside. In the fuel handling room, the fuel is received from the storage tanks and prepared to be sent to the main engine. Fuel supply leaves the fuel valve train at an increased pressure of 80 bar and passes through a double-walled pipe to the engine room (see Figure 3).

Figure 3: Ammonia fuel flow from storage to engine.



Machinery configuration

Two machinery configuration concepts were assessed as part of the feasibility phase – an ammonia-electric propulsion system with four-stroke (4S) main engine, and an ammonia-mechanical solution with a two-stroke (2S) main engine. Both solutions drive a controllable pitch propeller (CPP), allowing for improved manoeuvrability and better performance in ice. As the M/S NoGAPS will have an ice class designation, variable trading pattern, and potential to function as a bunkering vessel, CPP was considered an important feature.

The ammonia 2S configuration (Figure 4), consisting of a single prime mover in the form of an ammonia-fuelled two-stroke engine (7,200 kW), was chosen for M/S NoGAPS. This configuration offers lower fuel consumption and costs, as well as emissions.[2]

2 See the full assessment in NoGAPS Feasibility Study, pp.31-36.

Balancing emissions reductions with cost and risk, the main engine is the only ammonia consumer onboard. In port, three diesel auxiliary gensets supply electrical energy to avoid having two different ammonia fuel systems, minimise CAPEX, and reduce the operational risk from having multiple ammonia consumers and new engine technologies onboard. Zero-emission operation can be achieved by using biofuel for the auxiliary gensets and as the secondary pilot fuel for the main engine. The auxiliary generator sets will only be used during port stays and at anchorage, where fuel consumption is low. It is also possible to use a shore power connection for power needed in port, if available.

Figure 4: Machinery configuration.

A shaft generator has been included for generating electrical energy during transit. This decision was based on the emission reduction benefits and an evaluation of the economics, which concluded that the cost would be recouped within just five years, based on fuel savings and maintenance costs.

As ammonia dual-fuel engines are still under development, their emission profiles are currently unknown. However, there is a potential risk of ammonia slip and nitrous oxide (N2O) emissions, in addition to the need for nitrogen oxide (NOx) emissions compliance. These emissions risks are managed through the engine design and a selective catalytic reduction (SCR) system.

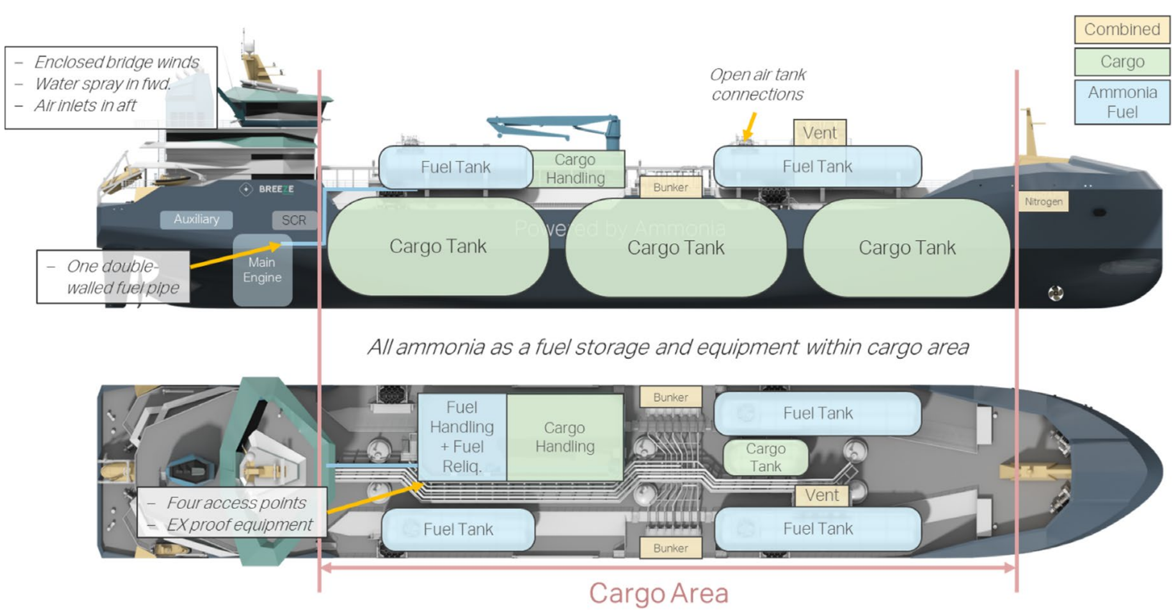
Safety concept

The NoGAPS project followed a risk-based alternative design process that included the completion of a hazard identification (HAZID) workshop attended by the project consortium, followed by a risk mitigation process, with the aim to reduce all risks to as low as reasonable possible (ALARP) in the initial design phase.

Using the International Gas Carrier (IGC) Code as a basis, the NoGAPS safety concept (Figure 5) has a clearly defined cargo area and hazardous zone, where ammonia storage and equipment are placed. The only ammonia-related equipment that is not placed in this zone is the main engine and piping from the fuel handling room to the engine. This concept reduces risks and unknowns by complying with the IGC Code to the greatest extent possible. As one of the high-risk areas onboard, the fuel handling room was carefully considered during the design process. It has multiple access points. The vent mast is placed forward, and tank connections are open air. The piping that connects the fuel handling room to the engine room is double-walled and protected within the engine room.

Careful attention has been placed on mitigating the risk of ammonia slips, leakages, or releases that could impact the accommodation area. The accommodation area has enclosed bridge wings, water spray in the forward and air inlets placed in the aft.

Figure 5: Preliminary safety concept.

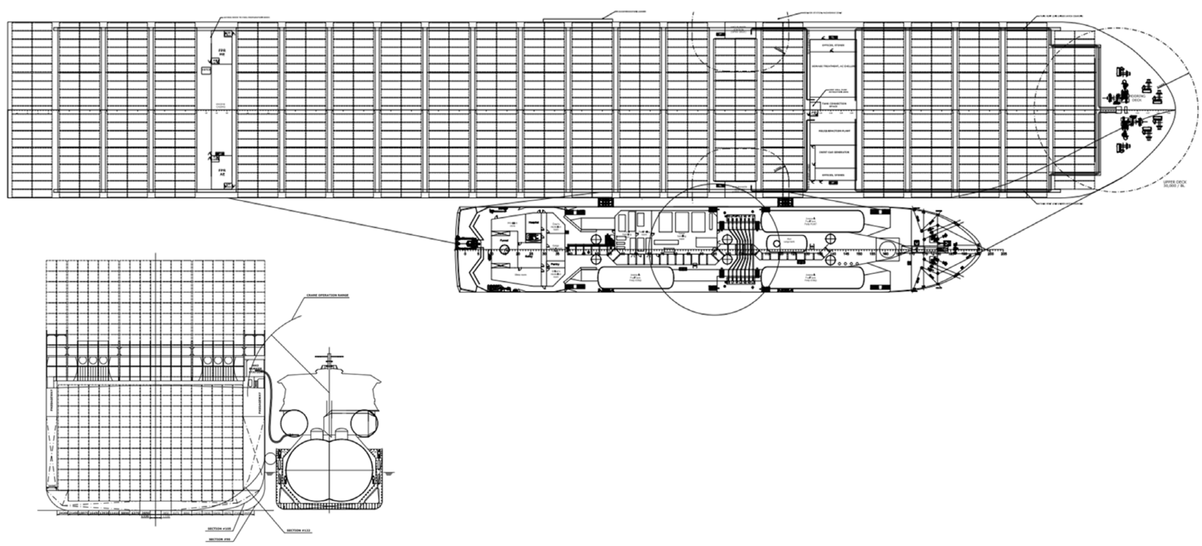


Bunkering capability

M/S NoGAPS can also be used as a bunkering vessel. Important considerations included bunkering system capacity, manifolds, crane and hose handling, fenders, and manoeuvrability.

The vessel has sufficient tank, cargo pump and refrigeration capacity to satisfy the bunkering requirements for various vessel types, including large container vessels. Mooring and hose handing equipment is also adequate for bunkering operations. A bunkering interface case study with a large container vessel was undertaken to confirm that the vessel could complete large-scale bunkering operations (Figure 6). The case study verified that the vessel's bunkering capability is sufficient.

Figure 6: Bunkering interface with large container vessel.



Manoeuvring is an important capability for bunkering vessels. A detailed manoeuvrability analysis completed for M/S NoGAPS concluded that additional manoeuvrability would be needed to improve bunkering capabilities. The NoGAPS team recommended that the vessel should be prepared to add a stern thruster if bunkering is an expected future operation.

Further development areas

The initial design phase of NoGAPS2 has now concluded, consisting of the initial design development, a HAZID risk assessment, obtaining an AiP, and completing the initial design package that can be used for submission to shipyards for official tenders.

However, there are multiple investigations that will need to continue into the next basic design phase with the shipyard. These investigations include detailed design of the fuel handling room, understanding potential onboard emissions, addressing ammonia leakage/release scenarios, and improving energy efficiency.

3. Financing

Ammonia is in its emergence phase as a shipping fuel. While there are many projects ongoing to develop and demonstrate the various elements of the value chain for ammonia-powered shipping, it has not yet achieved commercial application within the shipping fleet; as of today there are no ammonia-powered vessels active on the water in either a commercial or experimental capacity. This has several implications for and effects on financing early ammonia-powered vessels. However, the general impact can be easily summarised: early ammonia-powered ships present both a higher cost and risk profile than conventional vessels.

This section explores the outlook for financing early ammonia-powered vessels, based on the case of M/S NoGAPS. It begins by mapping and assessing the specific risks they are likely to face, before presenting proposed levers that could mitigate the key risks identified.

Investments in vessels require two core business cases to be made – that of the shipowner, who will own the vessel, and that of the financier, who will provide capital. The analysis in this section, therefore, draws on dialogue with the NoGAPS partners as well as interviews with roughly 15 actors from across the ship finance space, including banks, funds, private equity firms, lessors, export credit agencies, and public investment banks, particularly from the Nordic region.

What is the challenge?

There is alignment between financiers and shipowners that the commercial risks to investing in early ammonia-powered vessels outweigh the technical.

The risks and challenges posed by innovative ship projects can be divided into technical risks– including technology, safety, and operational risks - and commercial risks – including financial and market risks.

Expert input suggests the main technical risks relevant for financing early ammonia-powered vessels are the following:

Technology risk

Ammonia-powered shipping represents a breakthrough technology which is, by its nature, novel. Beyond the core uncertainty this creates regarding the feasibility of the design, a first-of-a-kind design will also be both unfamiliar to and more complex for the chosen shipyard to build. Depending on the specific shipyard, this creates more or less of a risk of overruns during the vessel's construction, which would negatively impact on the shipowners' business case and represent construction risk for a financier offering pre-delivery financing.

Safety risk

A characteristic that sets ammonia apart from today's shipping fuels and other candidate future fuels is its high toxicity, with the molecule being harmful to human health and the environment if exposed. While there is extensive real-world experience with ammonia as a cargo which can provide a basis for safe use of ammonia as fuel, this nonetheless represents a new challenge for the industry in terms of vessel design and operations. This challenge is recognised by financiers.

Operational risk

As a new technology, there is also uncertainty around the reliability and real-world operational performance of the first ammonia-powered ships. This has the potential to increase off-hire, affecting the revenue generation of the vessel.

Many of the financiers interviewed also raised concerns about the near-term availability of clean ammonia. Since having a stable supply of clean ammonia is crucial to justify the additional capital investment in the vessel and attract finance, this is a core challenge facing early ammonia-powered vessel projects.

While these risks were referenced by financiers, **they were not – individually or collectively - seen as a major barrier to investing in a project like NoGAPS**. This is noteworthy as, traditionally, debt providers primarily target mature and proven concepts to the detriment of innovative projects, which draw instead on equity or concessional finance. However, this was not the case among the financiers interviewed for this report, with this perspective being consistent across all types of financiers engaged, including those with significant technical expertise.

Figure 7: Technical risks and requirements highlighted by financiers.

Risk area	Requirements
Operational	• Evidence of stable fuel supply • Management expertise • Public acceptance of ammonia (along planned routes)
Regulatory and safety	• Documentation for equivalences, Flag approval, insurance • Crew training plan • Emergency response plan and accident preparedness
Technical	• Feasibility studies • Commercial availability of engine and liabilities in case of safety or technical issues • Construction at reputable shipyard
Environmental	• Emissions data for engine

Regarding the requirements financiers would need to see met in these risk areas, most noted that suitable documentation – including class certifications, flag approval, insurance papers, as well as feasibility and design studies – and the commercial availability of the relevant engine would provide them with enough comfort and reassurance about the overall technical feasibility of a project.

