LNG - LEADING MARITIME DECARBONISATION

SEA-LNG

A VIEW FROM THE BRIDGE

2023-2024

SEA-LNG.ORG

LNG - A FUEL IN TRANSITION

During 2023 attitudes towards decarbonisation shifted from theoretical discussions about what might work tomorrow to what works today and how much does it cost.

At the IMO in July, the Marine Environment Protection Committee (MEPC 80) adopted a revised GHG Strategy which aims to significantly curb GHG (greenhouse gas) emissions from international shipping. The new targets include a 20% reduction in emissions by 2030, a 70% reduction by 2040 (compared to 2008 levels), and the ultimate goal of achieving net-zero emissions by 2050. It aligns shipping with the Paris Accords and keeps the 1.5C target alive.

Last month at COP 28, five shipping CEOs joined forces to accelerate the decarbonisation of the global maritime transport[1]. They called for an end date for fossil-only powered newbuilds and urged the International Maritime Organization (IMO), the global regulator, to create the regulatory conditions to accelerate the transition to green fuels.

Their joint declaration called for the establishment of four regulatory 'cornerstones':

- **An end date for new building of fossil fuel-only vessels and a clear GHG Intensity Standard timeline** to inspire investment confidence, both for new ships and the fuel supply infrastructure needed to accelerate the energy transition.
- **An effective GHG pricing mechanism** to make green fuel competitive with black fuel during the transition phase when both are used.
- **A vessel pooling option** for GHG regulatory compliance where the performance of a group of vessels could count instead of only that of individual ships, ensuring investments are made where they achieve the greatest GHG reduction and thereby accelerating decarbonisation across the global fleet.
- **A Well-to-Wake or lifecycle GHG regulatory basis** to align investment decisions with climate interests and mitigate the risk of stranded assets.

> **Shipping is at the forefront of technological innovation when it comes to decarbonisation and at MSC our fleet renewal strategy includes 100 dual fuel vessels.**
>
> **Soren Toft, Chief Executive Officer, MSC Mediterranean Shipping Company**

24,346 TEU container vessel MSC LORETO delivered in April 2023.

24,346 TEU container vessel MSC MICHEL CAPPELLINI named in Bremerhaven in July 2023

LNG, and its pathway, complies with these "cornerstones" and is the most viable current and practical solution for decarbonisation of the maritime space.

- **LNG vessels built today can also burn net-zero carbon bio-LNG and e-LNG produced from renewable electricity as it becomes available in the future.**
- **LNG is in abundant supply as the base product. Bio-LNG availability is expanding and e-LNG will have the similar availability and cost issues as other renewable hydrogen based products.**
- **Major carriers are already embracing the LNG pathway so looking at fleet performance is a logical next regulatory step.**
- **SEA-LNG has always considered Well-to-Wake as the only true methodology for effective decision making. With the LNG pathway, which is well established, there is no concern about stranded assets.**

"The decarbonisation goals set by global and regional regulators present an unprecedented challenge to the maritime industry. Practical and realistic are concepts that need to be added to the dialogue as we consider the next decades of change.

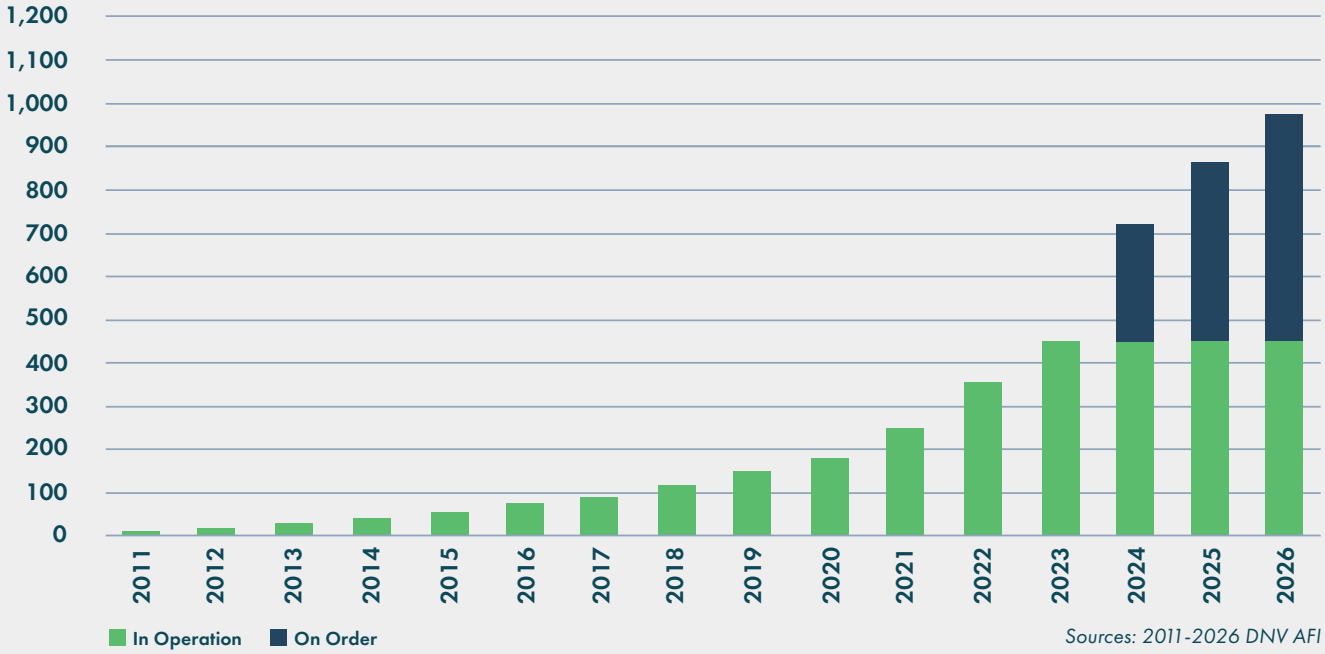
Peter Keller, Chairman, SEA-LNG

This year's *View from the Bridge* highlights LNG as a fuel in transition that provides a practical and realistic solution to decarbonisation. It provides an overview of the status of LNG as a marine fuel today and charts a pragmatic course to net-zero greenhouse gas emissions through developments in bio-LNG and e-LNG.

Matson's 3,600 TEU container vessel DANIEL K INOUYE under went retrofitting to allow LNG operation with its existing dual fuel engine and began sailing on LNG in late 2023.

