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The New Era of Navigation: Clean Fuels to Save the Oceans

The New Era of Navigation: Clean Fuels to Save the Oceans

Abstract:

The fight against climate change is now an unavoidable obligation. The International Maritime Organization (IMO) has approved binding legal regulations requiring all ships worldwide to drastically reduce their greenhouse gas emissions, with the ambitious goal of reaching net-zero emissions by 2050.

The maritime sector is seeking alternatives to traditional diesel fuel. Liquefied Natural Gas (LNG) is emerging as a transitional fuel, while methanol, ammonia, and hydrogen are key options poised to revolutionize ship propulsion. These new fuels demand redesigning vessels, as they take up more space, reducing cargo capacity, while also increasing costs and requiring strict safety measures.

Keywords:

Climate Change, Gasoil, Liquefied Natural Gas, Ammonia, Methanol, Hydrogen

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Introduction

Maritime transport, once dependent on coal and the harmful tar-like substance chapapote, is undergoing a full-scale revolution. Reducing emissions is no longer just an ideal but a requirement set by the IMO, which has set its sights on full decarbonization by 2050. However, marine diesel oil remains the dominant fuel for most ships, releasing tons of harmful gases into the atmosphere. In response to this challenge, innovation is accelerating engineers and shipping companies are betting on new fuels such as ammonia, methanol, and hydrogen. The transition will not be easy, but the course is set: sailing toward a cleaner and more sustainable future.

Marine Diesel Oil

Marine diesel oil: the veteran of naval propulsion facing its decisive moment.

For more than a century, marine diesel oil has been the beating heart of most ships around the world. From massive container ships to short-distance ferries, its reliability has made it the industry’s preferred option. But in the current era of decarbonization, this veteran is starting to lose its leading role**.**

Its Winning Cards

Guaranteed availability: Found in virtually every port worldwide, simplifying logistics and preventing delays.

Established network and infrastructure: Requires no additional investment in refueling systems.

Proven technology: Marine diesel engines are robust, easy to maintain, and backed by decades of operational experience.

Power and autonomy: High calorific value allows for long voyages without refueling.

Lower initial investment: Building a ship designed for diesel remains cheaper than adapting it for alternative fuels.

Photo No. 1. This image shows the typical polluting gases from diesel fuel.
Source: es.dreamstime.com

The Other Side of the Coin

Marine gasoil, which for decades has been the driving force behind commercial shipping, now faces a perfect storm. Although it remains the backbone of the global fleet, its high levels of pollutant emissions, dependence on oil, and the rising cost of low-sulfur fuel have placed it squarely in the spotlight. Environmental regulations from the IMO and local authorities demand multimillion-dollar investments in control technologies, while social pressure for clean energy continues to grow. In the midst of the energy transition, this veteran must either reinvent itself or give way to more sustainable fuels such as hydrogen, ammonia, or methanol.

LNG: The Fuel Leading the Clean Transition

LNG (Liquefied Natural Gas) is a fossil fuel obtained by cooling natural gas to –160 ºC, reducing its volume by 600 times, which makes it much easier to transport over long distances.

For years, LNG has been considered a key solution for decarbonizing naval propulsion. While it is not the ultimate answer to completely eliminating emissions, it remains a cleaner and more efficient transitional fuel compared to diesel or heavy fuel oil.

Its use in maritime transport is not new: LNG has been in use for half a century and continues to improve. Currently, 355 merchant ships already operate on LNG, with another 500 under construction or on order.

According to various studies, LNG-powered ships represent more than 2% of the global fleet, with forecasts to reach 4% in the number of vessels and up to 6% in total tonnage in the coming years, consolidating its role in the maritime energy transition.

Photo No. 3. This is the classic Liquefied Natural Gas (LNG) carrier. Source: Ingasing.

Advantages of LNG

The greatest strength of LNG lies in its low environmental impact compared to traditional fossil fuels. Its use significantly reduces emissions of carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SOx), and fine particles. In fact, CO_2 emissions can decrease by up to 25% compared to heavy fuel oil.

This reduction makes LNG a key ally in meeting stringent international regulations, such as IMO 2020, which limits the sulfur content in marine fuels.