The involvement of established companies was also viewed as an important mitigation against technical risk, since it was considered likely that they will have suitable technical resources and capability to solve the engineering challenges posed. However, this was especially true for safety, where the involvement of established companies is seen as a strong assurance, since it is deemed unlikely that established companies would risk putting an unsafe vessel on the water, given the reputational implications.

As for the remaining risks, a strategic and well-considered business case is vital. This is an area in which NoGAPS has several advantages. The participation of an ammonia producer like Yara and the industrial nature of ammonia shipping, with vessels transiting between ports and terminals with existing access to ammonia, removes major challenges around ammonia supply. Similarly, in terms of safety, while moving from 'having ammonia in the cargo hold to the engine room' undoubtedly presents new risks and challenges that must be solved, as an ammonia carrier, M/S NoGAPS has a much simpler learning curve on procedures and crew training than other vessels. The participation of BW Epic Kosan, as a specialist gas carrier owner, is also expected to be beneficial. It is likely these risks can also be mitigated by other projects with a similarly strategic business case.

Both financiers and the NoGAPS partners believe the key challenges for financing early ammonia-powered vessels lie in the commercial sphere.

As noted in the first NoGAPS report, the total cost of building and operating early ammonia-powered vessels will be significantly higher than conventional vessels. In the case of M/S NoGAPS, consortium calculations suggest that, without intervention, the ship will be between 50-130% more expensive to own and operate than an equivalent conventional gas carrier. This gap is driven by CAPEX, which could be up to ~20% higher than a conventional gas carrier[3], but crucially by the increased cost of fuel, with clean ammonia likely to be on average ~200-400% more expensive than conventional fuel during the vessel's early years of operation[4]. While these costs will decrease over time, as learning and production grow, early movers may be subject to the full premium.

This has clear implications in terms of risk.

3 Estimate from NoGAPS partners, including incremental cost of ammonia engines, fuel supply system, tanks, SCRs, and other new components.
4 From meta-analysis of ammonia cost modelling performed by DNV and Ricardo, 'Study on the Readiness and Availability of Low- and Zero-Carbon Ship Technology and Marine Fuels' (2023).

Most shipowners will not be able to invest in a new technology and, depending on the chartering arrangement, buy fuel at a significant premium without assurance that there is a market that will be willing to pay the additional cost. To enable investment, they will need a charter rate that provides enough revenue for a long enough period of time. In addition, the elevated CAPEX the shipowner will face could pose its own challenges, including raising sufficient capital and managing cashflow.

Financiers face the inverse risk – that, in light of the higher cost and risk picture, the shipowner will not be able to meet their repayments on the vessel. Credit risk was consistently highlighted as a concern by those interviewed, with financiers stressing that they would need to see a strong and credible plan for how the additional cost would be covered. For banks, this was identified as the single greatest barrier to participation.

There is also risk relating to the residual value of the vessel. Ships have a long economic life, generally more than 20 years. Although most analysts and industry actors now consider clean ammonia an important solution in decarbonising the sector, there remains some uncertainty over the exact role it will play. This generates uncertainty about the future earnings potential and, therefore, the future value of the vessel – a key factor in assessing the viability of the investment. Should the market for ammonia-powered shipping not develop as hoped, part of the value of the investment could become stranded. Residual value risk was particularly stressed by equity and leasing companies, who identified it as the greatest constraint on their participation. It should be noted that there is likely to also be residual value risk in ordering conventional vessels as the transition progresses over the course of this decade.

These challenges are seen by both the NoGAPS partners and financiers as significant; with some variation, all parties ranked commercial risk as the biggest barrier to realising the project. The core challenge for financing NoGAPS and similar vessels is, therefore, finding ways to reduce the project's commercial risks to acceptable levels.

What levers and structures are needed to solve the challenge?

Expert feedback suggests four interlocking levers can unlock suitable financing for NoGAPS.

These levers (elaborated below) represent different actions, contractual arrangements and financial tools that can reduce the cost and commercial risks of investing in an early ammonia-powered vessel. It is expected that all four of the identified levers will need to be pulled to unlock competitive financing for NoGAPS and similar vessels.

1. Cost-efficient, dual fuel vessel design

- Reduce capital requirement and related commercial risks
- Mitigate residual value risks should clean ammonia not become widely available

+

2. Competitive financing arrangement

- Cost-efficient finance from **bank** or **leasing** supporting breakeven and improving vessel chartering prospects

+

3. Public sector de-risking measures

- **CAPEX** grant to reduce capital requirement while internalising innovation benefits
- **Export Credit** guarantees or concessional finance, reducing credit risk and improving terms

+

4. Premium long-term charter with reputable charterer

- Provide revenue certainty for shipowner
- Facilitate lender participation by reducing credit and residual value risk

Figure 8: The four levers required to unlock competitive financing for NoGAPS. Source: Global Maritime Forum analysis, based on NoGAPS partner and financier insights.

The following section describes the identified levers and highlights the key opportunities and challenges surrounding them.

1. Cost-efficient, dual-fuel vessel design

No-regrets opportunities exist to reduce cost and risk in the ship design.

There are several ways in which both the capital and voyage costs of ammonia-powered vessels can be meaningfully reduced at source through a careful and considered design. They include optimising the design in areas subject to additional cost, installation of energy efficiency technologies, and various pragmatic trade-offs. While these considerations have always been important in the context of vessel design, their importance is heightened in the case of an ammonia-powered vessel. This represents a no regrets opportunity for the shipowner to improve their business case.

The box below provides information about how this topic was approached in the design of M/S NoGAPS to illustrate some of the potential and options available.

Minimising cost in the M/S NoGAPS vessel design

The initial ship design process for M/S NoGAPS was guided by two main design objectives, including that the design should demonstrate a credible business model while maintaining acceptable safety levels and fulfilling design requirements. This objective was carried into decision-making around the design, guiding several choices which minimised the CAPEX and fuel costs of the vessel.

CAPEX

The additional capital cost for ammonia-powered vessels will predominantly be driven by the engines, fuel system, and fuel tanks. As such, they represent the areas where vessel design can make the most significant inroads into CAPEX. Within the context of NoGAPS, the following design decisions were made to reduce CAPEX:

- The main engine will be the only ammonia consumer onboard the vessel, with auxiliary engines and emissions reduction technologies instead running on diesel/biofuel generator sets. By not having two ammonia fuel systems onboard, this decision reduces not only cost, but the safety and operational risks that would come with having two all-new ammonia consumers and engine technologies onboard.
- Optimisation of the vessel's tank storage enabled the number of fuel tanks to be reduced from four to three, saving the CAPEX associated with the tank system, piping, and equipment.

Fuel costs

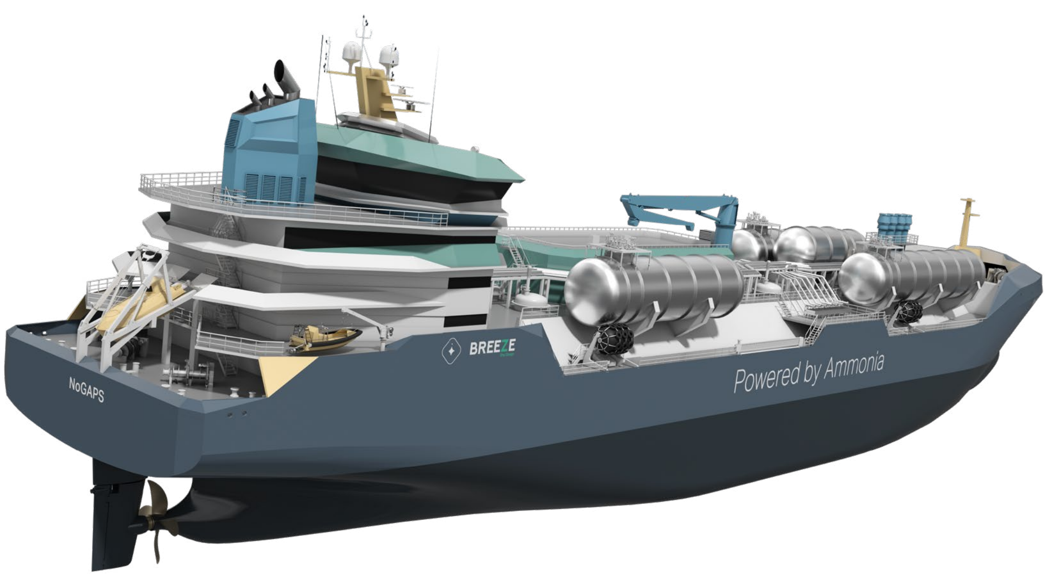
Minimising power requirements to reduce fuel consumption was also a focus of the vessel design process:

- The vessel's hull form was optimised using computational fluid dynamics analysis, to maximise propulsion efficiency.
- In addition, energy saving technologies, including gate rudders, wind assisted propulsion, air lubrication, and waste heat recovery, were explored as part of the design process, examining the fuel savings and resulting payback time associated with the investments.
- A shaft generator producing electrical energy during transit is included in the design, after an assessment of fuel savings concluded the payback time justified its inclusion.

Meanwhile, dual-fuel engine capability - or the ability for a vessel to run on conventional/drop-in fuels as well as ammonia – is an impactful design measure to mitigate residual value risk, enabling the vessel to continue operating should, for whatever reason, clean ammonia not eventually become a widely available shipping fuel. The use of dual-fuel engines was consistently highlighted by financiers as a requirement for them to invest in early ammonia-powered vessels.

Since the emerging engine designs from the sector's key manufacturers – MAN ES, Wärtsilä, WinGD – are dual-fuel as standard, this mitigation should not be a challenge to implement. The intention for M/S NoGAPS is to use a MAN ES 2-stroke engine, which can be expected to support the vessel's financing prospects.

Financier feedback highlighted that a modular design and/or a design that takes into consideration any potential future retrofits to other fuels would also be desirable.



Copyright: Breeze Ship Design / Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

2-3. Competitive financing arrangement

Typical ship finance instruments – including bank loans and leasing – remain fit-for-purpose and should be available, if complemented by suitable de-risking measures.

Given the elevated investment costs, a competitive financing structure will be important for shipowners to obtain a financially viable business case to invest in an early ammonia-powered vessel. Based on their ability to lead to a competitive financing structure, likely availability and simplicity, two options were identified for financing M/S NoGAPS: a "plain vanilla" deal and leasing.

It should be noted that the most appropriate commercial structures for financing early ammonia-powered vessels, as well as the ability to secure various types of financing, will vary from project to project. As such, other financing arrangements not considered here – such as, joint ventures and equity finance – are conceivable for other projects, while some conclusions that are true of NoGAPS may not be applicable to these projects.

Primary financing structures

→ "Plain vanilla" deal

The NoGAPS partners and financiers interviewed for this report viewed a "plain vanilla" deal, combining a bank loan and portion of equity from the shipowner, as the most relevant financing structure for M/S NoGAPS.

The key advantage of this type of finance is cost. Bank loans have the lowest interest rate of any ship financing instrument – generally, a spread of 100-300 points above LIBOR, now SOFR.[5] Despite the growing importance of alternative finance, such deals remain the most common means of financing ships - underpinning two thirds of the global ship finance portfolio[6] -, making them familiar to shipowners and relatively easy to execute.

A key uncertainty is bank interest in participating in first mover projects. Traditionally, banks have a low-risk appetite and are hesitant to take on technology and market risk, which limits the availability of bank finance for first-of-a kind technology projects.

5 Balance sheet financing would be less expensive than asset-backed financing, meaning that larger shipowners, with recourse to their balance sheet, will likely get more favourable terms than smaller shipowners.
6 Petrofin Research, 'Key Developments and Growth in Global Ship Finance' (2023), p.2.

However, all banks interviewed confirmed that they would be interested in financing early ammonia-powered ships. Indeed, there were indications that loans would not only be available, but available on good terms – suggesting that technical and safety risks should not drive a meaningful risk premium either. Two banks said they would consider offering a loan on their usual commercial terms, while all of the other banks interviewed indicated they could consider offering sustainability-linked loans, in which the interest rate on the loan is ratcheted down based on achieving environmental key performance indicators. With regard to tenor, there were suggestions that the upper end of the typical range would be possible - around the 7-year mark – and a loan-to-value ratio of around 60%. A number of banks also flagged their interest in offering pre-delivery finance, covering payments to the shipyard during the vessel's construction. Overall, this amounts to an attractive financing package.