LNG STATUS OVERVIEW

GROWTH OF LNG-FUELLED FLEET



Sources: 2011-2026 DNV AFI

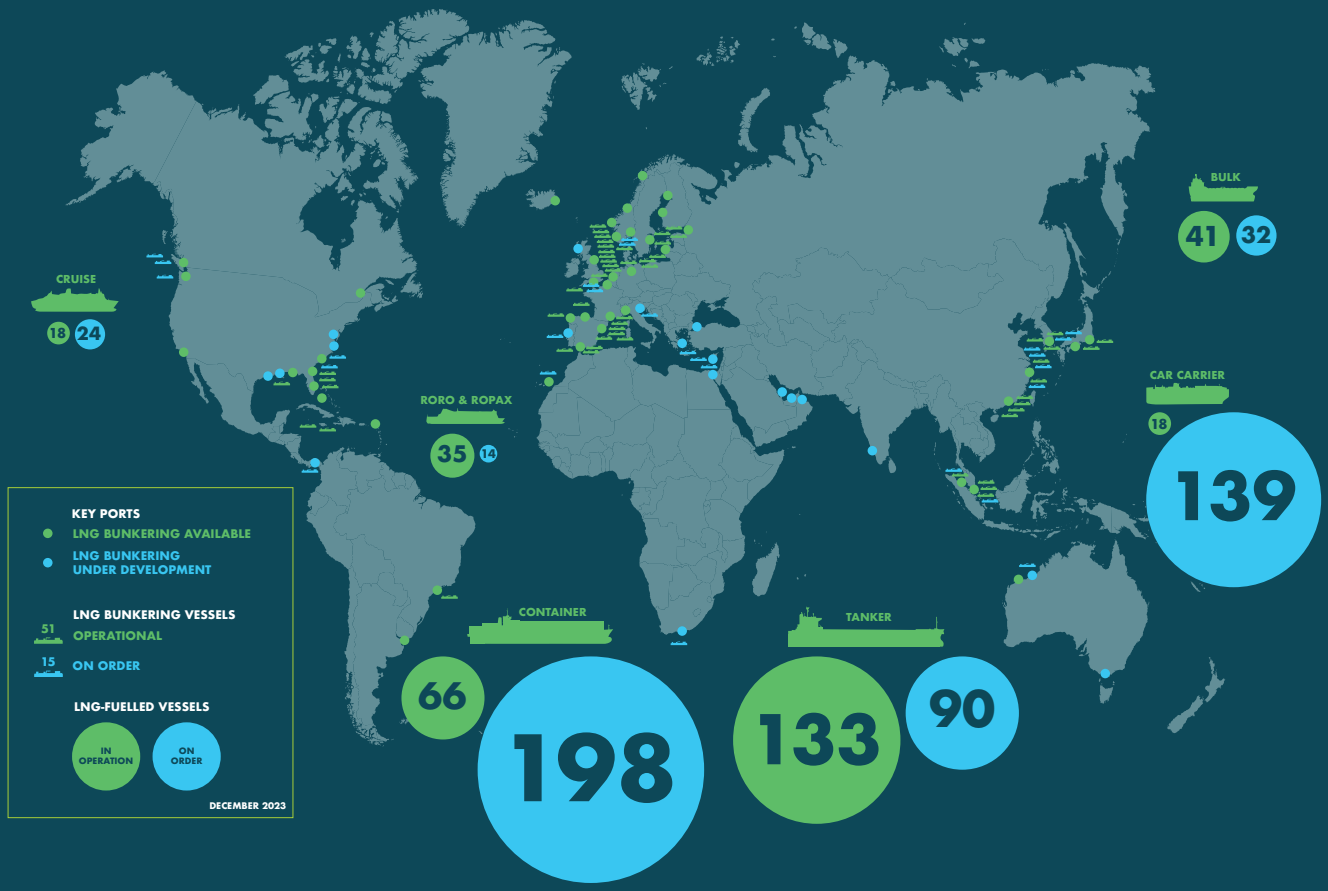
LNG remains the leader when it comes to the alternatively fuelled newbuild orderbook. At the moment the only other alternative fuel for which there are significant numbers of commercial orders is methanol. LNG orders remained strong in the first quarter of 2023. We saw a surge in dual-fuel methanol orders in the container sector in the middle of the year with LNG numbers picking up strongly again in the final quarter. Of particular note was CMA-CGM's decision in November to switch its order for eight methanol dual-fuelled, 9,200-teu box ships to LNG dual-fuelled.

According to DNV, as of December 2023, there are 469 LNG-fuelled ships – excluding LNG carriers – in operation, with a further 537 on order. DNV predicts that by the end of 2027, over 1,000 LNG fuelled ships will be carrying goods around the world with reduced emissions. This compares to only 36 LNG-fuelled vessels in operation a decade ago.

> **LNG is proving to be the most viable and safest pathway for maritime industry decarbonisation.**
>
> **Steve Esau, COO, SEA-LNG**

LNG has penetrated multiple shipping sectors, including container lines, tankers, car carriers, bulk carriers and cruise whereas in the case of methanol, once methanol carrier numbers are stripped out, more than 80% of the orders are in the container sector. It is noteworthy that some sectors, such as car carriers, are seeing a remarkably high degree of LNG penetration - with the latest data from Clarksons showing that almost all of new build orders are LNG dual fuel.

WORLDWIDE GROWTH IN LNG USE AND INFRASTRUCTURE



LNG BUNKER VESSEL FLEET DEVELOPMENTS – EXPANDING GLOBAL AVAILABILITY

LNG's global bunkering infrastructure continues to expand. According to Clarksons some 188 ports offer LNG bunkering services, with a further 82 bunkering locations decided and implementing plans or under active discussion.[2]

The number of LNG bunker vessels has grown from 40 at the end of 2022 to 50 with a further 34 on order or under discussion. 2023 has seen new LNG bunkering vessels coming into operation in Japan, Korea, Singapore, the US East Coast and Gulf of Mexico, NW Europe and the Mediterranean.

> **LNG is expected to dominate the bunkering landscape for many decades because it is a step up in the right direction.**
>
> Roger Holm, Marine Power President and Executive VP, Wärtsilä

Seaside LNG has taken delivery of a new LNG bunkering vessel for operations in the Gulf of Mexico. The vessel has a 5,500 m3 LNG capacity and will aid Seaside's bunkering expansion into the Gulf.

US shipping and logistics company Crowley plans to start providing liquefied natural gas (LNG) bunkering services on the Pacific side of the Panama Canal in 2024. The firm will deliver LNG via ship-to-ship transfers to LNG-powered vessels under the first permit issued by the Panama Maritime Authority for the provision of such services.

Titan has acquired two small-scale LNG carrier vessels for flexible bunkering and transportation of LNG, bio-LNG, and eventually e-LNG in the Mediterranean and Northwestern Europe.

Eagle LNG Partners has taken delivery of its first LNG carrier, the Coral Favia, from Anthony Veder. The 10,000 cubic metre LNG supply vessel is the first of a planned fleet from Eagle LNG offering LNG supply and bunker services for the Caribbean basin.

FueLNG Private Limited, the joint venture between Keppel Offshore & Marine and Shell Eastern Petroleum (Pte) Ltd, named its latest bunker vessel, FueLNG Venosa. With a total capacity of 18,000 cbm, the FueLNG Venosa will support the growing number of LNG-fuelled ships calling at the Singapore port and contribute to the country's ambition of becoming a regional hub for LNG bunkering.

South Korea has named its first-ever LNG bunker vessel, the Blue Whale.

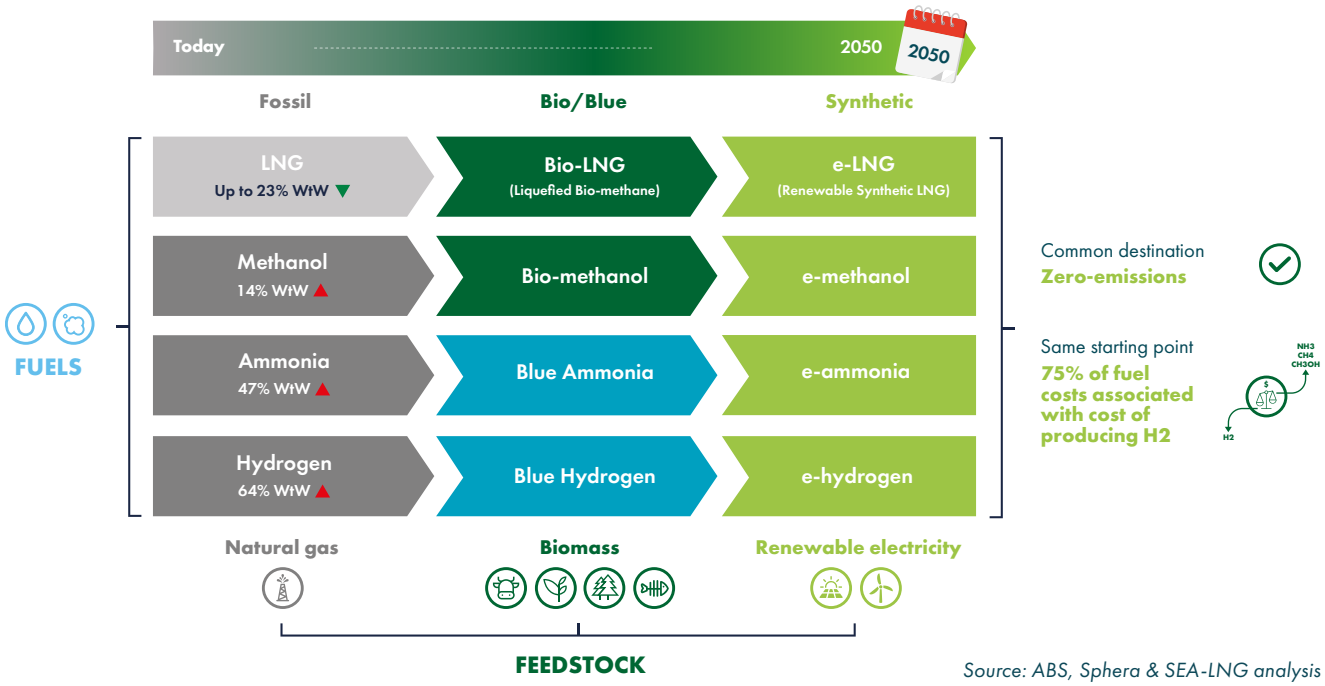
In October 2023 Seaside LNG took delivery of the 5,500 m^3 LNG articulated bunker barge CLEAN EVERGLADES.