Cleaner, Quieter, and More Efficient Engines

One of the most remarkable aspects of LNG (Liquefied Natural Gas) is the performance of the engines that use it. These engines not only produce less noise than traditional ones but also stand out for their efficiency and, most importantly, for causing less impact on marine ecosystems.

According to a study by the classification society DNV[1], choosing LNG for ship propulsion can result in up to 45% savings[2] in total operating costs compared to the use of standard heavy fuel oil. This reinforces its role as an alternative fuel that offers both economic and environmental benefits for maritime transport

Disadvantages of LNG

LNG is not a perfect solution, as it still produces greenhouse gases that must be further reduced in the near future. A major challenge lies in its logistics: it requires a specialized global supply network, which is gradually being expanded in the world’s main ports. In this regard, the International Association of Ports and Harbors (IAPH) has created a working group dedicated to LNG. Their goal is to develop standardized checklists for the high-risk bunkering operations, establish clear guidelines for approving gas suppliers, and ensure strict safety perimeter evaluations and risk analyses.

[1] Det Norske Veritas (DNV) is a global classification society headquartered in Norway. It was founded in 1864 and operates as an independent foundation. Its mission is to "safeguard life, property, and the marine environment," and it is also a leading provider of risk management services. https://www.wikiwand.com/es/articles/Det_Norske_Veritas

[2] Liquefied natural gas allows ships to save 45% of their operating costs. July 26, 2010. https://www.farodevigo.es/economia/2010/07/26/gas-natural-licuado-permite-buques-17826832.html

The current challenge is twofold: reduce infrastructure[3] costs and guarantee a reliable global supply, enabling LNG-powered ships to operate without limitations and with efficient, safe bunkering processes. In this regard, the International Association of Ports and Harbors (IAPH**)** has created a dedicated working[4] group focused on LNG. Its mission is to develop standardized checklists for the complex and delicate operations involved in fuel loading, ensuring greater safety and efficiency in these processes.

The challenge now is twofold: to reduce infrastructure costs and ensure a global supply network that enables LNG-powered vessels to operate without limitations, with safe, efficient bunkering[5] capable of meeting future demands.

Ammonia

The International Energy Agency (IEA), in its *2050 Carbon Zero Roadmap Report*, states that ammonia as a marine fuel could account for up to 46% of total fuel use by 2050.

Green or renewable ammonia is emerging as a strong future bet for the maritime sector, though it is not without its challenges. Analyzing its advantages and disadvantages is essential to understanding its true potential.

Ammonia has already been used as fuel for car and truck engines during World War II. The real recent breakthrough lies in discovering a new method to convert ammonia into nitrogen gas, which, through a catalytic process, helps significantly reduce the emission of associated polluting gases.

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[3] So far, shipping companies have been the driving force behind the adoption of LNG-powered vessels, while ports around the world are expanding their terminals to offer specialized bunkering services. There are now more than 200 ports equipped with this capability, and the number continues to grow, creating new employment opportunities in the process. These include positions for naval engineers, bunkering operators, safety technicians, and clean energy specialists. Source**:** Liquefied Natural Gas (LNG) in the Maritime Sector: Transformation and Opportunities – IMBS

[4] The project focuses on the development of standardized checklists for fuel bunkering operations, as well as guidelines for the approval of gas suppliers to fuel tanks.It also includes evaluating safety perimeters and conducting risk assessments to ensure safe and efficient processes.
Source: *International Association of Ports and Harbours* https://navclimate.org/about/navigating-a-changing-climate-partnership/iaph

[5] Liquefied Natural Gas (LNG) in the Maritime Sector: Transformation and Opportunities. Gas Natural Licuado (GNL) en el sector marítimo: transformación y oportunidades - IMBS

Photo No. 4. Prototype of a vessel powered by ammonia, featuring deck-mounted tanks and solar sails. **Source: #destacadas, ambiente y ecología integral, industrial naval**

An Intermediate Step Toward Total Decarbonization

The adoption of renewable[6] ammonia as a marine fuel could play a key role in achieving partial decarbonization. However, this transition would require significant modifications to propulsion systems and storage tanks. Experts and maritime institutions agree that ammonia has the potential to become the ideal fuel for ship propulsion. The challenge lies in the high initial investment required from shipowners. To overcome this barrier, subsidies are being considered to support the implementation of dual-fuel systems, where ammonia can coexist with traditional marine gasoil. The timeline for making these critical decisions is fast approaching, with 2030 set as a pivotal year.