It should be noted that banks' eventual interest in lending will depend on whether they feel able to identify the risks relevant to the project and have a suitable understanding of how they may impact on the cashflow of the project. A deal for an early ammonia-powered vessel will likely require more analysis, data sharing and dialogue between the bank and the shipowner than a conventional ship finance deal. Although it provides a positive signal, stated interest at this stage does not necessarily guarantee banks will eventually finance an early ammonia-powered vessel.

As for why this was the case, interviewees pointed to commitments as signatories to the Poseidon Principles and/or their own corporate climate strategies as drivers; these commitments seem, therefore, to be playing a role in pushing ship financiers' lending strategies towards supporting zero-emissions solutions.

→ Leasing

Were "plain vanilla" financing not feasible, leasing was identified as an attractive alternative.

Leasing separates the use and ownership of the ship. Rather than buying the ship outright, a third party (the lessor) buys and owns the asset. This third party then leases the ship to the shipowner (the lessee), who gains full control over it, as if they owned it, in exchange for rental payments.

While mortgage-backed loans have historically been the most common means of financing ships, over the last ten years ship leasing has become a serious alternative, now making up 15% of global ship finance[7], with China and Japan emerging as the largest providers.

7 Petrofin Research, 'The development of international ship leasing and the prospects of Chinese ship leasing' (2020), p.2

Leasing presents several relevant benefits in the case of zero-emission vessels, meriting its consideration as an option for M/S NoGAPS.

First, despite the cost of the lease itself tending to be higher, leasing transactions tend to have longer profiles than bank finance, thus often achieving a lower breakeven point. What's more, many countries offer tax incentives for investing in leased assets, which are passed on to the lessee in the form of reduced leasing costs, making structures such as Japanese Operating Leases with a Call Option (JOLCOs) highly cost-effective. Second, in some lease arrangements, the shipowner rents the vessel, operating it for a number of years before delivering it back to the leasing company at the end of the rental period. This would reduce residual value risk for the shipowner.

However, because of the intricacies associated with the ownership structure, leases can be complex and lengthy to negotiate even under normal circumstances (i.e. with proven technology). A zero-emission deal would likely exacerbate this. There is also uncertainty about whether lessors will be interested in zero-emission vessel projects in the first place, with the most attractive, tax-backed leases usually reserved for established business cases. Compounding this, the market is experiencing change, with new regulations and other political developments reducing the overall availability of leasing products.

Yet, given the very attractive returns that can be achieved by investors, and the leading role North Asian countries, in particular Japan, have taken in championing the ammonia economy, there is reason to believe there could be interest. Indeed, the lessors interviewed for this report responded positively about their interest in financing an early ammonia-powered vessel, although the sample was limited.

It should also be noted that, in the end, the availability of leases for early ammonia-powered vessels will rely on the appetite of banks to provide the underlying leverage for the investment by the lessor.

Public sector de-risking measures

Both the NoGAPS partners and financiers stress, however, that risk must be shared to facilitate investment, with the loan or lease being complemented by public sector de-risking measures. Two measures are likely to play a particularly important role - the involvement of an export credit agency for financiers and CAPEX grants for the shipowner.

→ Export credit agency support

Export credit agencies (ECAs) are government-backed institutions that provide financial support to exporters in their countries. ECAs, which have become an important part of the ship finance landscape in the period since the Global Financial Crisis, support vessel financing by directly offering favourable loans and/or providing loan guarantees, promising to pay the shipowner's debt in the event they were to default.

The financiers interviewed identified ECAs as the main actor they would be interested in sharing risk with. More strongly, a number of the banks engaged stated that ECA participation would be a necessary precondition for them to invest in a project of this sort, given the risk profile. This is not, perhaps, surprising, given credit risk was flagged as a significant concern and the benefit of an ECA guarantee is to effectively eliminate this risk.

An ECA guarantee could cover the vessel itself or the key machinery, such as the engine, tanks, and/or fuel supply system. In the first case, the guarantee would be from the ECA of the shipbuilding nation, which would most likely be a North Asian country. While it was not possible to test the appetite of North Asian ECAs in supporting early ammonia-powered vessels, some of the main ECAs involved in shipping in Europe were engaged. They showed a strong interest in supporting such a project. Given their interest in supporting the growth of their national export industries, including to new markets, and precedent from the development of liquified natural gas-powered shipping, it is anticipated that there should be potential for North Asian ECA support also. Otherwise, participation by European, including Nordic, ECAs could still be relevant, with many of the key onboard technologies for ammonia-powered shipping being designed in Europe.

→ CAPEX grant

Access to grants for the additional CAPEX of the vessel is an essential de-risking measure for early ammonia-powered vessels from a shipowner perspective.

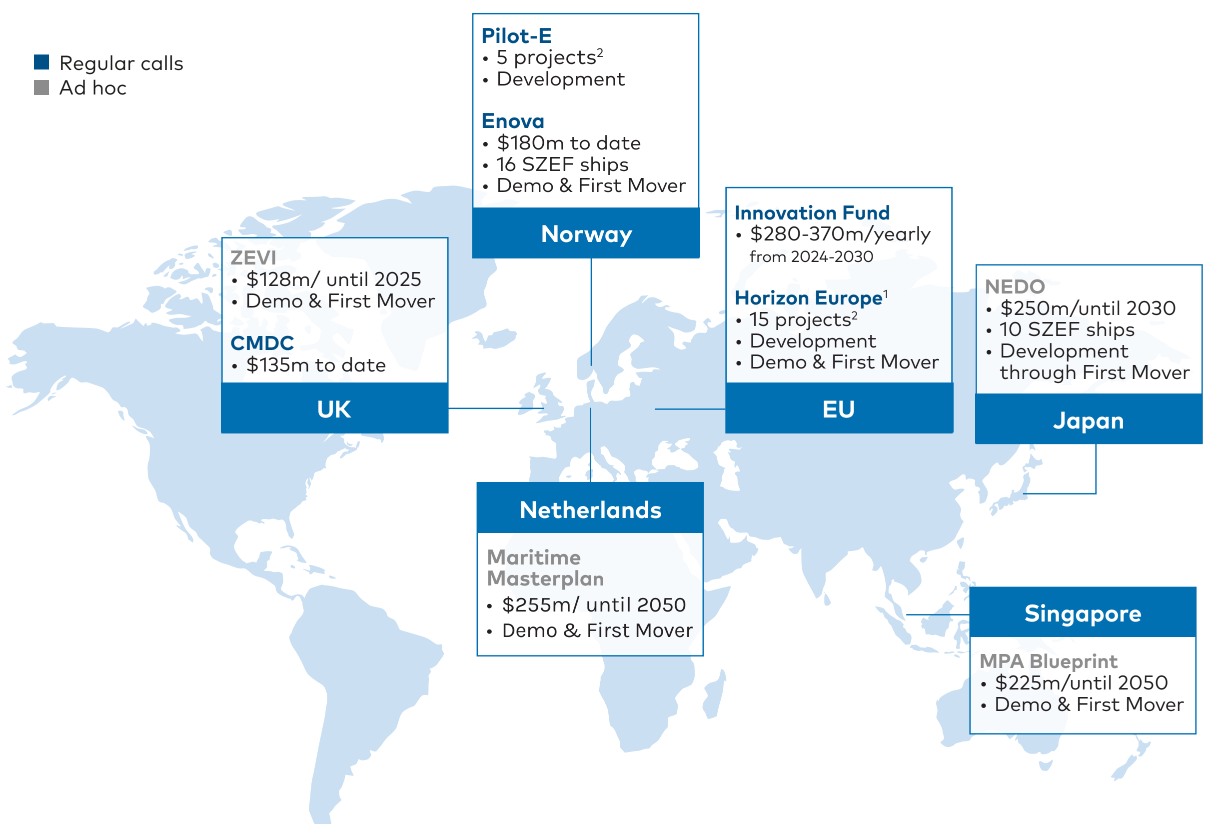
Grants represent an effective means of financial risk sharing and de-risking private investment; by reducing the overall capital requirement, they enable the shipowner to more easily reach breakeven, while improving the vessel's chartering prospects by reducing the downstream charter hire cost. There is also a strong economic rationale for support of this kind, with grants internalising the positive externality generated by the socially valuable technology, correcting a market failure.

As part of the NoGAPS project, partners engaged with other first-mover ammonia-powered vessel projects in the Nordic region. There was a common view among the projects that they would not be able to move forward without CAPEX grant support.

However, there is a lack of grant funding available for shipping decarbonisation globally, particularly for international shipping. The Getting to Zero Coalition tracks zero-emission shipping pilots and demonstration projects, including information about public sector support. It shows that the amount of government CAPEX support currently available is well below what is needed to galvanise the emergence phase of the transition. To illustrate, it has been estimated that reaching the IMO's goal of 5% uptake of zero-emission fuels by 2030 will require $95bn in capital, of which ~$12bn is associated with zero-emission vessel investments[8]. Total public sector funding globally is currently in the hundreds of millions of dollars, however, rather than billions.

As seen in Figure 9, currently available funding is concentrated in Europe and North Asia, limiting opportunities for early adopting companies outside these regions.

Figure 9: Overview of global CAPEX funding for zero-emission shipping. ZEVI = Zero Emission Vessels and Infrastructure scheme; CMDC = Clean Maritime Demonstration Competition; NEDO = New Energy and Industrial Technology Development Organization; MPA = Maritime and Port Authority of Singapore. Source: Global Maritime Forum analysis, based on Getting to Zero Coalition "Mapping of Zero-Emission Pilots and Demonstration Projects: Fourth Edition."



[1]Horizon Europe - includes Fuel Cells and Hydrogen Joint Undertaking (The Clean Hydrogen Partnership)
[2]Shipping technology projects to date.

Map of the world showing the main countries offering shipping decarbonisation funding, namely Japan, Singapore, the EU, the Netherlands, Norway, and the UK. The amount of funding or number of projects being funded by each country, and the stage of technology development the funding is applicable to are provided in boxes next to these countries.

8 Getting to Zero Coalition, 'The scale of investment needed to decarbonize international shipping' (2020)

Most of the existing funding schemes do not provide ongoing opportunities for projects to seek funding but are instead one-off or limited programmes focused on a specific objective. In addition, a significant proportion of the funding is directed towards technology and concept development, feasibility, and small-scale pilots, as opposed to commercial demonstration or early market introduction. This is not surprising, given that technologies for ammonia and hydrogen are still maturing. However, in the last year more than a third of all the pilot and demonstration projects in the Getting to Zero Coalition's latest pilot mapping have progressed to a new phase or reached an important development milestone, including more than 30 AiPs for zero-emission vessels, mostly ammonia-powered vessels[9]. These two factors create a risk that first-mover projects will not be able to able to access the CAPEX grants needed to progress to implementation in the coming years.

Best practice globally is represented by the EU and Nordic countries, which have developed RD&D ecosystems with structured funding opportunities for zero-emission ship projects across their lifecycle, including commercial demonstration and early market introduction. As far as NoGAPS is concerned, these schemes could be targeted as potential sources of funding support, but funding requirements would need to be carefully explored.

Best practice case study: Enova

Enova is a Norwegian government enterprise that provides financial support for innovative energy and climate technologies. As part of its mission, it has supported more than 180 low and zero-emission shipping projects, providing ~$180m of funding to-date; this includes grants for 16 larger ammonia and hydrogen vessel projects, which are expected to be among the first ships of their kind to be deployed globally.

In contrast with many government RD&D programmes, Enova assesses technologies' long-run potential to reduce emissions in their sector when evaluating projects. This approach is in line with recent research[10] that suggests "technology-specific" policymaking is more cost-effective and leads to faster innovation outcomes. It is likely that this approach has contributed to Norway's leadership in ammonia and hydrogen-related shipping technologies.

Though best-in-class, Enova's funding requirements stipulate that funded vessels must spend at least 30% of their time in Norwegian waters or be Norwegian-flagged, which may pose a challenge for international projects obtaining its support.

9 'Mapping of Zero-Emission Pilots and Demonstration Projects: Fourth Edition', p.5.
10 See insights from University of Exeter Economics of Energy Innovation and System Transition (EEIST) project: https://eeist.co.uk/download/932/.

4. Premium long-term charter

Investment crucially depends on securing a long-term charter agreement.

There are a number of commercial requirements that projects must meet to access ship finance. As far as early-ammonia powered vessels are concerned, financiers provided two main sets of conditions: a conventional security package, including the mortgage on the ship and a corporate guarantee, and, critically, evidence of long-term employment of the vessel.