THE DECARBONISATION CHALLENGE – REALITY CLOSING IN ON SHIPOWNERS AND OPERATORS

The reality of the magnitude of the decarbonisation challenge has started to really hit home for many in the maritime industry this year. From 1 Jan 2024, there remain only 312 months - 1,356 weeks or 9,497 days - until 2050, the date when shipping must achieve its net-zero target. Regulations such as the IMO's CII (effective from 2023), the inclusion of shipping into EU ETS (2024) and FuelEU Maritime (2025) are putting immediate and growing pressure and added costs on ship owners and operators in relation to their GHG emissions. How to meet these goals with practical, realistic and safe solutions in 312 short months is a dilemma that the industry must address in a concerted and coordinated manner.

Energy efficiency will be an important route to compliance in the short term - in June 2023 Clarksons estimated that energy saving technologies had already been fitted on over 6,250 ships, accounting for 27.3% of fleet tonnage. However, while all these innovations help the industry in a positive direction, to reach net-zero the industry must move to carbon neutral fuels following a realistic and practical pathway.

The LNG pathway provides that safe, realistic and practical solution utilising existing and proven infrastructure.

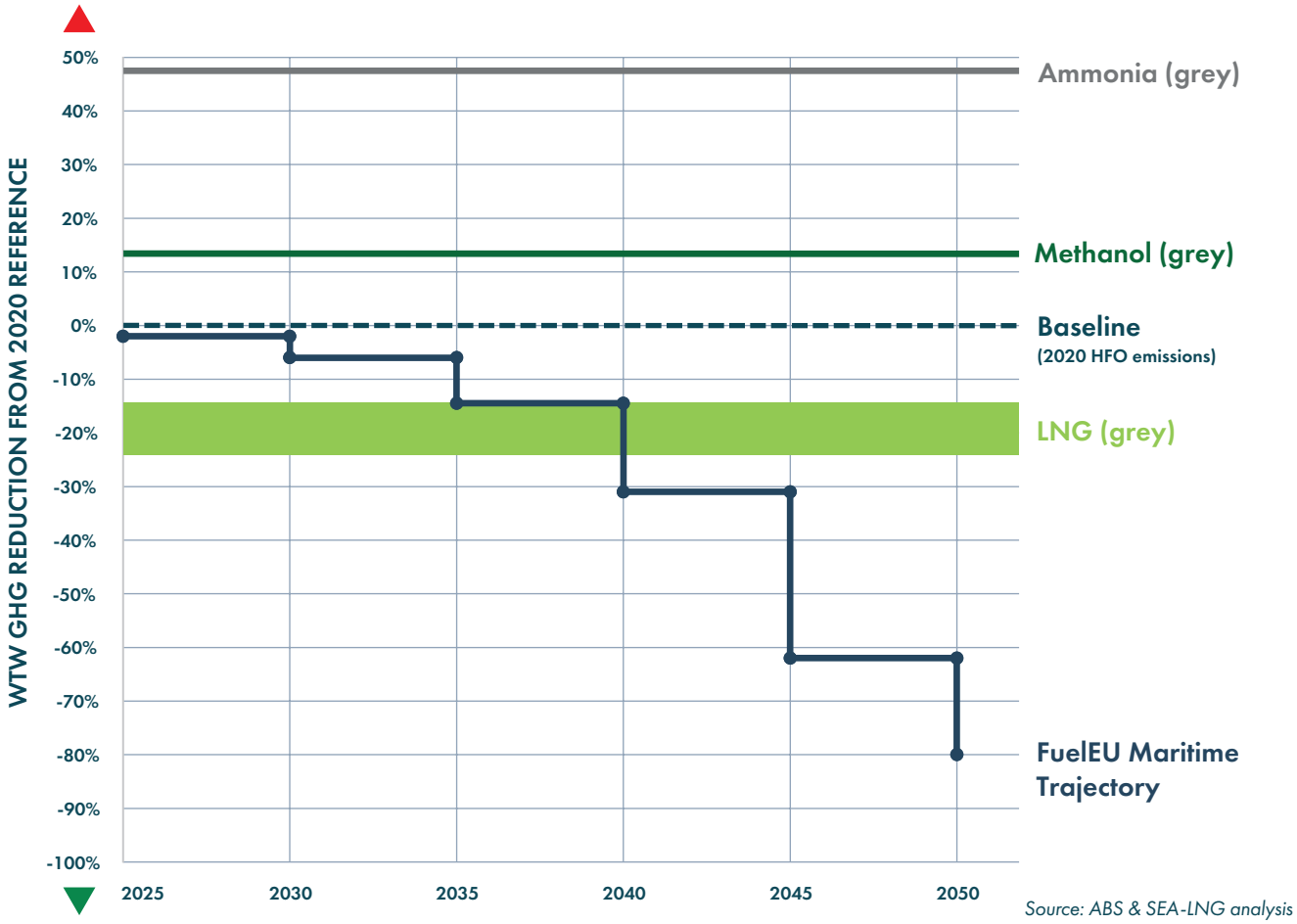


Source: ABS, Sphera & SEA-LNG analysis

There is a growing awareness of the fact that all the alternative fuels being discussed today share the same generic pathway: from fossil to bio-derived fuels (or blue fuels produced using carbon capture and storage) and eventually to electro-fuels produced from renewable electricity. **There is also a recognition that currently all these fuels are fossil, or grey.**

The use of grey methanol, grey ammonia and grey hydrogen as marine fuels will generate more GHG emissions than the traditional marine fuels they are looking to replace. This means they are not viable solutions for decarbonisation even in the short term. By contrast, grey LNG offers an immediate reduction in GHG emissions of up to 23%, after accounting for methane slip, for the two stroke engines which are fitted to the vessels that move most of the world's shipping tonnage. Consequently, the methanol, ammonia and hydrogen used by shipping will need to be green, or at least a blend with large volumes of green fuels, simply to achieve parity with VLSFO (Very Low Sulphur Fuel Oil) and comply with regulations such as FuelEU Maritime.

LNG, METHANOL AND AMMONIA VS FuelEU MARITIME TRAJECTORY



Source: ABS & SEA-LNG analysis

15,000 TEU LNG powered container vessel ZIM SAMMY OFER negotiating the lock in the Panama Canal in March 2023.

GREEN FUEL SUPPLY

The need to use truly green fuels to improve current GHG emissions brings us to the question of availability. For ammonia and hydrogen, which face major technology and safety hurdles, the answer to this question can be postponed for a decade or more as there are few newbuild orders. It will take at least that long to develop safe and sustainable supplies. For methanol, this is a more immediate issue. Methanol demand from shipping for vessels currently operating and on order will amount to almost 14 Mtpa (million tonnes per annum) by 2028. To reduce GHG emissions, this existing methanol fleet will need to use green methanol, however global green methanol production (almost all bio-methanol) is currently just 0.75 Mtpa;. This represents only about 6% of the energy consumption of the methanol-fuelled vessels in operation and on order. The Methanol Institute estimates a potential green methanol production of about 8 Mtpa by 2028. The question is: how much of this fuel will make its way to shipping when it is also needed by the chemicals industry who use existing grey methanol supplies where there are no obvious substitutes? The chemicals Industry also has ambitious decarbonisation goals.