[6] Green ammonia is produced from non-polluting sources: the hydrogen it contains is obtained through electricity generated from renewable sources, while the nitrogen is extracted from the atmosphere using an air separation unit. *What is green ammonia and what is it used for?* April 2, 2024. https://www.bbva.com/es/sostenibilidad/que-es-el-amoniaco-verde-y-para-que-sirve-caracteristicas-y beneficios/?msclkid=c0ffc5b516ef14ba6d94adcf07646c0&utm_source=bing&utm_medium=cpc&utm_campaig

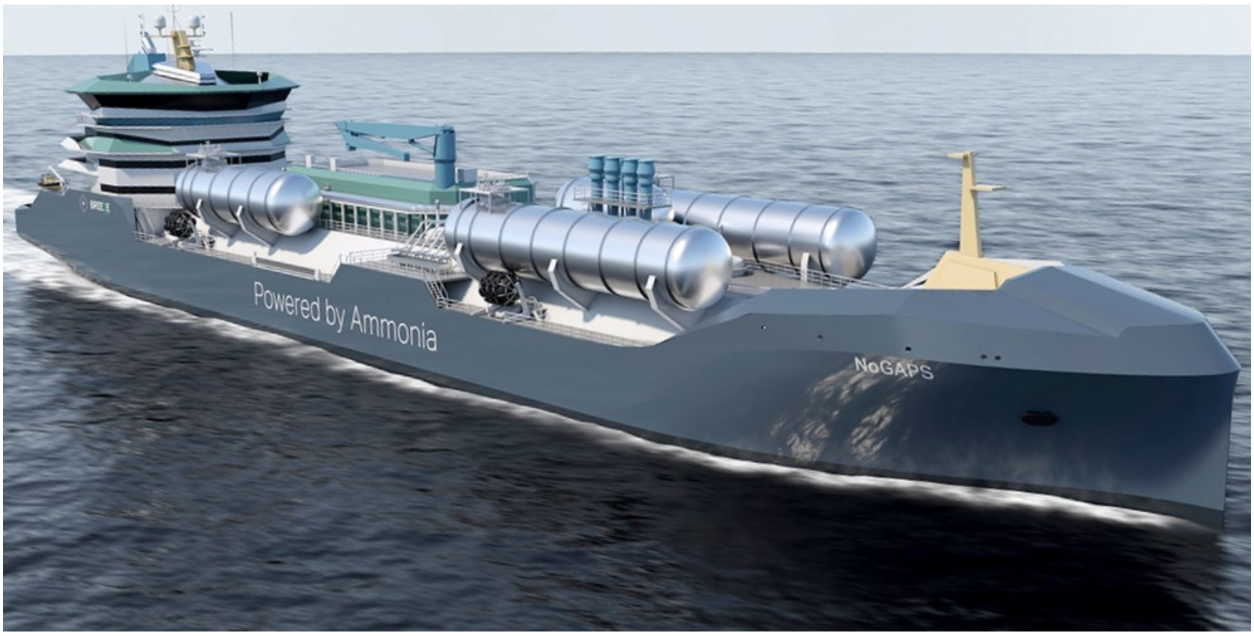
Advantages

The main advantage of ammonia[7] as a marine fuel—and the primary reason for its development—is its low pollutant emissions, which make a decisive contribution to the decarbonization process.

Another key benefit is its ease of storage and supply on land, as it can be transported in liquid form at room temperature and under relatively low pressures, simplifying handling and logistics.

Currently, over 120 international port**s**[8] are already equipped with the infrastructure needed to supply ships with ammonia, and several more are in the process of adapting.

Although the production cost of green ammonia remains higher than that of conventional fuels, its synthesis from carbon-free hydrogen through the Haber-Bosch [9]process is efficient and fully scalable.