Financiers consistently stressed that a vessel having long-term employment - in the form of contracts of affreightment or, more often, a time charter lasting at least 7-10 years -, would be the most important requirement for them to invest. This is also true of the shipowner, for whom the predictable and steady revenue of a long-term charter will be essential, with there being limited options to seek alternative employment for an ammonia-powered vessel at this stage in the market's development.

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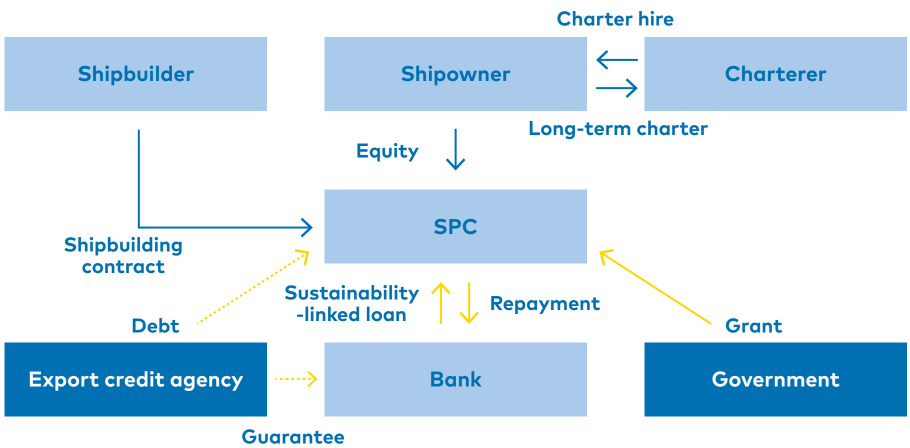
Securing a long-term charter of this length is likely to represent a major challenge, given the cost premium the charterer will face. This issue will be explored in more detail the report's next section on Economic viability.

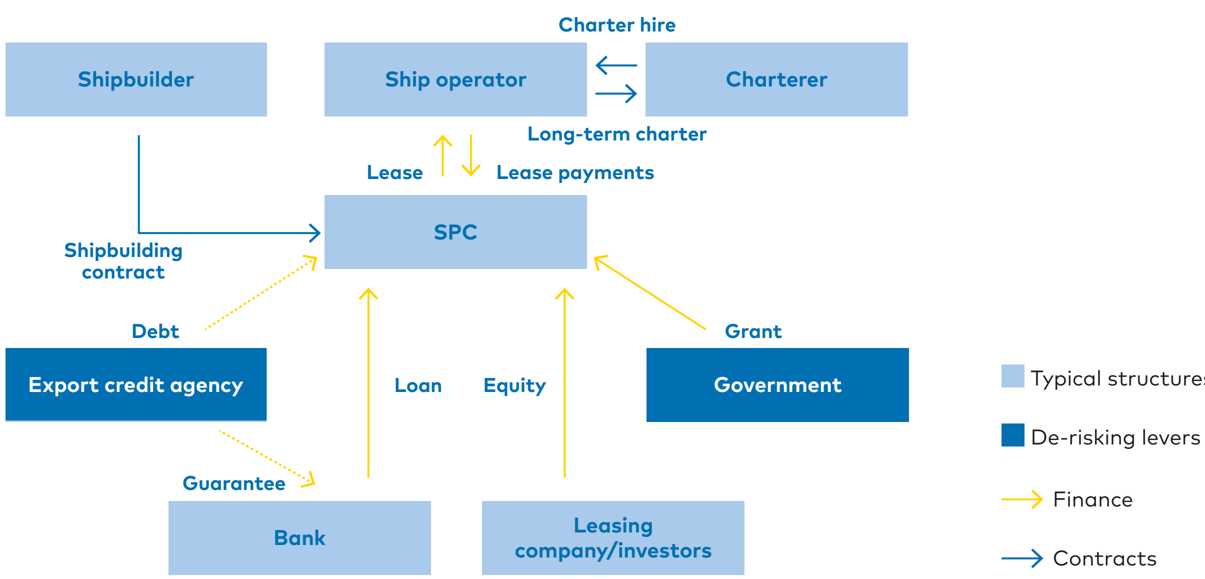
Two overall financing schemes emerge as potential models for M/S NoGAPS from the analysis in this section – shown below:

Figure 10: Proposed financing structures for M/S NoGAPS and similar early ammonia-powered vessels. SPC = special purpose company, a legal entity usually set up for ownership of the vessel. Source: Global Maritime Forum analysis, based on partner and financier insights.

Potential NoGAPS financing structure 1: "Vanilla with toppings"



Potential NoGAPS financial structure 2: Supported leasing



Two schematics are shown, summarising the proposed financing structures for M/S NoGAPS. The first structure is titled "Vanilla with toppings" and shows a special purpose company (SPC) owning the vessel. A sustainability linked loan from a bank, a grant from a government, debt or loan guarantee from an export credit agency, and equity from the shipowner are all directed toward the SPC. The SPC has a shipbuilding contract with a shipyard. The shipowner has a long-term chartering agreement with a charterer.

The second structure is titled "Supported leasing" and shows a special purpose company (SPC) owning the vessel. In this case, a bank provides the SPC a loan, while a leasing companies or group of investors provides the SPC equity. A grant from a government, debt or loan guarantee from an export credit agency, and equity from the shipowner are again directed toward the SPC. The SPC has a shipbuilding contract with a shipyard. The ship operator has a leasing agreement with the SPC and a long-term chartering agreement with a charterer.

4. Economic viability

The analysis in the previous section found that a premium long-term charter represents the most critical lever for enabling the financing of early ammonia-powered vessels. It was noted that securing a long-term charter is, however, likely to be a challenge, given the significant cost premium facing potential charterers. To facilitate a long-term chartering agreement, this premium must be reduced.

This section of the report investigates whether and how this can be done. Specifically, these questions are investigated through the prism of "commercial model archetypes" - different possible combinations of public sector and industry actions to reduce the total cost of ownership gap. After detailing the measures and archetypes considered, the impact of the different archetypes on the economics of M/S NoGAPS is presented, outlining three potential pathways for commercialising NoGAPS as well as conclusions on the possibilities for first mover action in the sector more widely.

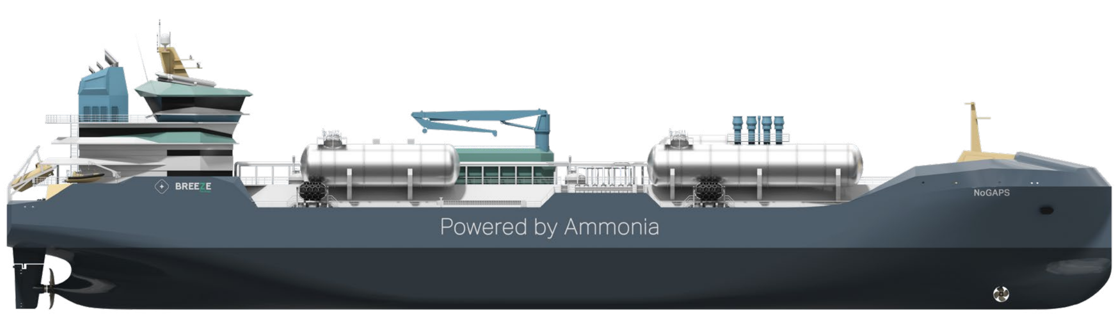
While the analysis is based on the case of NoGAPS, it is hoped that the approach can serve as a framework for exploring other first mover business cases, as well as the trade-offs and opportunities associated with different public and private actions to support them.

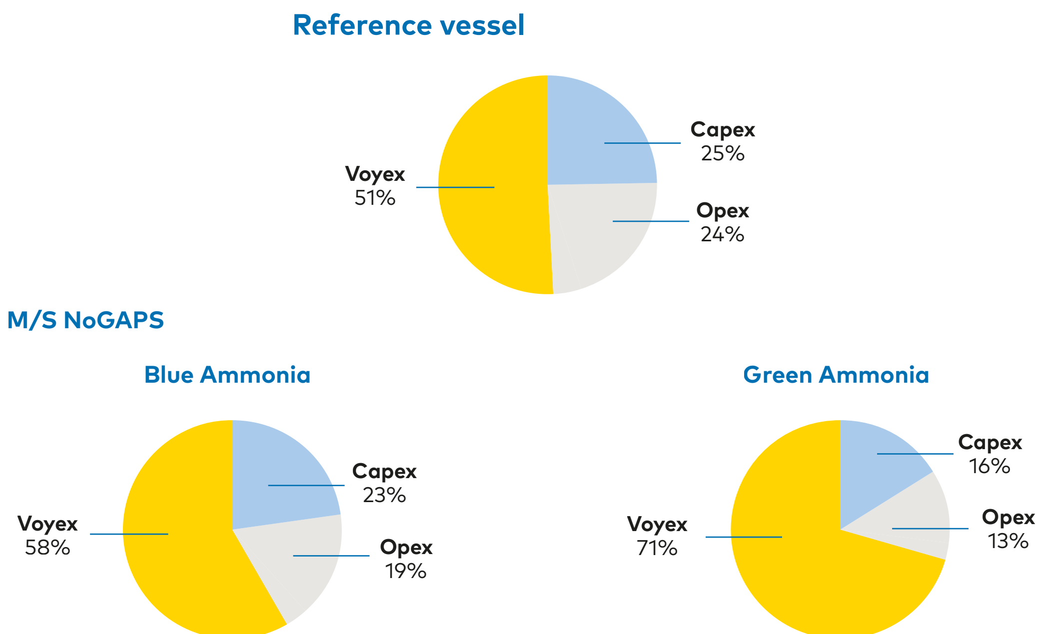
What is the challenge?

Securing a long-term charter agreement will depend on reducing early ammonia-powered vessels' total cost of ownership.

Early ammonia-powered vessels will be significantly more expensive to own and operate than their conventional equivalents. While the higher capital cost of the vessels themselves is a factor, the overwhelming driver of the increased cost of ownership is the cost of clean ammonia. Much like the other zero-emission fuels under consideration by the sector, clean ammonia – both its blue variety, produced by conventional means with applied carbon capture and storage, and green variety, produced with renewable energy – is expected to be significantly more expensive than conventional bunkers.

This is true of M/S NoGAPS, where the cost of clean ammonia is likely to account for ~80-90% of the additional cost of ownership of the vessel compared to a conventional gas carrier.





Three pie charts showing the breakdown of costs for a reference vessel, M/S NoGAPS operating on blue ammonia, and M/S NoGAPS operating on green ammonia in 2026. For the reference vessel, the voyage expenditure is 51%, capital expenditure 25%, and operating expenditure 24% of the cost. For M/S NoGAPS operating on blue ammonia, the voyage expenditure is 58%, capital expenditure 23%, and operating expenditure 19% of the cost. For M/S NoGAPS operating on green ammonia, the voyage expenditure is 71%, capital expenditure 16%, operating expenditure 13% of the cost.

Figure 11: Breakdown of the main cost items for M/S NoGAPS compared to equivalent conventional vessel in 2026. Source: Global Maritime Forum analysis.

Under a time chartering arrangement, much of this increase will fall on the charterer. In this arrangement, the charterer not only pays charter hire to the shipowner for use of the vessel but is also responsible for paying the vessel's voyage costs, including the cost of fuel. This means that the charterer faces a double cost increase for a vessel like NoGAPS – higher chartering costs and higher fuel costs. This makes it difficult for the charterer to obtain a viable business case. If projects are to secure a long-term charter agreement, and move forward, it is, therefore, crucial that the total cost of ownership gap is bridged.

What levers and structures are needed to solve the challenge?

There are multiple levers that can be pulled to support the first mover business case.

The NoGAPS1 report concluded that a combination of public and private measures would likely be required to support the commercialisation of M/S NoGAPS; this conclusion has been taken as the starting point for this analysis.

Partner input and desktop research suggest there are seven measures that could reduce the cost gap and would be feasible to implement. They can be placed into the four main categories described below: energy efficiencies, value chain cost sharing, regulation, and subsidies.

Measures to support first-mover project economics

Operational efficiencies

On top of the technical efficiencies examined earlier in the report, the manner in which vessels are operated also greatly affects their fuel usage. As highlighted by recent industry work under the Getting to Zero Coalition's Short-Term Actions Taskforce[11], operational efficiencies represent an under-exploited opportunity to reduce emissions from conventional ships, but also an important tool for managing the extra costs associated with zero-emission ships.