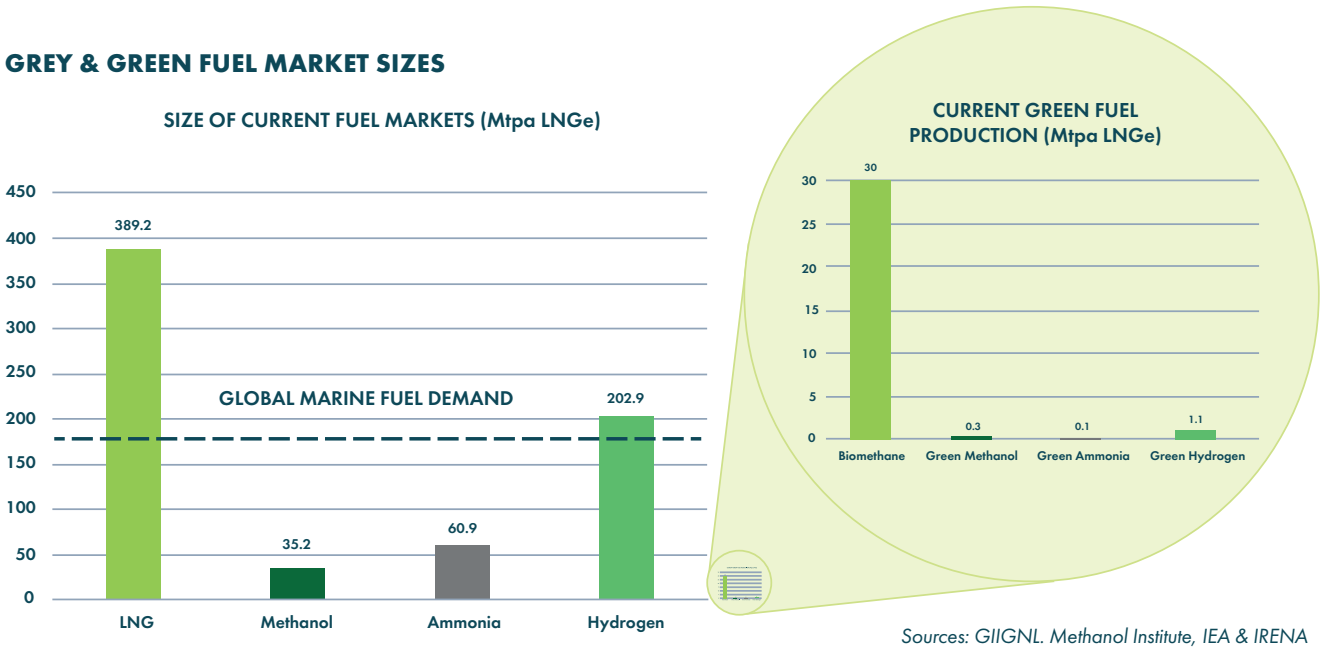
Does this mean dual fuel methanol vessels will utilise grey methanol or VLSFO? Neither choice helps the environment but rather exacerbates the climate problem.

LNG and the LNG pathway provide available fuels globally that more than meet maritime fuels demand.

LNG bunker vessel CORAL METHANE refueling cruise ship AIDAnova with LNG in Tenerife in 2018.

FUTURE MARINE FUELS

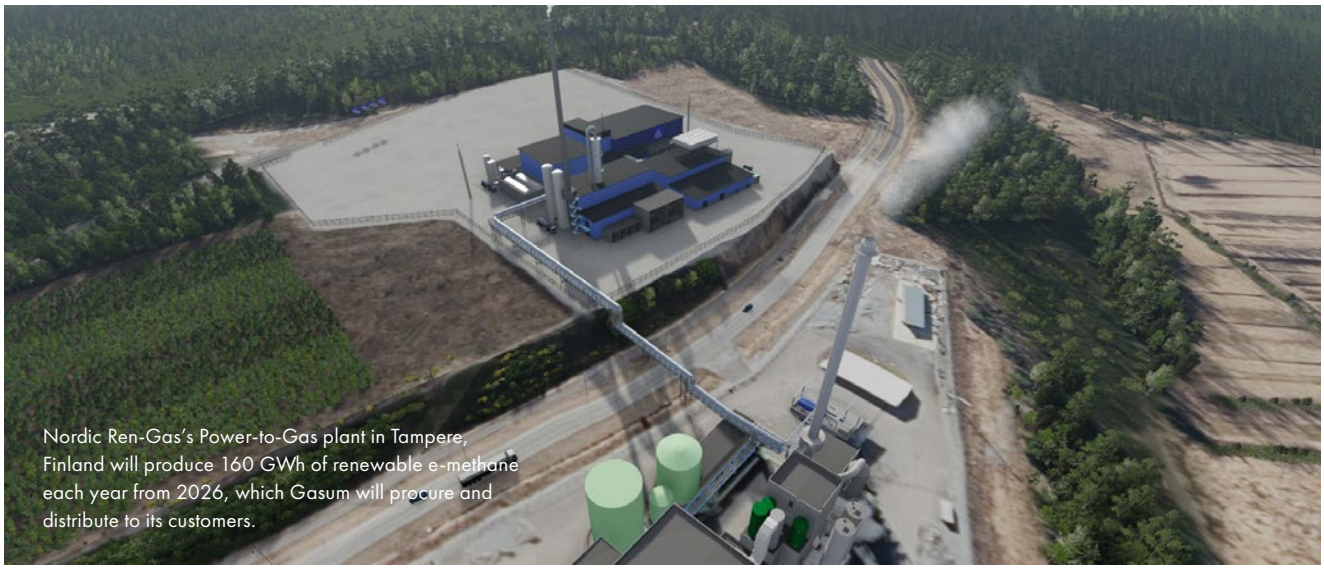
GREY & GREEN FUEL MARKET SIZES



Sources: GIIGNL. Methanol Institute, IEA & IRENA

AVAILABILITY IS ALSO ABOUT INFRASTRUCTURE

Availability is not just about supply but also about infrastructure. Methanol is a niche market mainly serving the chemicals industry. Annual production is a small fraction (10%) of the LNG market and the associated global infrastructure is less developed as 65% of methanol is produced and consumed locally. Although methanol storage infrastructure exists in a number of ports, these facilities are generally small. Globally there is only one methanol bunkering vessel in operation and eight on order. By contrast, LNG bunkering has developed off the back of massive, globally distributed integrated energy infrastructure provided by a worldwide network of 270 LNG liquefaction and regasification terminals with a capacity exceeding one billion tonnes per annum.



Nordic Ren-Gas's Power-to-Gas plant in Tampere, Finland will produce 160 GWh of renewable e-methane each year from 2026, which Gasum will procure and distribute to its customers.

MAKE EFFICIENT USE OF SCARCE RESOURCES

In the medium term, shipping is going to be dependent on biofuels and biogases for decarbonisation as they are cheaper and more widely available than electro-fuels. Electro-fuels are in the early stages of production and will not be available at scale for a decade or more. These biofuels represent a relatively scarce resource which needs to be used carefully and directed towards the hardest sectors to decarbonise such as shipping, aviation and HGV (Heavy Goods Vehicle) road transportation.

Plans for green methanol production announced to date for shipping are dominated by projects in which the bio-methanol is produced from biomethane. This means taking a scarce green resource, biomethane, which can already be used as a fuel, bio-LNG, and using it as a feedstock. This conversion process is about 65% efficient, compared with 95% efficiency simply to liquefy biomethane into bio-LNG. As a result, significant quantities of precious green energy will be consumed to make a more expensive fuel, bio-methanol. This does not seem to make sense, environmentally, or commercially.

> **Today, when sources of green marine fuels are scarce, we must maximise the propulsive energy from each tonne of precious fuel. This means utilising biomethane as bio-LNG, not bio-methanol.**
>
> **Peter Keller, Chairman, SEA-LNG**

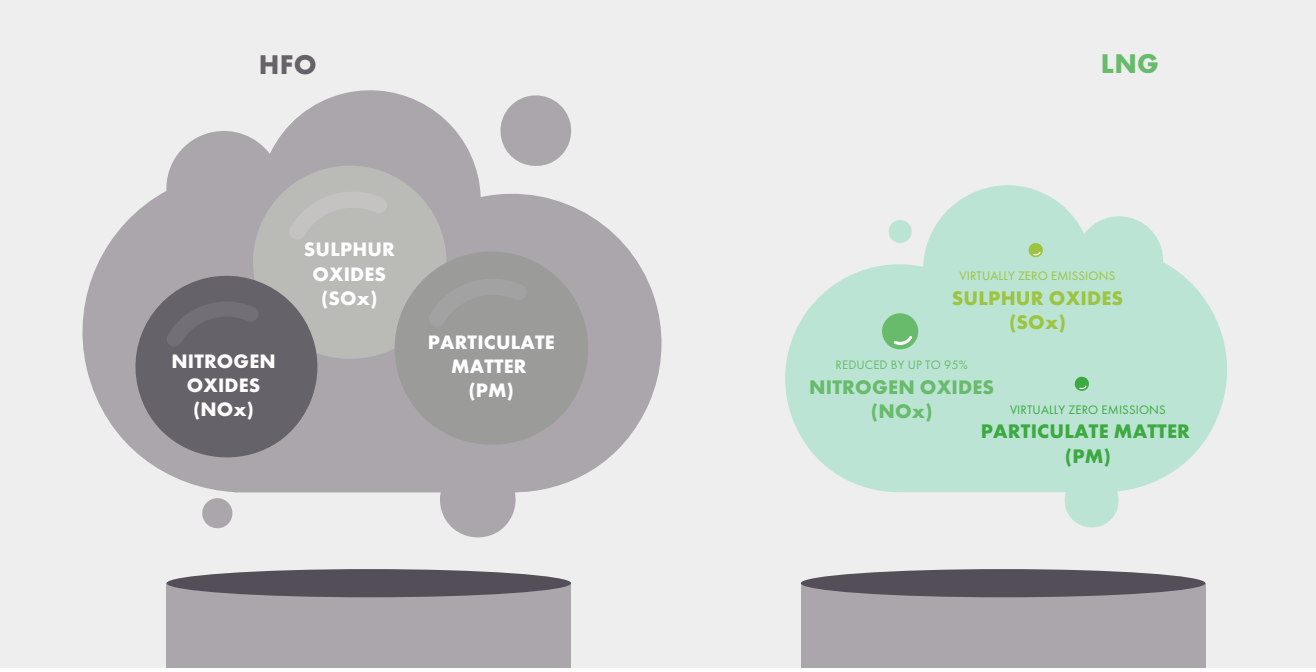
LNG bunker vessel GAS AGILITY refuelling the LNG powered Very Large Crude Carrier (VLCC) ANTONIS I ANGELICOUSSIS with fuel supplied by TotalEnergies in 2023. Photograph by Ingebridgt R. Arnoy.