[7] Use of Ammonia as Marine Fuel Deserves Respect, Jun 9, 2025. https://www.nuestromar.org/destacadas/uso-del-amoniaco-como-combustible-marino-merece-respeto-pero-no-debe-ser-temido/

[8] Ammonia: An Immediate Solution for Naval Decarbonization, February 11, 2025. https://www.mapfreglobalrisks.com/gerencia-riesgos-seguros/articulos/amoniaco-solucion-inmediata-descarbonizacion-naval/#:~:text=El%20amoniaco%2C%20tradicionalmente%20utilizado%20en%20la

[9] The Haber-Bosch process is an industrial method for synthesizing ammonia (NH_3) directly from nitrogen gas (N_2) and hydrogen gas (H_2) at high temperature and pressure, in the presence of a catalyst. It was developed by German chemists Fritz Haber and Carl Bosch in the early 20th century.
Source**:** Haber-Bosch Process, April 26, 2015.
https://www.bing.com/search?q=haber-bosch+process+ammonia&form

Photo No. 5. Project of a ship powered by ammonia with deck-mounted tanks. Source: amoniaco_informe_viabilidad-2.jpg (993×499)

Disadvantages of Ammonia as Marine Fuel

Ammonia has a significantly lower volumetric density compared to marine gasoil, which requires the use of much larger storage tanks. This reduces the available cargo space, leading to economic losses for shipowners. Additionally, these tanks are harder to adapt to the shape of the hull, increasing installation costs.

While ammonia does not emit CO_2, it does produce nitrogen oxides (NO_x), which contribute to the greenhouse effect. Its high toxicity poses another serious concern: a spill could be extremely hazardous for both the crew and the environment.

Furthermore, ammonia is in high demand across various industrial sectors, which could limit its availability for maritime use.

Is the Future Written in Ammonia?

Green ammonia could become a cornerstone in the puzzle of maritime decarbonization. However, its success will depend on overcoming significant technical, economic, and safety challenges.

The shipping industry and regulators now face a crucial decade to decide whether to fully commit to ammonia — or to treat it as a transitional step toward an even cleaner fuel.

Grimaldi Powers Up for the Ammonia Era

As part of the global drive toward zero-carbon shipping, ammonia is emerging as one of the most promising alternatives to marine gasoil. Major shipping companies are integrating it into their strategies, but few have done so as decisively as the Grimaldi Group.

Photo No. 6. Grande Tianjin, the first vessel delivered to Grimaldi on August 8, 2025, adapted to use ammonia as fuel. Source: Grimaldi.

Grimaldi Leads the Ammonia Revolution in Maritime Transport

The Neapolitan shipping giant Grimaldi has placed ammonia at the heart of its fleet renewal plan. The company has ordered 17 new PCTC[10] vessels, certified as Ammonia Ready by RINA[11], capable of operating with this carbon-free fuel.

These impressive ships, measuring 200 meters in length and with a capacity for 9,000 vehicles, will be equipped to connect to the shore power grid, eliminating emissions during loading and unloading operations. With an investment of over $630 million, Grimaldi aims to reduce CO_2 emissions by up to 50% per unit of cargo transported.

This move is not an isolated effort. Shipyards in Japan, South Korea, and Europe are already developing prototypes, while shipping companies such as Maersk, Höegh Autoliners, and Norwegian operators are financing pilot projects.

The major challenge now lies in adapting port infrastructure, ensuring a steady supply of

[10] PCTC (Pure Car & Truck Carrier).
[11] The RINA Ammonia Ready certification is a technical qualification granted by the Italian classification society RINA (Registro Italiano Navale) to ships whose design and construction meet the requirements to be adapted in the future for the use of ammonia as a marine fuel.

green ammonia, and perfecting safe storage systems — key factors to fully establish this energy revolution across the seas.

Methanol Onboard Ships

The new candidate to dethrone marine diesel on the high seas

The energy transition has reached the maritime sector. After decades of reliance on marine diesel and, more recently, natural gas, methanol has emerged as a strong contender to become the fuel of the future for shipping. Currently, around 30 ships equipped with dual-fuel propulsion systems —capable of running on either marine diesel or methanol— are already sailing the oceans. However, this figure is expected to multiply sixfold in the coming years, surpassing 200 vessels, driven by stricter environmental regulations and the growing demand for sustainable solutions.

Methanol offers clear advantages, but it also presents significant challenges. Its lower calorific value, about 55% less than diesel, requires the installation of much larger tanks —up to 2.5 times bigger than those used for heavy fuel oil. In addition, its production costs and the need to redesign ship architecture are major obstacles. Despite these challenges, the industry is moving decisively toward a cleaner, more sustainable future at sea.