Two sets of operational efficiencies are considered relevant for M/S NoGAPS:

- **Slow steaming**: A large body of evidence has shown that slow steaming - deliberately operating a vessel below its design speed – is one of the most effective means for ships to reduce their fuel consumption.

  In keeping with other estimates[12], it is estimated that a fuel reduction in the mid to high teens could be possible for M/S NoGAPS. It should be noted that there exist trade-offs with implementing slow steaming. There is an opportunity cost, with slower travel meaning that voyages take longer to complete and the ship thus has less cargo carrying capacity on e.g. a yearly basis, and logistical disadvantages, namely making it more difficult to fulfil deliveries in a timely fashion, which is especially relevant for speciality products, including ammonia.

- **Incremental operational efficiencies**: Other operational measures are also relevant and have lower barriers to implementation, including voyage optimisation, weather routing, Just-in-Time port arrivals, and hull and propeller fouling management, which have the potential to unlock up to 10% energy efficiency gains per ship if combined[13].

  In the case of NoGAPS, partners estimate that a 5% additional reduction in fuel consumption could be achievable by "leaning into" these efficiencies.

11 See Resources (globalmaritimeforum.org) for recommendations and learnings from the Taskforce.
12 Based on NoGAPS Fuel Consumption report (unpublished).
13 For example, MMMCZCS, 'Maritime Decarbonization Strategy 2022', p.18.

Value chain cost-sharing

The NoGAPS1 report highlighted the potential for in-kind contributions to support the project business case, by spreading the cost premium through the value chain. Two forms of value chain cost sharing are viewed as most realistic as NoGAPS moves forwards:

- **Discounted port dues**: Many ports offer discounts on the fees vessels pay to enter and use the port's services if they achieve predefined standards of environmental performance, usually those set out by an independent scheme like the Environmental Ship Index or Clean Shipping Index. Starting in the Nordics, such initiatives have spread and are now common in Europe and the Americas. It is anticipated that ammonia-powered vessels would be able to benefit from the discounts offered, due to their high level of environmental performance.

  The level of discount offered by ports varies on a case-by-case basis. On the potential route for M/S NoGAPS, there is limited participation from the main ammonia export ports in the Gulf, but stronger uptake in Northwestern Europe, with an average discount in relevant ports[14] of just under 10%. Therefore, a 5% discount is deemed to be realistic for NoGAPS.

  However, best-in-class differential port dues schemes already offer significantly more generous discounts than this average, with Singapore, Oslo, and Vancouver currently offering up to 30%, 40%, and 75% discounts respectively[15]. This shows the upper end of what may be considered feasible and has, therefore, been used to model a higher-ambition scenario for value chain cost sharing.

- **In-kind contributions by project partners**: There are many avenues for the project partners themselves to share cost and risk, with financing discounts, in-kind cost coverage, and discounts on the cost of clean ammonia all highlighted as potential options in NoGAPS1.

  Given the likely ownership structures and allocation of costs and risks for NoGAPS, an in-kind contribution from the shipowner, who could offer a modest reduction in the charter hire rate to facilitate the agreement, was seen as the most relevant measure within the project consortium.

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14 Ports with ammonia terminals in Northwestern Europe, including Rostock, Brunsbüttel, Hamburg, Rotterdam, Antwerp, Terneuzen, Grenland, Glomfjord, Köping, Stenungsund. Uusikaupunki.

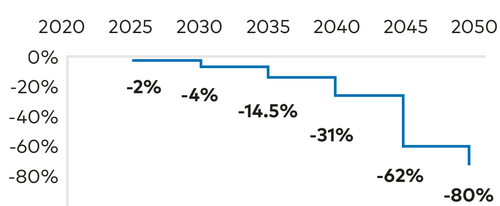
15 Port of Vancouver EcoAction Program incentives: EcoAction Program | Port of Vancouver (portvancouver.com); Port of Oslo incentives: prices-and-commercial-terms-2023.pdf (oslohavn.no); Maritime and Port Authority of Singapore 'Green Port Programme' incentives: Maritime Singapore Green Initiative | Maritime & Port Authority of Singapore (MPA).

Regulation

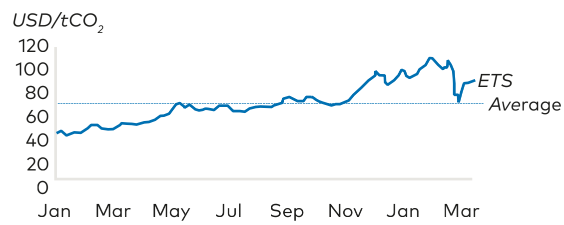
In the two years since the first NoGAPS report, there has been major progress in implementing policy measures to drive the shipping transition.

The most significant piece of regulation to emerge is the EU Fit for 55 package, the shipping components of which were agreed in July 2023. It consists of two separate measures - bringing shipping into the Emissions Trading Scheme and the FuelEU Maritime regulation.

FuelEU Maritime
Sets emissions intensity reduction targets



EU-ETS
Caps emissions and forms a tredeable market



	FuelEU Maritime		EU-ETS
General	Mandates demand requirement for fuels with a decreasing GHG intensity content over time, grams of CO_2 equivalent per MJ	**General**	Defines a maximum amount of allowable emissions. For each tone of CO_2 one emission allowance is issued, auctioned, and traded among the emitters on secondary markets during a trading period
Emissions	WTW, GHG emissions (recalculated to CO_2-equivalents)[1]	**Emissions**	WTT GHG emissions
Scope	All ships ≥5,000 GT visiting aport in EU and transporting cargo or passengers for commercial purpose. Capturing all intra-EU voyages emissions, and 50% of emissions from extra-EU voyages	**Scope**	Same as FuelEU
Baseline	Using a reference value corresponding to the 2020 average GHG intensity	**Baseline**	Maritime emissions tradable allowancies will be added to the EU-ETS trading scheme. All allowancies are made available by auction with a scheduled linear reduction of ~4% tradeable allowancies early
Cost	A "pay-to-comply" mechanism – set at 2,400 EUR/tHFOe (~800 USD/tCO_2) - can be paid when breaching the limit. Only the part breached is subject to the penalty. This option gives firms the option not to comply with the GHG intensity targets against simple payment of a penalty.	**Cost**	Supply and demand of allowancies will determined the trading price

Graphic shows the decrease in the carbon intensity threshold set by FuelEU Maritime from 2025 to 2050. Reductions are 2% in 2025, 4% in 2030, 14.5% in 2035, 31% in 2040, 62% in 2045, and 80% in 2050.

Graphic is indicative, showing how the cost of EU Emissions Allowances should increase over time. It shows an upward trend.

Figure 12: Overview of FuelEU Maritime and EU ETS regulations. Source: Adapted from Maersk McKinney Moller Center for Zero-Carbon Shipping, "What can the industry learn and adopt from regional regulations?." Updated to reflect final regulatory proposals.

Shipping's inclusion in the EU Emissions Trading Scheme is expected to have a greater impact on cost in the medium term, with ship operators having to pay for their full onboard carbon, nitrous oxide, and methane emissions for voyages within EU waters and 50% for voyages that start or end in EU ports from 2026, following a two-year phase-in. FuelEU Maritime, meanwhile, imposes a limit on the lifecycle greenhouse gas intensity of the fuel used onboard ships, which will be reduced over time. If ship operators do not comply, they must pay a remedial penalty to achieve compliance. Both regulations will, directly or indirectly, increase the cost of conventional fuel and therefore help to bridge the cost gap with ammonia-powered ships.

While the IMO, shipping's global regulator, has made progress in shortlisting potential "mid-term measures" to support the reduction of emissions from the sector, there will not be certainty on the shape and stringency of the eventual measures until 2025 at the earliest. While the eventual measures will have a significant impact, because of the uncertainty, they are not considered within the archetypes described in the following section.

Subsidies

In addition to regulation, governments may offer subsidies to incentivise the deployment of green vessels, which recent research shows can be a highly effective means of kickstarting the roll out of clean technologies[16].

Two types of subsidies would be relevant to M/S NoGAPS – capital and fuel subsidies.

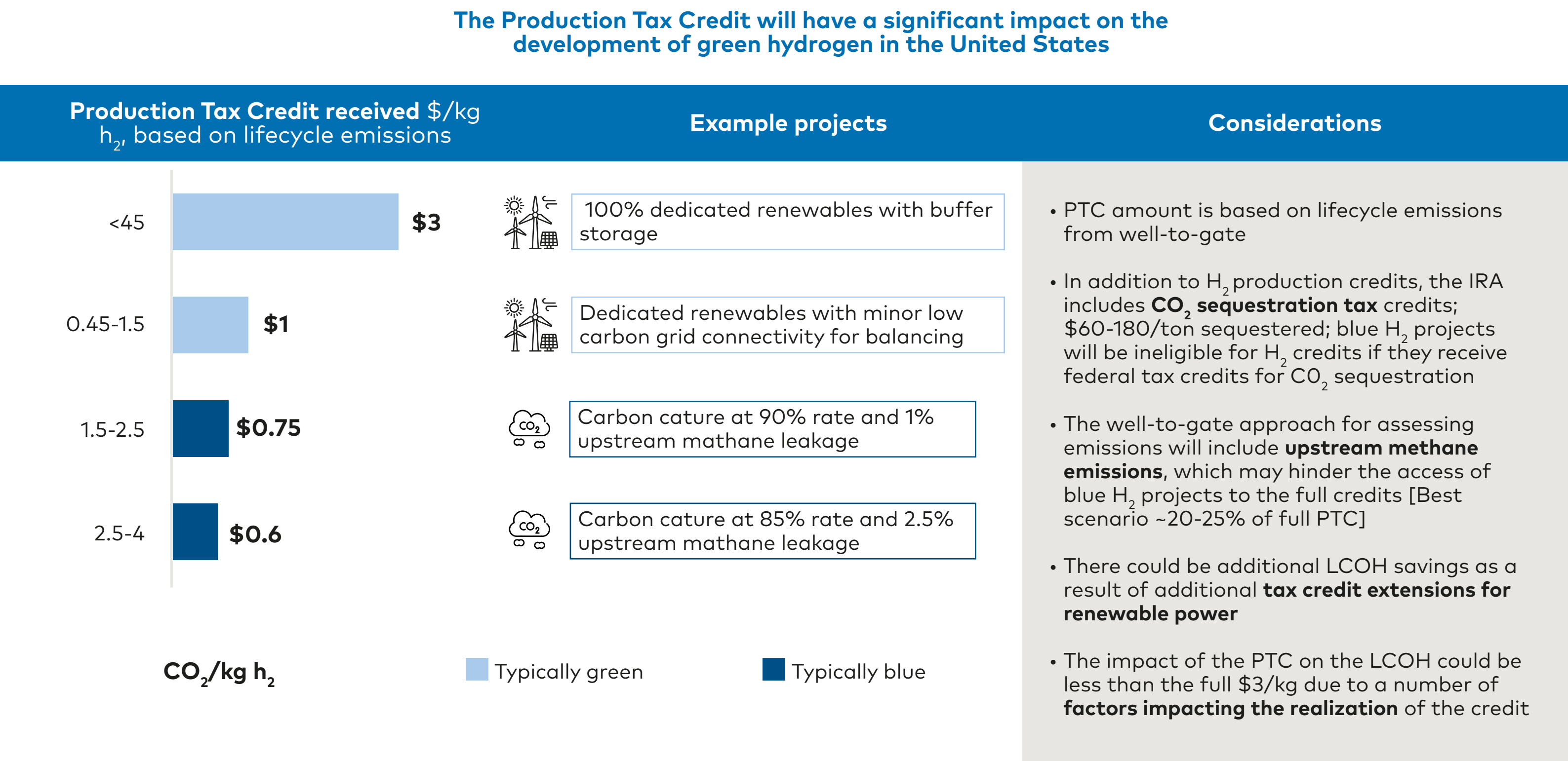
- **CAPEX subsidies**: Traditionally, subsidies for green ships have been focused on capital and project development costs, which was examined in detail in the Financing section.
- **Fuel subsidies**: Despite growing traction, at present, there is no support available to bridge the cost gap between conventional and zero-emission fuels in the shipping sector specifically.

However, over the past year many countries have proposed incentives to galvanise the scale up of hydrogen production more broadly. While not targeted directly at shipping, these incentives will have a significant impact on the sector.

16 See, for example, EEIST 'Ten Principles for Policy Making in the Energy Transition' (2022).

The most relevant incentive in the case of NoGAPS is the US Inflation Reduction Act (IRA). The IRA provides an array of clean energy tax incentives, accounting for up to $369bn across the US economy. Most relevantly to zero-emissions shipping, the IRA includes a set of tax credits for the production of clean hydrogen.