LNG – THE FACTS

LNG offers a safe, proven, practical, low-cost and low-risk incremental pathway to decarbonisation via bio-LNG and renewable synthetic e-LNG.

While not currently receiving the attention it deserves, LNG supports human health and environmental goals by virtually eliminating harmful local emissions, such as SOx, NOx and particulate matter. This while providing immediate reductions in GHG emissions of up to 23% on a Well-to-Wake basis, inclusive of methane emissions, compared to VLSFO.[3]

AIR QUALITY BENEFITS OF LNG VS HFO



LNG's volumetric energy density is much greater than other alternative marine fuels – approximately twice as much as ammonia and methanol and four times that of liquid hydrogen. The higher the energy density of a fuel, the less space needed for fuel storage, and more space available for paying cargo. This is a major consideration as revenue capacity is essential in vessel design. Owners and operators always want to maximize revenue potential and carrying fuel rather than cargo is inconsistent with business goals.

15,000 TEU LNG powered container vessel ZIM SAMMY OFER pictured in New York City in December 2023.

LNG as a marine fuel has over 60 years of operational history without any major safety incidents in port or at sea. This is testament to the LNG industry's rigorous design guidelines for both ships and shore facilities, as well as high standards of training and operations, supported by global regulators.

> **LNG has consistently provided substantial benefits in maritime operations over time, including virtually zero sulphur and significantly reduced overall emissions, as the industry's most advanced fuel available to date.**
>
> **Tom Strang, SVP Maritime Affairs, Carnival**

PROGRESS ON METHANE SLIP

Methane slip, when unburnt fuel "slips" through the engine combustion process, is a known problem and engine manufacturers are diligently working to solve it. Since LNG engines were first introduced 20 years ago, the levels of methane slip in susceptible engines have been cut by four times.[4] Today, over 50% of LNG-fuelled ships on order have high-pressure two-stroke engines with minimal or no methane slip.

Over the past year considerable progress has been made in tackling the issue of methane slip through initiatives such as the Methane Abatement in Maritime Innovation Initiative (MAMII) and the EU-funded GREEN RAY project. These important initiatives started by first quantifying the problem through onboard operational measurements of methane slip and fugitive methane emissions for multiple vessel and engine types.

These initiatives are now looking at methodologies and pilots that support the reduction and ultimately the elimination of methane slip through the development of new engine technologies and exhaust stack abatement solutions. Examples of this can be seen in the GREEN RAY project where Wärtsilä has piloted technologies on the AURORA BOTNIA ropax ferry resulting in methane slip reductions of up to 56% in one of its most popular dual fuel, low pressure four-stroke engines. MAMII has begun a process of piloting exhaust stack methane abatement technologies and in November 2023 MAN Energy Solutions announced that it is launching the IMOKAT II project to develop an after-treatment technology to reduce methane slip from its four-stroke engines.

The regulations being developed and implemented by the IMO and the EU reinforce this industry-led direction, making methane slip a compliance issue for the shipping industry. Explicit regulation of methane emissions provides a strong incentive for industry action and accelerates the adoption of cleaner technologies. Engine manufacturers are confident that the issue of methane slip in engine technologies where it exists will have been resolved before the end of the decade.

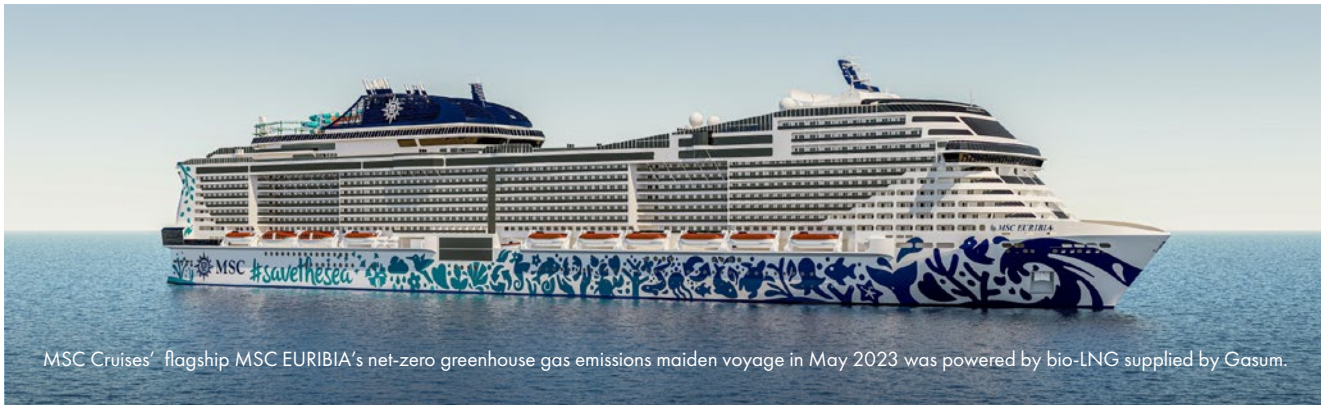
BIO-LNG – READY NOW

The entire LNG pathway to decarbonisation benefits from existing infrastructure. Bio-LNG can be used as a drop-in fuel in all current and future LNG-fuelled engines with minimal, if any, modification. Bio-LNG can be transported, stored and bunkered in ports using the established infrastructure. As a result, LNG currently offers the most efficient, lowest risk, known-cost pathway to a zero-emissions future for the maritime sector.

Bio-LNG's emissions credentials make it a compelling fuel solution. Typically, bio-LNG (liquefied bio-methane) can reduce GHG emissions by up to 80% compared to marine diesel on a full well-to-wake basis. If avoided emissions are taken into account, when it is produced from anaerobic digestion of manure, bio-LNG can achieve net-negative emissions of up to -190% compared with heavy fuel oil.

> **MSC EURIBIA's first voyage [on bio-LNG] is an incredible feat and represents years of commitment and determination. It proves that we have the capability to operate on a net zero greenhouse gas emissions basis with existing ship technology.**
>
> **Michele Francioni, SVP, MSC Cruises**

It is important to note that bio-LNG production is already well-established. Global biomethane production currently amounts to 30 Mtpa, which if converted to bio-LNG represents approximately 90% of the total energy consumption of the LNG-fuelled fleet. Longer term, the International Energy Agency (IEA) estimates a global biomethane production potential of 600 Mtpa in bio-LNG terms. While there are many competing uses for bio products, including aviation, the current and anticipated growth is encouraging. Increasing biomethane production also helps mitigate another global issue, how we handle waste and develop a real circular economy.



MSC Cruises' flagship MSC EURIBIA's net-zero greenhouse gas emissions maiden voyage in May 2023 was powered by bio-LNG supplied by Gasum.

Research into bio-LNG costs and availability conducted by the Maritime Energy and Sustainable Development Centre of Excellence at Nanyang Technological University Singapore shows that pure bio-LNG could realistically cover up to 3% of the total energy demand for shipping fuels in 2030 increasing to 13% in 2050. If used as a drop-in fuel blended with fossil LNG, bio-LNG could cover up to 16% of the total energy demand in 2030 and 63% in 2050, assuming a 20% blending ratio.