Where does this "clean" methanol come from?

The maritime sector focuses on two main production pathways:

Biomethanol:[12] Produced by gasifying sustainable waste, such as agricultural, livestock, forestry residues, and even urban waste. This method could also help solve the forest management problem, a current environmental concern.

E-methanol: Generated from green hydrogen, produced using renewable electricity, combined with captured CO_2, offering a truly clean and circular solution.

[12] According to an interesting technical report, biofuels are expected to be used in the short term, while methanol is projected to play a key role in the long term. The study, titled *Methanol as an Alternative Fuel for the Decarbonization of Maritime Transport* (December 15, 2023), highlights methanol as a promising solution for reducing greenhouse gas emissions in the shipping industry. This clean and versatile fuel could become a cornerstone in the global effort to achieve a greener and more sustainable maritime sector. https://www.interempresas.net/construccion-naval/Articulos/509946-

Methanol may not be perfect, but it is rapidly positioning itself as one of the most promising fuels to revolutionize global shipping

Photo No. 7. Ship powered by methanol. *Source:* hydrocarbonprocessing.com

Advantages Convincing the Maritime Industry

Zero direct emissions**:** Its combustion does not produce CO_2 or nitrogen oxides, emitting only water[13] vapor.

Renewable and flexible: It can be produced through water electrolysis, reducing dependence on fossil[14] fuels.

Significant tax savings: In a world where ships pay for every ton of CO_2 emitted, methanol could save [15] between 259% and 459% per ton avoided.

Simple logistics: Being liquid at room temperature, it does not require refrigeration or special materials for pipelines.

One of methanol's biggest strengths is its ease of storage and distribution. However, this logistical advantage comes with a major challenge: to achieve the same thermal

[13] DNV: Methanol as an Alternative Fuel for Container Ships Is a Reliable Option *September 30, 2022.* DNV: El metanol como combustible alternativo para los portacontenedores es una opción fiable - Camae
[14] Hydrogen Ships: The Clean Future of Maritime Transport**.** *July 11, 2025* Source: Cryospain
[15] Decarbonization of Maritime Transport: Hydrogen and Methanol as Alternative Fuels *November 22, 2024.* Source: https://synerhy.com/2024/11/descarbonizacion-del-transporte-maritimo-hidrogeno-y-metanol-como-combustibles-alternativos

performance as heavy fuel oil, methanol tanks must be 2.5 times larger[16], impacting ship design and cargo capacity. Even compared to LNG, methanol requires tanks that are 30% larger design challenge that forces a complete rethink of the available space onboard. Available technology**:** The extensive experience accumulated in handling methanol on land facilitates its adoption in maritime bunkering[17] operations.

Methanol is poised to play a key role in the race toward cleaner maritime transport. However, its success will depend on whether the industry can reduce production costs, adapt vessels, and, most importantly, manage safety risks. If achieved, the familiar smell of diesel fuel in ports may soon become nothing more than a memory of the past.

Drawbacks

Despite its advantages, methanol presents significant challenges.

Economically, its use still implies a considerable increase in costs, both due to the price of the product itself and its high production expenses, although these are expected to decrease in the near future.

From a chemical standpoint, methanol is aggressive with certain materials, acting as a powerful solvent and absorbing water, which can promote corrosion in onboard systems.

Additionally, its lower calorific value —55% less than gasoline or diesel— means ships need to consume a greater volume of fuel, requiring much larger[18] tanks to maintain navigation autonomy.

Finally, there's a critical safety concern: methanol burns with an almost invisible flame, posing a high-risk during emergencies or uncontrolled situations for the crew.

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[16] DNV: Methanol as an Alternative Fuel for Container Ships is a Reliable Option. *November 30, 2022.* .https://www.vaffausa.org/blog/2022/12/06/dnv-el-metanol-como-combustible-alternativo-para-los-portacontenedores-es-una-opcion-fiable/

[17]Bunkering refers to the supply of fuel to ships while they are docked in port or even out at sea. This process is carried out using tanker vessels that act as floating service stations, ensuring ships receive the necessary fuel to continue their operations. https://lucera.es/blog/que-es-el-bunkering

[18] Von der Leyen will also raise maritime transport costs: Methanol use to drive higher consumption than diesel Sep 21, 2023. https://www.libertaddigital.com/libremercado/2023-09-21/von-der-leyen-tambien-disparara-los-costes-del-transporte-por-mar-usaran-metanol-con-mucho-mas-consumo-que-el-diesel-7050849/

Which shipping companies are interested in methanol?