Figure 13: Overview of the hydrogen tax credits offered under the US Inflation Reduction Act. Source: RMI.



Under the IRA, producers of green hydrogen can receive credits of 2.6 cents per kWh toward the cost of the renewable energy for the plant and up to $3 per kg of hydrogen for the first ten years of production. Credits are also available for blue hydrogen, made from carbon capture-enabled conventional production, in the form of either a more limited version of the full hydrogen credit, at up to $0.75 per kg, or a dedicated $60-$180 per ton carbon sequestration tax credit.

These incentives are expected to make the clean ammonia produced in areas of the US with good renewable energy or low-cost gas resources the cheapest in the world. Accessing American clean ammonia, therefore, has the potential to greatly close the fuel cost gap for first mover projects.

Commercial model archetypes for M/S NoGAPS

These levers can be combined in different ways; four combinations are explored for M/S NoGAPS.

To understand how far the total cost of ownership gap could be closed, four commercial model "archetypes" were created, combining these measures in different ways. The archetypes do not represent predictions about future action, but, rather, a way to explore what could be possible within the NoGAPS business case in different action and policy scenarios.

All four of the archetypes - Base case, Industry leadership, Policy pull, and Strategic opportunity – share the same base.

Compliance with the forthcoming regulation under the EU Fit for 55 package is factored into all of the archetypes. By definition, the cost of compliance under the ETS is variable, depending on supply and demand in the carbon market, which makes forward investment planning more difficult. For the purposes of modelling, an assumption that the ETS will achieve a price of ~$105 per ton of CO_2 equivalent is used[17]. Conversely, for FuelEU Maritime, the requirements are clearly defined as part of the regulation and the stipulated greenhouse gas intensity in the regulation have been included, namely a -2% reduction in 2026 and -6% reduction in 2030.

All archetypes also include a 50% grant on the incremental CAPEX for M/S NoGAPS, given this is required for the deployment of the vessel in any scenario.

The individual archetypes are distinguished by the levers on top of this common base:

- **The Base case archetype** represents a scenario in which there is incremental operational efficiencies and modest value chain cost sharing only, and, as such, represents something close to a business-as-usual scenario.
- **Industry leadership** is more ambitious than the Base Case by one degree; it includes slow steaming and best-in-class port dues discounts in addition to incremental operational efficiencies and value chain cost sharing.
- **Policy pull** features modest value chain cost sharing and incremental operational efficiencies, but assumes NoGAPS benefits from IRA-subsidised clean ammonia.
- While the **Strategic opportunity** archetype represents the most collaborative and ambitious scenario, exploring what could be achieved if the full range of measures were deployed - incremental operational efficiencies, slow steaming, ambitious value chain cost sharing, and access to IRA-subsidised fuel.

17 Assumption based on expert forecasts on the average EUA price between 2026-2030 from the International Emissions Trading Association (IETA) - IETA GHG Market Sentiment Survey Report 2022.pdf.

M/S NoGAPS commercial model archetypes

	1. Base case	2. Industry leadership	3. Policy pull	4. Strategic opportunity
Description	Realistic cost sharing + future compliance	Maximum value chain action + future compliance	Realistic cost sharing + future compliance + deployment subsidies	Maximum value chain action + future compliance + deployment subsidies
Measure Efficiencies	-5% fuel from incremental operational efficiencies • Propeller and hull cleaning • Voyage optimisation	-18% fuel from slow steaming -5% fuel from incremental operational efficiencies • Propeller and hull cleaning • Voyage optimisation	-5% fuel from incremental operational efficiencies • Propeller and hull cleaning • Voyage optimisation	-18% fuel from slow steaming -5% fuel from incremental operational efficiencies • Propeller and hull cleaning • Voyage optimisation
Cost Sharing	-5% port dues Small discount on charter hire	-30% port dues Small discount on charter hire	-5% port dues Small discount on charter hire	-30% port dues Small discount on charter hire
Regulation	EU - 50% application of ETS at ~$105/t CO_2 and 50% of FEUM	EU - 50% application of ETS at ~$105/t CO_2 and 50% of FEUM	EU - 50% application of ETS at ~$105/t CO_2 and 50% of FEUM	EU - 50% application of ETS at ~$105/t CO_2 and 50% of FEUM
Subsidies	50% subsidy for CAPEX increment	50% subsidy for CAPEX increment	50% subsidy for CAPEX increment IRA 45V, 45Y, 45Q tax credit-supported fuel	50% subsidy for CAPEX increment IRA 45V, 45Y, 45Q tax credit-supported fuel

Figure 14: : Four commercial model archetypes explored for NoGAPS project economics. Global Maritime Forum analysis.

Modelling was undertaken to estimate how far the archetypes could close the cost gap.

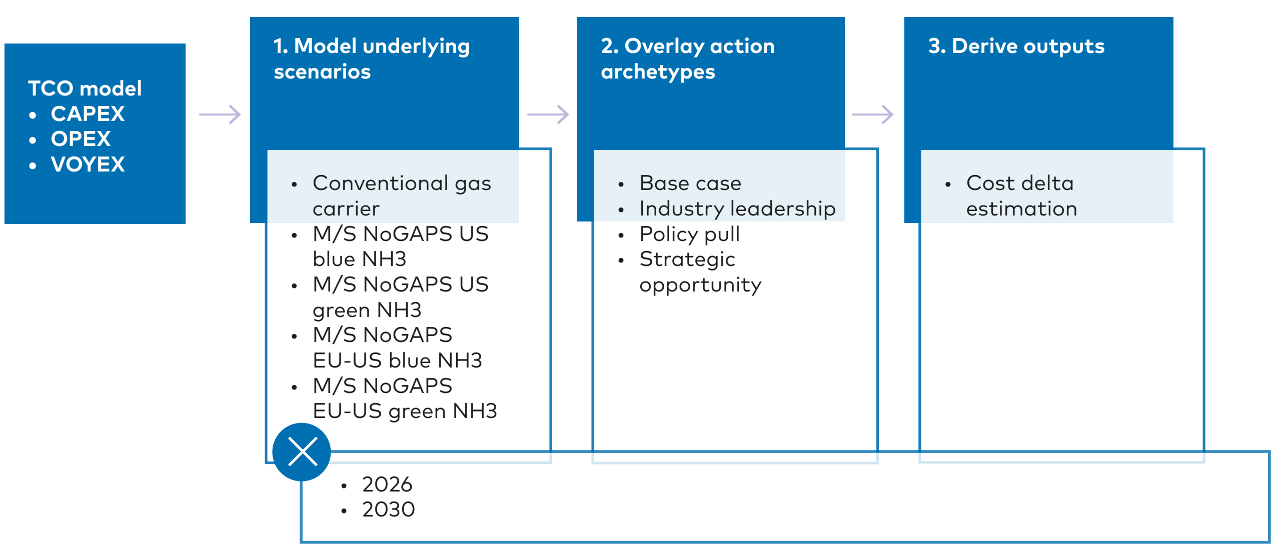
Five underlying scenarios are examined: the annual cost to operate M/S NoGAPS on blue ammonia bunkered in the US and EU; the annual cost to operate M/S NoGAPS on blue ammonia bunkered only in the US; the annual cost to operate M/S on green ammonia bunkered in the US and EU; the annual cost to operate M/S on green ammonia bunkered in the US only; and the annual cost of an equivalent conventional gas carrier.

The two bunkering scenarios - in which M/S NoGAPS were to either bunker twice per roundtrip, once in the Gulf of Mexico with clean ammonia produced in Texas and once in Europe with ammonia produced in Northwestern Europe, or once per roundtrip only, in the Gulf of Mexico with clean ammonia produced in Texas – would both be feasible, given the vessel's fuel storage capacity. They are considered because, like the colour of ammonia, the cost of ammonia is expected to differ based on bunkering location.

The four archetypes are then overlayed on the blue and green ammonia scenarios, with the estimated cost reductions from each being subtracted from the initial cost.

This is done for two discrete years - 2026 and 2030, the vessel's likely start of operation and the end of this decade - to provide a sense of the potential cost development of the vessel, accounting for the tightening of regulations over time as well as the decrease in the cost of green ammonia costs that are expected to be achieved over course of the decade (and beyond).

Figure 15: Cost modelling approach for economics assessment.



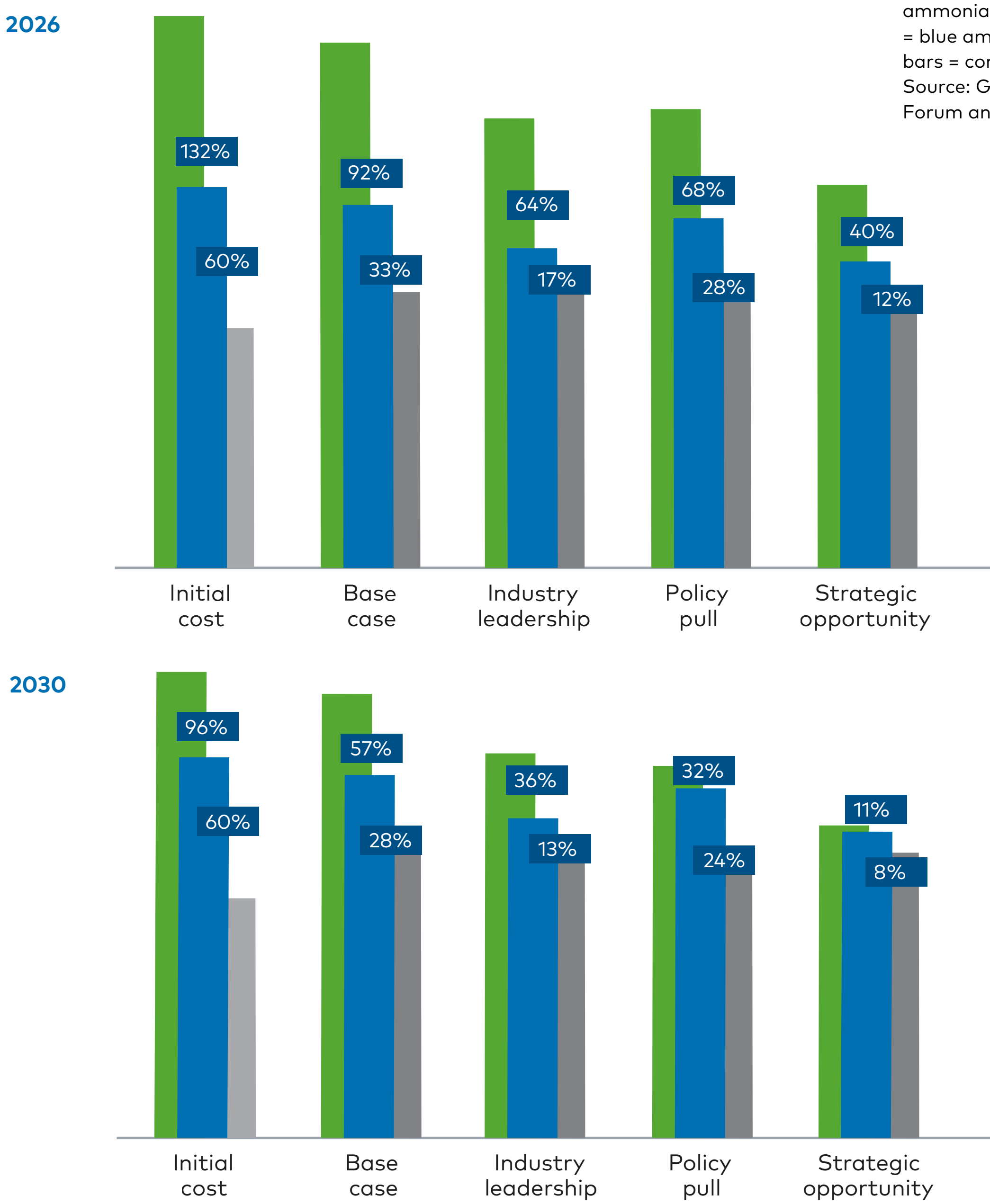
A list of the CAPEX, OPEX, and VOYEX assumptions used can be found in the Appendix. For the purposes of the exercise, both green and blue molecules are assumed to be available in sufficient quantities for NoGAPS.

The findings are described below.

Bunkering scenario 1: US and EU

With public-private action, blue ammonia can approach parity with conventional bunkers. However, green ammonia faces a premium until the early 2030s.