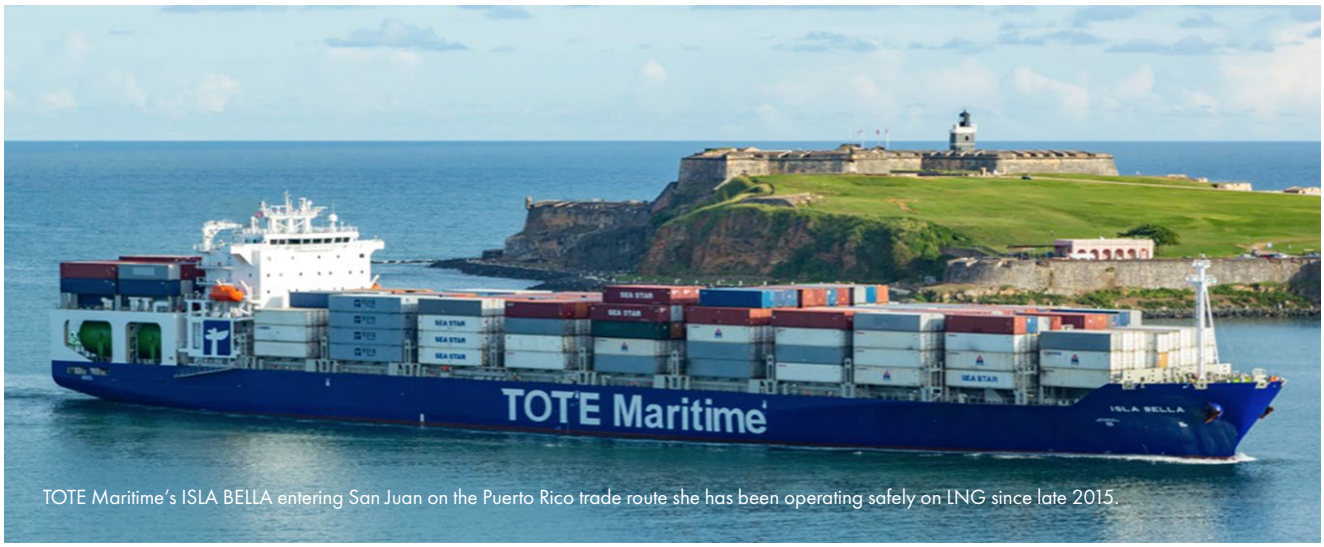
Cost is another important issue for vessel owners and operators. Analysis from the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping suggests that bio-LNG is the lowest cost green fuel, with significantly lower costs of production compared with bio-methanol and electro-fuels, including e-ammonia and e-methanol.

LNG and its pathway fuels provide the most realistic solution for decarbonisation of the deep-sea shipping fleet. It is cost competitive with other alternative fuels, globally available and proven, with over 60 years of safe operations.

BIO-LNG DEVELOPMENTS

Bio-LNG production is ramping up rapidly. The European Biogas Association reported a 20% growth in European biomethane production in 2022 to around 21 billion cubic metres (14.2 Mtpa). This is more than Poland's total natural gas consumption and around 6% of the EU's 2022 consumption. Growth was similar in North America with the renewable natural gas (RNG) market growing by 20% in 2022 and RNG projects doubling in the last five years with a tenfold increase possible by 2050.[5] According to the IEA the Asia-Pacific region has the biggest potential for biomethane production.

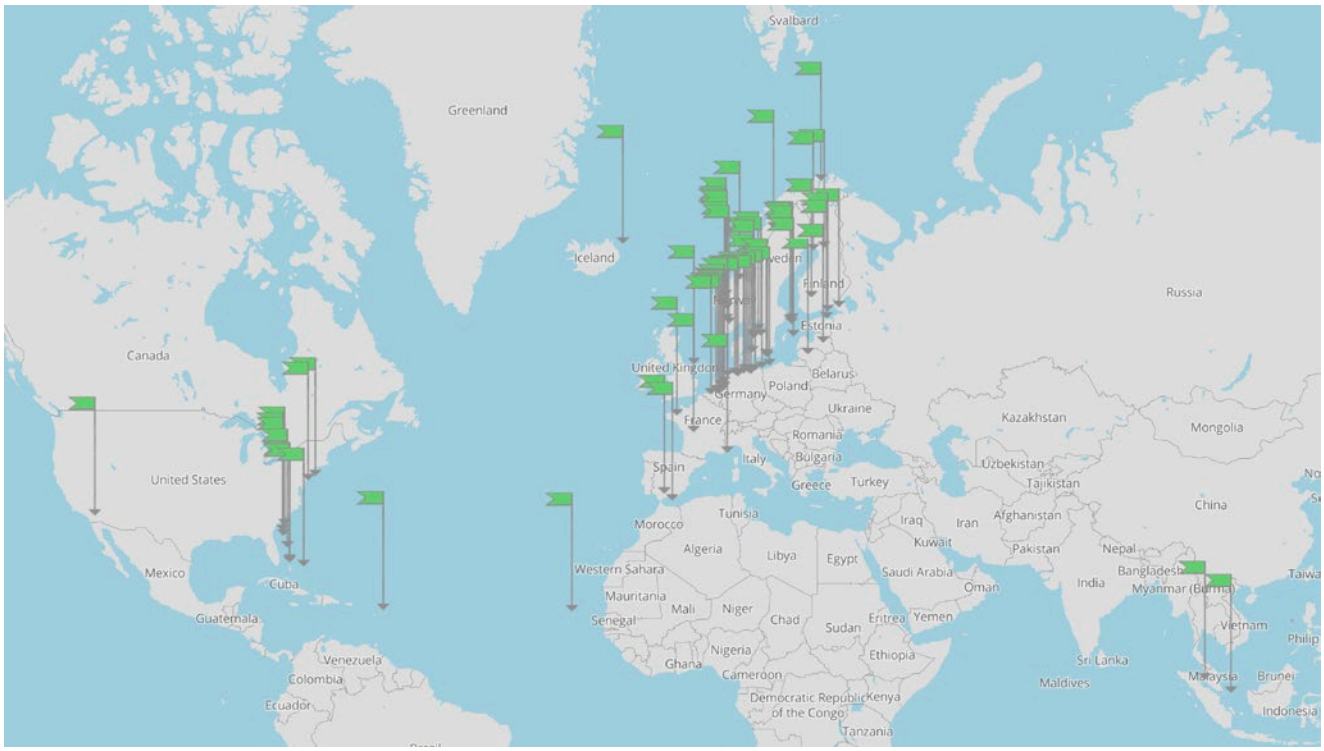
SEA-LNG members can offer bio-LNG bunkering today and it is already in almost 70 locations in Europe, North America and Asia – including Singapore, Rotterdam and the US east-coast. This global roll-out of today's green marine fuel is mapped on SEA-LNG's Bunker Navigator tool.



TOTE Maritime's ISLA BELLA entering San Juan on the Puerto Rico trade route she has been operating safely on LNG since late 2015.

BIO-LNG AS A MARINE FUEL

COMMERCIALLY AVAILABLE TODAY



Source: SEA-LNG Bunker Navigator

Regulation will have a key role to play both in stimulating biomethane and bio-LNG production. The industry must also continue to work with regulators to ensure the maritime sector has access to the bio products. The acceptance of mass balancing of bio-methane, or virtual liquefaction, by the EU in 2023 is a key milestone. Mass balancing enables bio-methane injected anywhere on the European gas grid to be bunkered as bio-LNG from connected LNG terminals in ports with the appropriate certification. This is the lowest cost and most efficient way of delivering bio-LNG to shipping, avoiding the costs of building separate supply chain infrastructure. It allows shipping to access the European grid-connected biomethane market and is a precedent for regulations in other markets. The same principle is used in the supply of green electricity, where renewable generation of electricity is distant from its consumption. Other jurisdictions around the globe need to adapt similar regimes to ensure bio products are accessible from existing supply infrastructure.

TotalEnergies inaugural LNG bunkering of MSC Cruises vessel MSC WORLD EUROPA by LNG bunker vessel GAS AGILITY in April 2023.

TOTE Maritime's Orca class vessels began running on LNG for the Alaska trade route in 2023.

Gasum and its partners plan to build a new biogas plant near Trondheim in Norway. The Vormstad plant will treat up to 500,000 tons of organic waste per year and produce up to 150 GWh of biogas. Production should start at the end of 2025.

MOL and six other companies successfully completed a trial using bio-LNG derived from cattle manure as a marine fuel on the domestic LNG-fuelled vessel Ise Mirai.

Shell bunkered CMA CGM's containership, Aurora, a 1,400 TEU LNG-powered vessel, with a nearly 10% blend of bio-LNG while calling at Rotterdam.

Gasum will supply bio-LNG to Wasaline's LNG-powered ferry Aurora Botnia as part of a pilot project. Wasaline is operating the ferry with certified biogas one day a week in line with EU ETS.