In 2023, Maersk made history with the Laura Maersk, the world's first container ship designed to run on methanol and diesel, with a capacity of 2,100 TEU[19]. This milestone marked the beginning of an ambitious fleet of 12 mega-ships of 16,000 TEU, some of which are already in service.

In Asia, COSCO Shipping placed an order for 12 container ships of 14,000 TEU. Meanwhile, in the ferry sector, Stena Line revolutionized maritime travel with the Stena Germanica, achieving a 99% reduction in SOx emissions and a 25% reduction in CO_2 emissions after its conversion to methanol.

Companies such as Waterfront Shipping, Wallenius Wilhelmsen, Safebulkers, JPMorgan Global Transportation, and the Proman–Stena Bulk alliance are also advancing projects, solidifying methanol as a key fuel in the ecological transition of global maritime transport.

Hydrogen

A Strong Candidate for Decarbonizing Maritime Transport

Hydrogen is emerging as one of the most promising fuels to achieve the decarbonization of maritime transport in the short and medium term. Many experts see this gas as a viable alternative to drastically reduce polluting emissions.

This fuel can be used in two main ways:

Directly in adapted engines, designed to run on hydrogen.

Converted into electricity through specially designed fuel cells.

In both cases, it must be stored on board, and its use depends on factors such as navigation speed, weather conditions, and the type of vessel.

[19] The term TEU (*Twenty-foot Equivalent Unit*) is the most widely used standard unit in the maritime freight transport industry. It represents the capacity of a 20-foot-long container, the traditional format in international logistics. Its use is widespread in multiple contexts: it is employed to measure a ship's cargo capacity, calculate port activity, and even assess the global flow of maritime trade. Thanks to this unified measure, shipping companies, ports, and logistics operators can compare and plan operations with greater precision, improving efficiency in global transport management.

Green Hydrogen: The Cleanest Option

In the race toward decarbonization, hydrogen stands out as a key fuel, but not all hydrogen is the same. Its **"**color label" indicates how it is produced and how clean it is for the planet. Among the different types are gray, blue, turquoise, pink, and black hydrogen.

Here, we focus exclusively on green hydrogen, produced using renewable energy sources. Its use strengthens global efforts to develop cleaner propulsion systems and reduce dependence on fossil fuels.

When used directly in adapted engines, hydrogen can be stored in two forms:

Compressed hydrogen**:** Best suited for smaller vessels.

Liquid hydrogen**:** The preferred choice for larger ships, but it must be stored at -253 °C, requiring special handling and strict safety measures.

Photo No. 8. Hydrogen tank on the ship's deck. **https://stock.adobe.com/es/images/liqiud-hydrogen-renewable-energy-in-vessel-lh2-hydrogen-gas-for-clean-sea-transportation-on-ship-with-composite-cryotank-for-cryogenic-gases/432949761**

Fuel Cells: Silent and Efficient Energy

Another highly valued alternative is the fuel cell, a system that generates electricity by combining oxygen and hydrogen. These cells, true electrochemical converters, can be custom designed depending on the application.

Ships powered by fuel cells offer two key advantages: reduced noise and lower vibration, making them ideal for passenger vessels or ferries operating on short routes[20] or inland waters, where refueling is simple and frequent.

In addition, hydrogen can be produced from compounds like bioethanol and then released through a straightforward transformation process, adding flexibility and sustainability to this clean energy solution.

Advantages of Hydrogen as a Marine Fuel

Zero CO_2 and nitrogen oxide emissions**:** only water vapor is released.

Produced through water electrolysis, harnessing renewable energy sources.

High thermodynamic efficiency, with relatively low consumption.

Attractive for shipowners and operators seeking efficiency in cargo and passenger transport.

Drawbacks and Challenges Ahead

Low density: requires large storage volumes.

Cryogenic tanks needed onboard to keep them in liquid form.

High costs**:** green hydrogen must reduce[21] its price to one-third of the current level to be competitive, though the industry is actively working on this.