Figure 16: Estimated cost gap between M/S NoGAPS and conventional equivalent prior to and after application of the archetypes were it to bunker in the US and EU. Green bars = green ammonia cost, blue bars = blue ammonia cost, grey bars = conventional vessel. Source: Global Maritime Forum analysis.



The graphic contains two sets of bar charts showing the estimated cost gap between M/S NoGAPS and the reference vessel were it to bunker in the US and the EU. The first set of bars show the cost gap in 2026. The initial cost is 132% higher for green ammonia and 60% higher for blue ammonia. Green ammonia is 92% higher and blue ammonia is 33% higher in the Base case archetype. Green ammonia is 64% higher and blue ammonia is 17% higher in the Industry leadership archetype. Green ammonia is 68% higher and blue ammonia is 28% higher in the Policy pull archetype. Finally, green ammonia is 40% higher and blue ammonia is 12% higher in the Strategic opportunity archetype.

The second set of bars show the cost gap in 2030. The initial cost is 96% higher for green ammonia and 60% higher for blue ammonia. Green ammonia is 57% higher and blue ammonia is 28% higher in the Base case archetype. Green ammonia is 36% higher and blue ammonia is 13% higher in the Industry leadership archetype. Green ammonia is 32% higher and blue ammonia is 24% higher in the Policy pull archetype. Finally, green ammonia is 11% higher and blue ammonia is 8% higher in the Strategic opportunity archetype.

Looking first at the scenario in which M/S NoGAPS bunkers in the US and Europe, were it to use green ammonia, the vessel would face a significant cost premium of between 40-90% in 2026 across all of the archetypes. This gap would not be closed until at least the early 2030s.

In the Base case archetype, it would experience the upper end of this premium, or around a +90% cost premium in 2026 and a +50% gap in 2030. These results strongly indicate that business-as-usual, even the "new business-as-usual" that will be ushered in once the EU Fit for 55 package kicks in in the middle of the decade, will not support a viable business case for vessels like M/S NoGAPS.

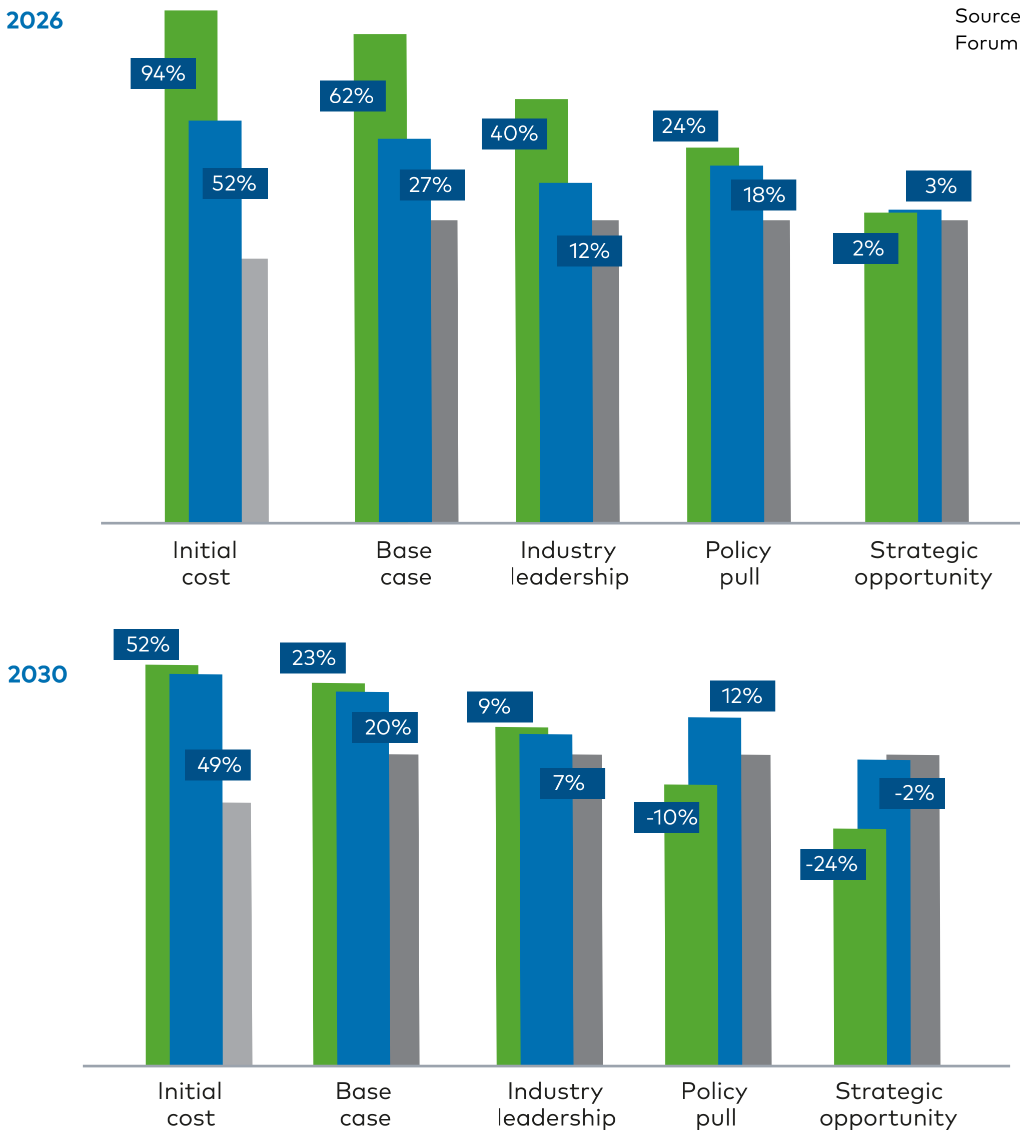
Although the outlook is improved if either slow steaming can be implemented or IRA-subsidised green ammonia is available, M/S NoGAPS would still face a roughly 35-65% premium through the decade. Rather, the full suite of measures considered – including Fit for 55, IRA-subsidised clean ammonia, and ambitious value chain action, including slow steaming – would be needed to make significant inroads into the cost premium. This would not close the gap, but it could have a major impact, reducing it from 65% to as little as 10% by 2030.

Meanwhile, the results show that using blue ammonia is likely to be significantly cheaper than green; it would be not far from being competitive with conventional bunkers in two archetypes from 2026, with the Strategic opportunity and Industry leadership archetype bringing the cost premium down into the teens by the middle of the decade and as low as 8% by 2030.

Bunkering scenario 2: US only

In contrast, thanks to lower ammonia costs and higher IRA benefits, using US-produced ammonia could close the cost gap from day one.

Figure 17: Estimated cost gap between M/S NoGAPS and conventional equivalent prior to and after application of the archetypes were it to bunker only in the US. Green bars = green ammonia cost, blue bars = blue ammonia cost, grey bars = conventional vessel. Source: Global Maritime Forum analysis.



The graphic contains two sets of bar charts showing the estimated cost gap between M/S NoGAPS and the reference vessel were it to only bunker in the US. The first set of bars show the cost gap in 2026. The initial cost is 94% higher for green ammonia and 52% higher for blue ammonia. Green ammonia is 62% higher and blue ammonia is 27% higher in the Base case archetype. Green ammonia is 40% higher and blue ammonia is 12% higher in the Industry leadership archetype. Green ammonia is 24% higher and blue ammonia is 18% higher in the Policy pull archetype. Finally, green ammonia is 2% higher and blue ammonia is 3% higher in the Strategic opportunity archetype.

The second set of bars show the cost gap in 2030. The initial cost is 52% higher for green ammonia and 49% higher for blue ammonia. Green ammonia is 23% higher and blue ammonia is 20% higher in the Base case archetype. Green ammonia is 9% higher and blue ammonia is 7% higher in the Industry leadership archetype. Green ammonia is 12% higher and blue ammonia is 10% lower in the Policy pull archetype. Finally, green ammonia is 24% lower and blue ammonia is 2% lower in the Strategic opportunity archetype.

There would be a significant contrast if M/S NoGAPS were to only bunker in the US.

The initial delta facing NoGAPS is immediately reduced from an estimated 60-132% gap in 2026 and 60-96% gap by 2030 to 52-94% and 59-52% respectively, driven by the lower cost of Texan clean ammonia.

Once the archetypes are applied, the results become highly favourable; rather than experiencing a cost premium of some size up to 2030, both green and blue ammonia could hit cost parity with conventional fuel as early as 2026.

Green ammonia hits cost parity immediately in 2026 in the Strategic opportunity archetype, with its combination of measures reducing the cost gap to just 3% by this point. Two archetypes then achieve parity in 2030 – Strategic opportunity and Policy pull, with a third – Industry leadership – not far behind, at just a 7% premium. More than just hitting parity, the results in fact suggest that using green ammonia could be value additive, saving money compared to operating a conventional vessel. In practice, it is unlikely that value chain cost sharing and efficiencies would be prioritised in this scenario. As such, although these savings may not be realised in reality, they highlight the large potential to reduce the cost gap in this scenario.

The results for blue ammonia are promising across the board, with the premium being reduced to a maximum of 27% and as little as 2% by 2026. This improves slightly further by 2030, ranging from a 20% premium to a potential 2% cost saving. While only the Strategic opportunity archetype reaches full cost parity, by 2030 the Industry leadership archetype also comes close, emphasising the potential for slow steaming to impact on the cost gap.

Although using blue ammonia remains cheaper than green in almost all cases across the two sets of scenarios, in two of the archetypes in 2030 green is found to be cheaper than blue. This is likely due to two reasons. First, blue ammonia is not expected to achieve the same cost declines over time as green ammonia. Second, the IRA hydrogen production tax credits are significantly more generous for green than blue, as previously noted.

No one existing lever can close the cost gap, but all levers can in combination.

Across each of these cases, three measures drive the lion's share of cost reductions – the IRA, Fit for 55, and slow steaming.

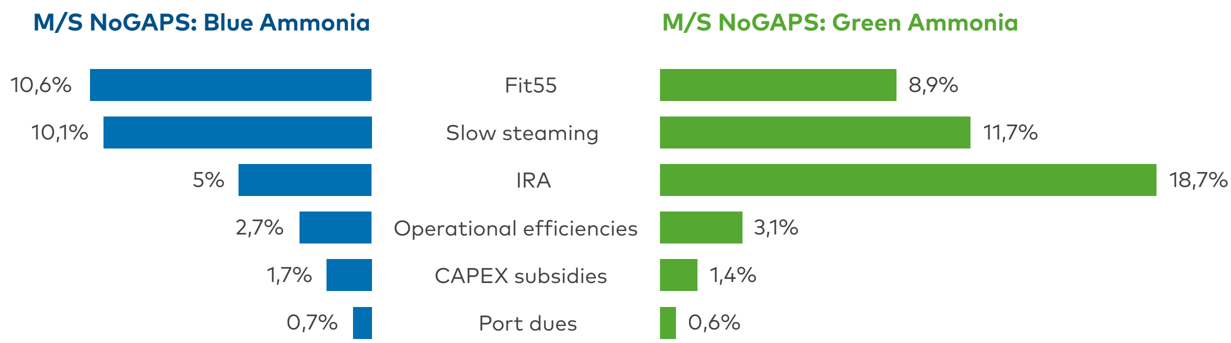


Figure 18: Average cost reduction achieved by different measures across the archetypes and scenarios. Source: Global Maritime Forum analysis.

The impact of public sector action in supporting economic viability is clear. As shown in Figure 18, the IRA reduces the annual cost of running M/S NoGAPS on green ammonia by an average of just under ~20% where present - the biggest reduction from any single lever. Conversely, since the subsidy available for blue ammonia is less generous than green – at up to 80 cents per kg versus up to $3 per kg – the IRA closes the cost gap between blue ammonia and conventional fuel by just 5%. From the other direction, the Fit for 55 package also makes a key inroads into the cost delta, by increasing the total cost of operating the conventional vessel; this reduces the cost gap by around 10% across the scenarios - 9% in 2026, increasing to 11% in 2030, as the regulations become more stringent.

Besides these public sector measures, the results also highlight the potential for value chain action to accelerate the commercialisation of early ammonia-powered vessels. While discounted port dues and incremental operational efficiencies can play a valuable supporting role in bridging the gap, slow steaming emerges as the key opportunity to reduce cost within the value chain – at an average of 10-12% in the model, similar to the Fit for 55 package. While the absolute impact of CAPEX grants on the total cost of ownership is relatively small, their overall value in reducing risk remains significant, as highlighted in the Financing section.