> **We do not see why the shipping sector couldn't secure 5-10% of European bio-methane production by 2030, which would be 1.25 Mtpa to 2.5 Mtpa of bio-LNG, perhaps equivalent to 20-40% of European maritime LNG demand.**
>
> **LANDSDOWNEMoritz**

Eagle LNG Partners took delivery of the LNG bunker vessel CORAL FAVIA from Anthony Veder in October 2023 to provide bunkering services in the Caribbean basin.

e-LNG DEVELOPMENTS

We are unlikely to see commercial quantities of e-LNG and other electro-fuels until renewable electricity and electrolysis capacity required to produce the common green renewable hydrogen feedstock is scaled massively. This is unlikely to happen before 2030 and will take well into that decade to begin to really scale. The scale of the e-fuel challenge is breathtaking due to the huge demand for renewable electricity to create the new electro-fuels. The International Chamber of Shipping estimates the shipping industry will need as much renewable energy as is currently produced globally – up to 3,000 terawatt hours (TWh), to reach its net-zero goals. This is more than the total EU electricity demand of 2,809 TWh[6] and three-quarters of the 4,048 TWh total US electricity demand.[7]

As with other electro-fuels, such as e-methanol, e-ammonia and e-hydrogen, production of e-LNG today is only at the pilot, or demonstration stage. The notable exception is the kiwi AG power-to-e-methane plant in Wertle Germany which has been in operation since 2013.

Once we have developed the ability to make large quantities of green hydrogen from renewable energy sources we can combine it with biogenic CO2, or CO2 captured from the atmosphere, to make green or e-LNG. Interest in e-LNG is growing rapidly both within and outside the shipping sector. There is growing recognition of the opportunity to utilise the existing LNG supply chain infrastructure to deliver this carbon neutral form of the methane molecule to customers.

> **e-methane has the potential to be an important carbon-neutral fuel – a direct substitute for natural gas – that avoids the cost associated with new infrastructure and new industrial processes, which for many sectors are not yet technically feasible, affordable or available.**
>
> **Alan Stuart-Grant, Executive Vice President, Santos Energy Solutions**

Gasum and the leading Nordic Power-to-Gas developer Nordic Ren-Gas have signed a long-term sales and purchase agreement whereby Gasum will buy all of the e-methane produced by Nordic Ren-Gas at its Tampere plant from 2026 onwards and distribute it to its customers.

Santos has teamed up with Tokyo Gas to explore opportunities for the production of carbon-neutral e-methane in Australia. The first production of e-methane is targeted for 2030.

Santos has signed an agreement Toho Gas, one of the largest gas utility companies in central Japan, to investigate the potential for producing carbon-neutral e-methane in South Australia's Cooper Basin.

Tokyo Gas, Osaka Gas, Toho Gas, and Mitsubishi plan to produce e-methane in Texas or Louisiana, liquefy it at Sempra's Cameron LNG facility, and transport it to Japan. The targeted e-methane production volume is 130,000 tons per year and the partners plan to start the project in 2030.

PETRONAS, Sumitomo Corporation and Tokyo Gas Co., Ltd agreed to conduct a feasibility study to establish a supply chain of carbon neutral methane to Japan. The carbon neutral methane will be produced in Malaysia by methanation, using green hydrogen from renewable energy and carbon dioxide.

Osaka Gas is proceeding with several feasibility studies to produce e-methane in strategic locations, such as North America, South America, Australia, the Middle East, and Southeast Asia.

Marubeni, Osaka Gas and the consortium behind the Peru LNG plant (Shell, US oil company Hunt and South Korean oil company SK Innovation) plan to produce 60,000 tonnes of e-methane per year at Peru LNG. They are aiming for a final investment decision by 2025 and commercial operation in 2030.

Shell, Tokyo Gas and Osaka Gas signed a tripartite letter to jointly explore and evaluate the potential of renewables-based synthetic gas.

TotalEnergies is joining forces with Tree Energy Solutions (TES) to study and develop a large-scale production unit in the United States for e-LNG. The project, which is expected to produce 100,000 to 200,000 metric tons of e-LNG per year, will be equally owned by the partners and operated by TotalEnergies. They aim to reach a Final Investment Decision (FID) in 2024.

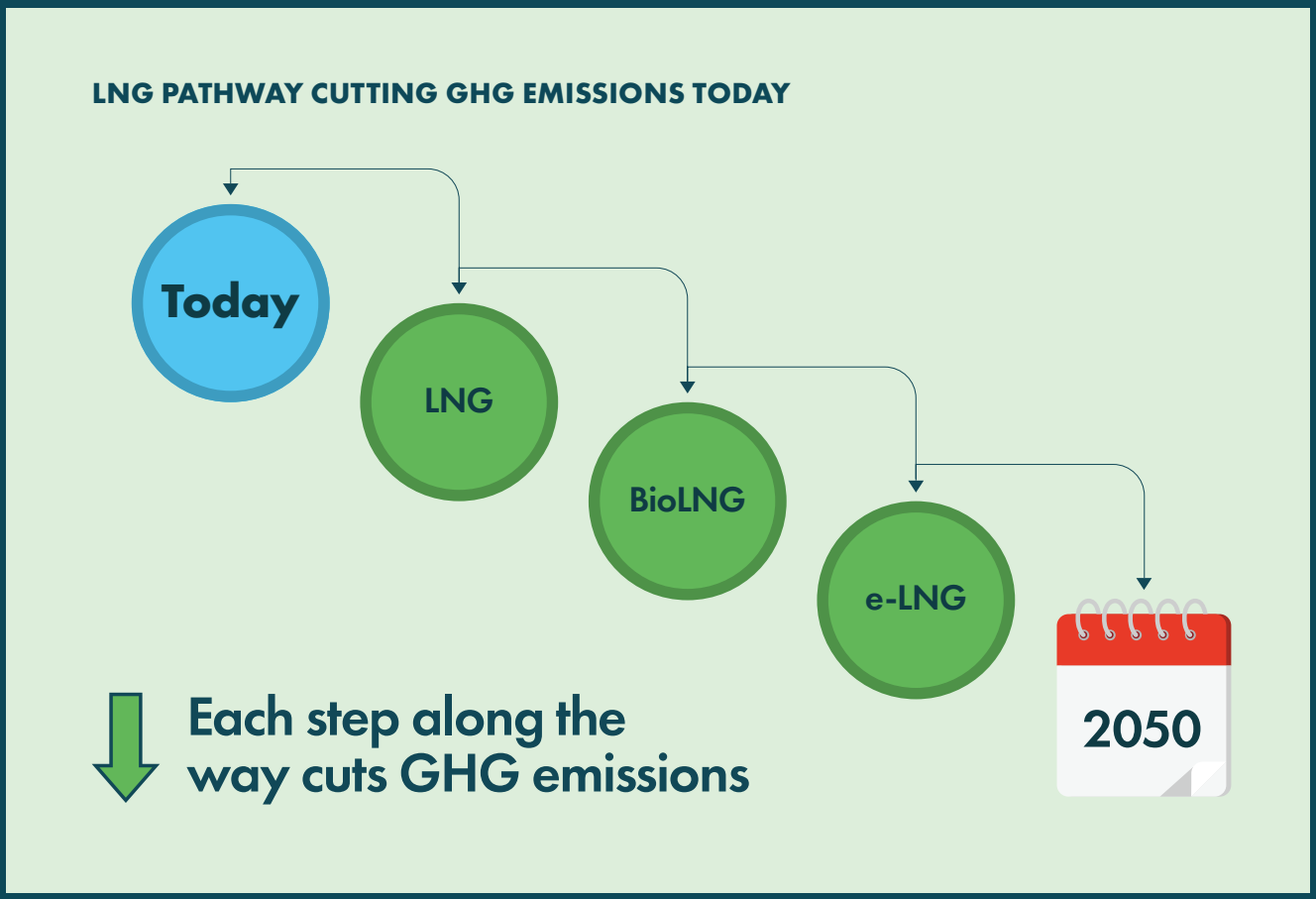
AS REALITY BITES, WAITING IS NOT AN OPTION

The shipping industry shares a collective challenge. To achieve decarbonisation targets, we must avoid a "my fuel versus your fuel" mentality and learn from each other to accelerate towards a diverse multi fuel future.

Every fuel shares the same decarbonisation pathway. They are all initially derived from fossil fuels and they all share a common, long term electro-fuel destination derived from the same building block; hydrogen produced from renewable electricity.

In addition, every fuel pathway shares the same global challenge of upskilling the maritime workforce and introducing new fuels to ports.

None of these challenges are easy, or quick, to overcome. As an industry, therefore, we need to be honest about the difficulties we collectively face. Not least as we are running out of time. University College London (UCL) estimates that every year of inaction this decade will add an extra $100bn to the cost of shipping's decarbonisation.