Limited infrastructure: currently, few ports have refueling stations, and supply chains are

[20] Revolution in the Naval Sector: Possibilities of Hydrogen-Powered Ships and Other Electrofuels. Los sistemas de propulsión del futuro para buques civiles y militares - Noticias Defensa defensa.com noticias industria defensa.

[21] Hydrogen Ships: The Clean Future of Maritime Transport. 11 jul 2025. https://cryospain.com/es/barcos-de-hidrogeno.

complex.

Hydrogen still faces technical, economic, and logistical challenges, but its potential to transform maritime transport is undeniable. If technology, infrastructure, and costs evolve as expected, it could become one of the main drivers of zero-emission shipping by the middle of this century.

Hydrogen-Powered Ships: The Future of Clean Navigation

When it comes to hydrogen at sea, it's not just about a single type of ship. Current technology offers two main paths: vessels powered directly by pure hydrogen and those that rely on fuel cells to generate electricity.

Adding to this dynamic is a third crucial element**:** ships designed specifically to transport hydrogen, a technological challenge that plays a vital role in shaping the future of the sector. These specialized vessels will be essential for creating a safe and efficient global hydrogen supply chain, supporting the transition to greener maritime transportation.

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Fuel Cells: Clean Energy Onboard

Ships equipped with hydrogen fuel cells can transform this gas into electricity to power electric motors, whether for propulsion, onboard systems, or auxiliary applications. The process is as clean as it is efficient: hydrogen reacts with oxygen, producing energy, heat, and water as the only byproducts.

This technology is already being tested in prototypes and is emerging as an ideal solution for short-distance ferries or vessels operating in inland waters, where power demands are lower and frequent refueling is feasible.

Passenger ships, in particular, benefit from reduced noise and vibrations, providing a smoother and more comfortable experience for those onboard.

Photo No. 9. Hydrogen-powered ferry. Source: International Maritime Organization

Hydrogen Internal Combustion Engines

Another line of development focuses on internal combustion engines adapted to run on hydrogen, which can be modified from existing diesel engines. This makes the technological transition easier, although their energy efficiency is slightly lower compared to fuel cells. The main advantage lies in leveraging existing infrastructure and technical knowledge.

Cryogenic Engineering: The Big Challenge

For medium- and large-sized merchant vessels, liquid hydrogen is the most viable option. However, it requires advanced cryogenic engineering. Storing hydrogen in liquid form means keeping it at temperatures below –253°C, in double-layer tanks made of austenitic stainless steel with vacuum insulation. These tanks must minimize losses and be equipped with special pipes and valves.

Ongoing Projects and Real-World Applications

Today, hydrogen-powered vessels are already navigating the seas in different configurations: liquid storage or fuel cell-based systems. These include tugboats, research vessels, recreational boats, transport ships, and ferries.

The logistical challenge is evident: major ports must develop refueling infrastructure. To achieve this, hydrogen transport ships will play a crucial role in supplying the growing demand.

World's First Hydrogen-Powered Cruise Ship

The Viking Libra takes center stage as the first cruise ship in the world powered by hydrogen. This massive vessel will feature a hybrid system combining liquid hydrogen and polymer electrolyte membrane (PEM) fuel cells, enabling it to operate with zero direct carbon emissions.

Photo No. 10. The Viking Libra, the world's first hydrogen-powered cruise ship. Source: www.diarioelcanal.com

In addition, the ship will be equipped with its own hydrogen storage and refueling system, ensuring an optimal supply of fuel throughout each voyage. With this groundbreaking project, Viking and Fincantieri set a milestone in the maritime industry, proving that hydrogen propulsion is not only feasible but also scalable to large vessels, paving the way for a cleaner and more sustainable future in cruise travel.

Hydrogen Carrier Ships: Giants of Clean Energy

Suiso[22] Frontier[23]: A Pioneer on the Hydrogen Route In 2021, the Suiso Frontier, built by Kawasaki Heavy Industries in Japan, made history by becoming the first ship to transport liquid hydrogen (LH_2). It sailed over 9,000 km from Australia to Japan, marking a milestone in the clean energy revolution. With a length of 116 meters and a beam of 19 meters, the vessel is operated by a crew of 25. It can carry 75 tons (1,250 m^3) of hydrogen, cooled to –253 °C to reduce its volume by 800 times. The fuel is stored in a double-layer cylindrical tank made of vacuum-insulated austenitic[24] stainless steel, ensuring safety and efficiency during transport.