The underlying cost of clean ammonia also has a significant impact on the economics of early mover projects. This can be shown through a sensitivity analysis, which examines how changing the cost of fuel impacts on the modelling results. It shows that using green ammonia that cost, for example, $700 per tonne – a favourable cost for the middle of this decade – rather than $1000 per tonne - an average cost – would reduce M/S NoGAPS annual cost by almost 20%, as much as the IRA again. This underscores the importance of a well-considered fuel strategy and operational model in early projects, but also reinforces the potential for shipping to benefit from emerging hydrogen policies. While the Inflation Reduction Act is perhaps best-known, over the past year several countries have brought forward their own schemes to subsidise the production of clean hydrogen, including the EU through its Hydrogen Bank, the UK through the Hydrogen Business Model, Australia with the Hydrogen Headstart programme, Germany via H2Global, and Denmark through its Contracts for Difference scheme. Given their potential impact, early movers should explore whether they can benefit from these subsidies.

As can be seen, no one measure is sufficient to close the gap on its own. Rather, they must be combined in order to close the gap for clean ammonia. This explains why it is the Strategic opportunity archetype - combining Fit for 55, the IRA, high action of energy efficiency, and high-level value chain cost sharing - that overwhelmingly achieves cost parity in the cases examined.

Potential commercialisation pathways for M/S NoGAPS

These results suggest there are at least three feasible pathways to commercialising M/S NoGAPS.

From an investment perspective, it is important to minimise the cost gap from as early as possible. In this context, three pathways for commercialising M/S NoGAPS emerge from the modelling:

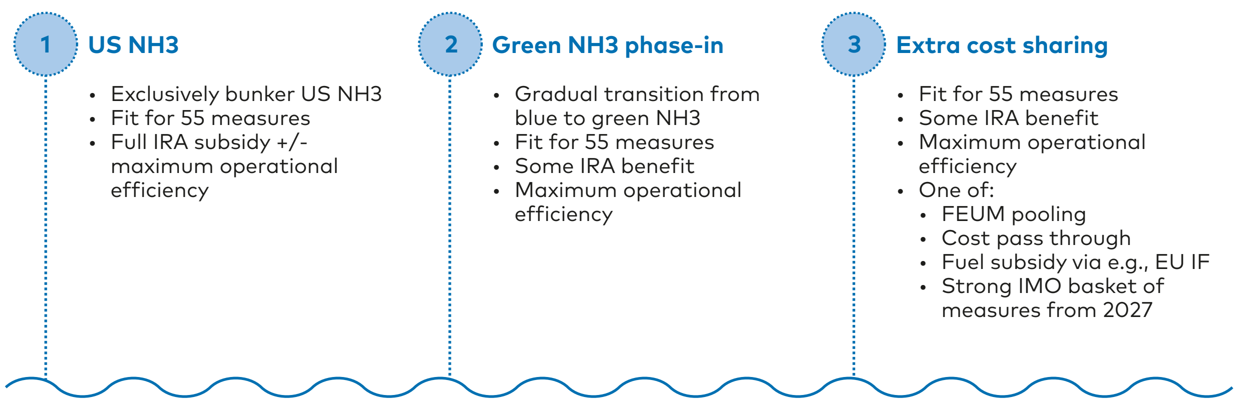


Figure 19: Three anticipated pathways for commercialising M/S NoGAPS.

Pathway 1: US NH3

Bunkering in the US with IRA-subsidised clean ammonia should be viable for M/S NoGAPS, if suitable action is taken within the value chain, namely strong cost sharing and slow steaming.

Bunkering in Northwestern Europe, which could be required, could also be viable, albeit with trade-offs and/or dependent on pulling additional cost reduction levers.

Pathway 2: Green NH3 phase-in

One option would be a transition pathway, with M/S NoGAPS initially using blue ammonia until the green cost gap is closed in the early 2030s, supporting the project economics in the near term while progressively ramping down the ship's emissions. However, it should be noted that the vessel would face a moderate premium and that this pathway would require a high and sustained level of value chain action.

Pathway 3: Extra cost sharing

If there was a desire to use green ammonia from day one or if key measures within the other pathways could not be put into place, there are other options for responding to the remaining cost gap which could be relevant:

- **Timely introduction of a basket of strong policy measures at IMO**: The 2023 IMO Greenhouse Gas Strategy sets a timeline for agreeing and implementing a basket of mid-term measures by 2027. Options that will be considered include a fuel standard, which, like FuelEU Maritime, would mandate improvements in the greenhouse gas intensity of energy used onboard ships, and an economic instrument, such as a feebate system or levy, under which shipowners would pay for the emissions they create.

  The introduction of a strong set of policy measures by the IMO will be vital to stimulate a mass market transition to zero-emission shipping and ensure an equitable transition. But these measures, if implemented in a timely fashion and with a suitable level of stringency from early in their operation, can also play a role in supporting first movers, by helping to ensure the long-term viability of zero-emission investments and allowing solutions to get closer to parity earlier.

  This is true of M/S NoGAPS, where even a relatively modest greenhouse gas price of $50 per tonne of carbon dioxide equivalent could meaningfully support the business case. Although a carbon price of this magnitude would have a small impact in absolute terms - reducing the gap by roughly 8% by 2030 - it could have a significant marginal impact, nudging the project from the red to black:

Archetype	Cost gap without IMO GHG price	Cost gap with IMO GHG price
Initial green	+65%	+57%
Base case	+57%	+50%
Industry leadership	+36%	+30%
Policy pull	+32%	+25%
Strategic opportunity	+11%	+5%
Initial blue	+35%	+28%
Base case	+28%	+22%
Industry leadership	+13%	+8%
Policy pull	+24%	+18%
Strategic opportunity	+8%	+3%

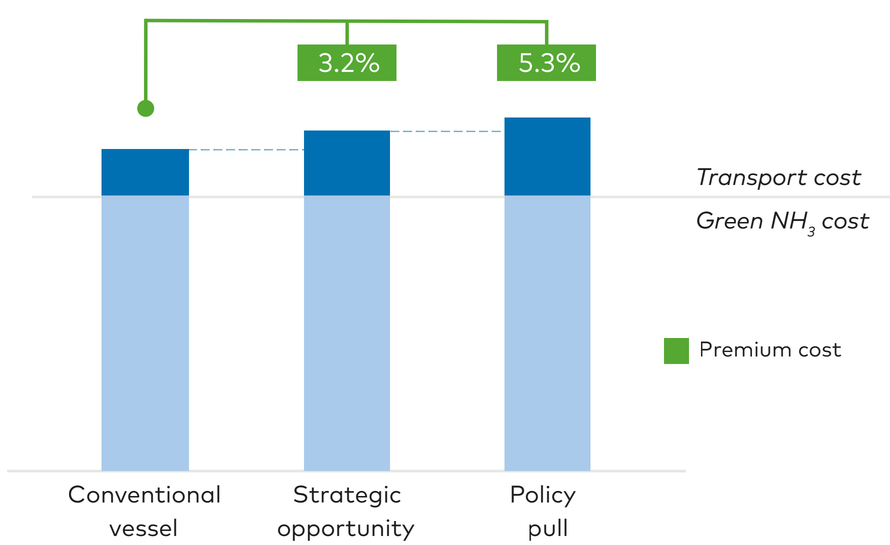
Figure 20: Estimated incremental cost gap reduction from $50/t C02e price for EU and US green ammonia bunkering case in 2030. Source: Global Maritime Forum analysis.

- **Supplementary fuel subsidy**: Timely implementation of a Contracts for Difference scheme or fixed cost premia at the national/regional level would offer an effective way of bridging the remaining near-term fuel cost gap.

  At present, no maritime RD&D scheme provides support for fuel costs. However, the EU has positioned itself as an early leader, with its Innovation Fund exploring "competitive auctions" that would subsidise zero-emission fuels for shipping. Based on the number of allowances that have been allocated to the Fund, it is likely it will have an annual budget of €250-333m/year of dedicated funding available for shipping decarbonisation between 2024 and 2030[18]. Closing the residual cost gap for M/S NoGAPS would require a small fraction of this yearly budget – in the single digits – between 2026 and 2030 and could take the form of a Contract for Difference or fixed cost premium covering the gap between very low sulphur fuel oil (VLSFO) and clean ammonia[19].

- **Cost pass through**: Willingness among shipping customers to pay a premium for green transport is developing rapidly. According to recent research[20], 82% of shipping customers are now willing to consider paying a premium for zero-carbon shipping – an 11% increase from 2021. The average premium these actors report being willing to consider is 3%, with indications that this figure will increase in the future.

Figure 21: Estimated green transport premium required to pass on cost, 2026 EU-US green ammonia scenario. Source: Global Maritime Forum analysis, based on RMI ammonia cost modelling.



Bar chart showing the increase in the cost of the ammonia cargo from it being transported on a ship powered by ammonia. It consists of three bars - the conventional cost, the cost in the NoGAPS EU-US Strategic opportunity archetype, which is 3.2% higher, and the cost in the NoGAPS EU-US Policy pull scenario, where it is 5.3% higher.

18 Transport & Environment analysis presented at Getting to Zero Coalition/ Transport & Environment webinar, 'EU ETS and Innovation Fund: accessing EU finance' (14 June 2023). Recording available at: EU Emissions Trading Systems & the Innovation Fund | Getting to Zero Coalition - YouTube.

19 Global Maritime Forum analysis, based on EU-US Policy Pull archetype. See research by the Getting to Zero Coalition for how an EU Contracts for Difference scheme for shipping could be implemented.

20 BCG, 'Customers' Willing to Pay Can Turn the Tide Toward Decarbonized Shipping' (2022).

It is estimated that a ~5% premium on the delivered cost of green ammonia could fully cover the remaining residual for M/S NoGAPS, and potentially less, depending on the cost levers pulled. As such, while the underlying cost premium would represent a very large increase in cost for the charterer, it would be a small increase in the cost to the end-customer. To enable this pathway, an accepted certification scheme for clean ammonia and/or book and claim system, which allows the emissions profile of a zero- and near zero-emission fuel to be separated from the physical flow of that fuel in a transportation supply chain, would likely need to be in place.

- **FuelEU Maritime pooling mechanism**: Finally, with clean ammonia having the potential for low to zero lifecycle greenhouse emissions, NoGAPS would overcomply with the FuelEU Maritime greenhouse intensity requirements for the foreseeable future. This would generate a surplus of FuelEU Maritime credits, which, under the regulation, could be used to offset the underperformance of other vessels in the operator's fleet. This would mean that the operator would not need to make changes to these vessels to bring them into compliance; given the extent to which NoGAPS would overcomply, it could potentially offset the underperformance of a large portion of the operator's fleet, saving significant effort and expense. This could also be a solution for justifying the cost premium for M/S NoGAPS.

  It should be noted, however, that this is a solution that may not be available to smaller ship operators. Furthermore, by its nature, the value of this strategy declines for each vessel deployed, such that it is unlikely to represent a pathway to achieving large-scale deployment of zero-emission vessels.

Overall, the analysis provides a positive outlook on the prospects for commercialising M/S NoGAPS, with the existence of three pathways to close the total cost of ownership gap providing a high probability that a sustainable business case can be made.

Appendix

Cost model elements and assumptions

Expenditure	Cost items	Item elements	Assumptions
VOYEX	Fuel costs	Fuel consumption	Based on fixed operation between Houston, USA, and Porsgrunn, Norway; x10 32-day roundtrips a year at 16 knots, with 5% sea margin assumed.

		Forecasted fuel costs/ prices	Clean ammonia costs based on RMI modelling of clean ammonia production costs in Texas and Northwestern Europe.
			• EU and US bunkering scenario
			  • Green ammonia = 2026 $1000/t, 2030 $775/t
			  • Blue ammonia = $550/t
			• US only bunkering scenario
			  • Green ammonia = 2026 $798/t, 2030 $523/t
			  • Blue ammonia = $500/t
			Conventional fuel costs based on long-run average prices from ARA region.
			• VLSFO = $490/t
			• MGO = $680/t

	Port fees	-	Estimates from NoGAPS partners
CAPEX	Vessel cost	-	• Current build cost for conventional Handysize gas carrier with • Increment for ammonia engine, fuel supply system, tanks, and SCRs, based on NoGAPS partner input
	Financing cost	Debt payments	Estimate from NoGAPS1
OPEX	Daily operating cost	Crew Messing Stores Spares Repairs Insurance	Estimates from NoGAPS partners
	Drydock	-	Estimates from NoGAPS partners
	Management fees	-	Estimates from NoGAPS partners