LNG has driven the first transition in the way that ships are propelled since the move from coal to oil. The industry has over 60 years' experience of using and transporting LNG, providing rich learnings in areas such as safety, handling, infrastructure, storage, and supply chain organisation.

The LNG pathway currently has significant advantages over other alternative fuel pathways. First and foremost, it is safe and operationally proven. We owe our seafarers and others working in the industry safe solutions to Industry challenges. Existing LNG infrastructure can transport, store and bunker bio and e-LNG with minimal, if any, changes required. LNG and its green alternatives can be blended and used in existing LNG powered vessels. There are no stranded assets.

Commercially LNG and the pathway to zero-emissions it enables makes sense. LNG offers immediate greenhouse gas reductions and the lowest cost of compliance with European and IMO regulations. Bio-LNG has the lowest production costs of all alternative marine fuels and is increasingly available. LNG's high energy density compared to other alternative fuels allows owners and operators to carry less fuel and more revenue paying cargo.

Waiting is not an option. GHG emissions are cumulative and the longer we wait to reduce them the tougher, and more expensive, the decarbonisation challenge will be.

15,000 TEU LNG powered container vessel ZIM SAMMY OFER transiting the Panama Canal in March 2023.

SEA-LNG: SHARING FACTS AND KNOWLEDGE TODAY

SEA-LNG remains committed to providing factual, credible and timely information. We are developing a Cost of Compliance Calculator which will enable ship owners, investors, charterers and operators to understand and easily explore the commercial implications of different fuel choices in complying with EU and IMO regulations for different ship types and trading routes. The Calculator is scheduled to be released in the first quarter of 2024 with the aim of providing a common, transparent platform to inform the alternative fuels debate.

SEA-LNG is part of the Rotterdam-Singapore Green and Digital Shipping Corridor, focusing on decarbonising the container trade value chain. Working with the Maritime and Port Authority of Singapore (MPA) and the Port of Rotterdam, together with CMA CGM, Hapag-Lloyd and Shell, SEA-LNG is leading the work on the 'Methane Track'. As the most advanced of the alternative fuels, this track is focused on using bunkering pilots in Singapore and Rotterdam to crystallise regulation and certification processes with the aim of accelerating the uptake of bio-LNG as a marine fuel. Learnings from this work will be shared with the other – ammonia, methanol and hydrogen - fuel tracks.

Also in 2024, SEA-LNG will share the findings of an alternative fuels perception study. Working with Thetius, the maritime technology research firm, 25 industry stakeholders from ship owners and operators, classification societies, marine engineering firms, journalists, ports and consultancies have been interviewed to understand perceptions around future marine fuels. Thetius has analysed market developments over the past 12 months, looking in depth at key figures and statistics to identify whether perceptions around the future marine fuels landscape align with reality.

Gasum LNG bunker vessel KAIROS supplying Ponant polar exploration cruise ship LE COMMANDANT CHARCOT.

ANNEX: MYTHS VS REALITY

MYTH	REALITY
LNG as a marine fuel offers no **GHG benefits** compared to conventional marine fuels	Sphera's 2nd Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel, widely recognised as the most definitive analysis to date of the GHG emissions of LNG as a marine fuel, reports **emissions reductions of up to 23% in GHG emissions compared with conventional marine fuels.** The results are assessed on a full life cycle, well-to-wake, basis inclusive of methane slip and upstream methane emissions. The study is based on primary data from all major marine engine manufacturers and peer-reviewed by independent academics.
Methane slip is a fatal flaw for LNG-fuelled vessels	**Methane slip is a recognised issue by the industry and where it exists, is being addressed.** LNG-fuelled engines were first introduced to address local emissions of SOx and NOx at the turn of the century. Levels of methane slip have been reduced by a factor of four since then. Sphera's 2nd Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel, reports that for technologies where methane slip is an issue, engine manufacturers have identified clear technology pathways to eliminate slip by 2030. Support from programmes such as Methane Abatement in Maritime Innovation Initiative (MAMII) and EU-funded GREEN RAY and pressure from the Global Methane Pledge will also drive this change. Finally, DNV data on the LNG-fuelled vessel orderbook shows that it is dominated by engine technologies with low, or negligible levels of methane slip.
Upstream methane emissions more than offset CO2 emissions benefits of LNG as a marine fuel	Sphera's 2nd Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel study analysed methane emissions from all major LNG supply chains and found that **upstream methane emissions account for a small fraction, 5% to 6%, of total, well-to-wake GHG emissions.** There are a number of UN, World Bank, European, US and industry-led initiatives focused on reducing upstream methane emissions. Examples include the Global Methane Pledge announced at COP26 and co-convened by the US and European Union, the Oil and Gas Decarbonization Charter announced at COP28 and the Oil and Gas Climate Initiative (OGCI) Aiming for Zero Methane Emissions Initiative.

Investments in LNG as a marine fuel will become **stranded assets**	LNG-fuelled vessels and the associated bunkering infrastructure can use and deliver carbon neutral forms of LNG such as bio-LNG today and e-LNG, as and when it becomes available. Bio-LNG and e-LNG are chemically identical to LNG and can be used as simple drop-in fuels without the requirement for additional investments. LNG-fuelled vessels also provide optionality – LNG can be blended with other fuels, such as hydrogen and it is particularly suitable for onboard carbon capture – providing additional pathways for decarbonisation.
Investing in LNG now will **divert resources** from true net-zero emission shipping solutions	Investing in LNG fuelled ships and bunkering infrastructure offers immediate GHG emission reductions and a **low risk, incremental pathway to net-zero emissions** through the use of bio and renewable synthetic e-LNG as drop-in fuels. This pathway is consistent with those set out for other alternative marine fuels, based on the use of sustainable biomass resources and synthetic fuels produced from renewable electricity, with the difference that with LNG emissions reductions start today.
Bio-LNG availability is limited, and it will be **too expensive** for shipping to use	Liquefied biomethane, or bio-LNG, produced from sustainable biomass resources i.e. which does not interfere with production of food, fodder and fibres, can meet a significant proportion of future shipping demand even when considering growing demand for biomass from other sectors such as heat and power, industry, aviation and heavy-duty road transportation. The October 2022 study by Singapore's Maritime Energy and Sustainable Development Centre of Excellence forecasts that could meet up to 3% of total energy demand from shipping in 2030 rising to 13% by 2050. If used as a 20% drop in fuel these numbers increase to 16% and 63%, respectively. Analysis from the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping suggests that Bio-LNG is the lowest cost green fuel, cheaper than biomethanol and electrofuels, including e-ammonia and e-methanol.
Renewable synthetic LNG (e-LNG) will be far **too expensive** for use in maritime	In the long term it will be the relative price of alternative fuels that matters to customers. Approximately 75% of the cost of electro-fuels (e-fuels) such as e-LNG, e-methanol and e-ammonia are related to the cost of producing hydrogen from renewable electricity. This means that the **production costs all e-fuels such as will be broadly similar.** It also means that the infrastructure costs associated transporting, storing and delivering these fuels to vessels will be a significant differentiator. Here e-LNG will have a clear advantage as most of the supply infrastructure is already built.

[1] https://www.cmacgm-group.com/en/news-media/shipping-ceos-join-forces-accelerate-decarbonization-global-maritime-transport

[2] https://www.hellenicshippingnews.com/clarksons-45-of-all-newbuild-orders-placed-in-2023-alternative-fuel-capable/

[3] These figures are based on analysis of primary data from all major marine engine manufacturers as cited in the 2nd Lifecycle GHG Emission Study on the use of LNG as a Marine Fuel study conducted by Sphera.

[4] Paper submitted by SGMF to IMO ISWG-GHG 7/3/1 - FURTHER CONSIDERATION OF CONCRETE PROPOSALS TO REDUCE METHANE SLIP AND EMISSIONS OF VOLATILE ORGANIC COMPOUNDS (VOCS)

[5] https://www.woodmac.com/press-releases/north-american-renewable-natural-gas-market-could-expand-tenfold-by-2050-to-reach-4-bcfd/

[6] https://ember-climate.org/insights/research/european-electricity-review-2023/

[7] https://www.statista.com/statistics/201794/us-electricity-consumption-since-1975/

Visit sea-lng.org/2024/01/lng-leading-maritime-decarbonisation/ to download all the infographics used in this report and access the online version

ZIM SAMMY OFER, the first of ten 15,000 TEU LNG-powered container vessels ordered by Seaspan as part of a long-term charter with ZIM, launched in February 2023.

SEA–LNG

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