Photo No. 11. The Suiso Frontier, the first ship to transport liquid hydrogen.

Source: https://anave.es/botado-el-primer-buque-tanque-para-transporte-de-hidrogeno-liquido/

[22]Suiso means hydrogen in Japanese.
[23] The Suiso Frontier, the first liquid hydrogen (LH_2) transport ship, named Ship of the Year 2021 in Japan. November 26, 2021. https://vadebarcos.net/2022/11/26/el-suiso-frontier-el-primer-buque-de-transporte-de-hidrogeno-liquido-lh2-buque-del-ano-2021-en-japon
[24] Austenitic stainless steel contains between 16% and 25% chromium and may also contain nitrogen in solution, both of which contribute to its relatively high corrosion resistance.

Gaia: The Giant Tanker of the Future

If the *Suiso Frontier* proved that hydrogen transport logistics were possible, Gaia aims to demonstrate that this model can be profitable and scalable.

Designed by C-Job Naval Architects[25] in collaboration with LH2 Europe, this tanker measures[26] 141 meters in length and is equipped with three cryogenic tanks, each with a capacity of 12,500 m³, for a total of 37,500 m³ of liquid hydrogen.

To put this into perspective, this amount of hydrogen could power 400,000 fuel cell cars or 20,000 heavy-duty trucks, marking a decisive step toward a cleaner and more sustainable energy future in both maritime and land transportation.

Photo No. 12. Future Hydrogen Vessel GAIA. Source: C-Job Naval Architects

Protecting the Environment... Even in Port

Maritime pollution isn't limited to the open sea. When ships are docked, their auxiliary

[25] www.hibridosyelectricos.com.
[26] C-Job Naval Architects Presents Tanker Capable of Supplying Hydrogen to 400,000 Fuel Cell Cars May 9, 2022, https://h2news.cl/2022/05/09/c-job-naval-architects-presento-buque-cisterna-con-capacidad-para-suministrar-hidrogeno-a-400-000-coches-de-pila-de-combustible/.

engines continue running to generate electricity, control climate systems, and maintain essential services, releasing harmful gases into the atmosphere.

To tackle this hidden source of pollution, the Grimaldi Group has developed a groundbreaking mega lithium battery with a capacity of over 5 MWh, powerful enough to supply all the energy a vessel needs while in port.

This innovation eliminates the need for diesel generators, achieving zero emissions at the dock and cutting fuel consumption — a decisive step toward a cleaner and more sustainable maritime industry.

Photo No. 13. Ship docked without emitting any type of polluting gases. Source: Grimaldi.

Reducing Emissions[27] at Sea: Much More Than Just Changing Fuel

Maritime sustainability is no longer a distant goal, but an urgent necessity. In the race for cleaner oceans, hull design has become a key player. Optimizing its shape, applying special coatings to reduce friction, and using lightweight materials such as carbon fiber or aluminum help lower fuel consumption and emissions.

Innovation goes beyond the underwater structure. On deck, solar panels, wind turbines,

[27] Energy Efficiency in Ships: Naval Engineering Strategies. Sep 6, 2025. https://todoingenierias.com/eficiencia-energetica-en-barcos-estrategias-de-ingenieria-naval/

and hybrid diesel-electric systems are combined with smart technologies that adjust energy use based on speed, weather conditions, or cargo weight. Even LED lighting and efficient climate control systems contribute to energy savings and sustainability.

Conclusions

The International Maritime Organization (IMO) has set a historic goal: achieving zero emissions in maritime transport by 2050.

While fuel oil will continue to play a role in the short term, its days are numbered.

In its place, Liquefied Natural Gas (LNG) is establishing itself as a transitional fuel, while the true future lies in methanol, ammonia, and hydrogen. These green fuels promise to revolutionize naval propulsion, though they also come with significant technical and safety challenges.

The path forward is challenging, but the course has been set cleaner, quieter, and more sustainable seas are now part of the maritime horizon.

The future of maritime transport will not rely on a single solution but rather on the combination of innovation, green fuels, and technological efficiency.

Only through this synergy can our oceans breathe easier, and navigation become a true ally of the planet.

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