Is the Shipping Industry Headed Towards Significantly Reduced Emissions?

A container ship approaching the port of Santos in Brazil.
Image courtesy of Associated Press

More than 90% of world trade takes place across the world's oceans, carried by marine vessels. Over 95% of the 100,000 ships operating worldwide today – both passenger and freight - are powered by engines that run on some version of diesel fuel. These engines run on petroleum products like heavy fuel oil (HFO), marine gas oil (MGO), and marine diesel oil (MDO). While some ships are partly electrified using diesel-electric systems, the vast majority rely on diesel combustion engines for both propulsion and onboard power generation.

Emissions from shipping have increased over the last decade as vessels have gotten much larger, delivering more cargo per trip and using immense amounts of fuel. As a result, the maritime industry is responsible for a significant share of greenhouse gas (GHG) emissions.

According to the United Nations, shipping is now responsible for about 3% of the global CO_2 emissions. The Internation Maritime Organization (IMO), which is a specialized agency of the UN responsible for regulating international maritime transport – and focusing on safety, security, and environmental protection - reported back in 2018 that the maritime sector contributed about 2.89% of human-caused GHG emissions. This included emissions from both international and domestic shipping, as well as fishing vessels. A recent article in Environment + Energy Leader noted that cruise ship pollution now exceeds urban emission levels. The article highlighted a Transport and Environment (T&E) campaign group report which stated that the world's largest cruise operator, Carnival, emitted more carbon pollution in 2023 than the city of Glasgow, Scotland. (Some sources report that maritime transportation is responsible for 12% of sulfur oxide (SOx) emissions and 13% of nitrous oxide (NOx) emissions. And other studies have reported that pollution from the maritime industry is responsible for between 60,000 and 100,000 premature deaths per year globally).

But it looks like things are going to change.

In April 2025, the IMO signed off on new draft regulations intended to help the global shipping industry get close to net-zero greenhouse gas emissions by 2050. The regulations were formulated by the IMO's Marine Environment Protection Committee. (The IMO has 176 member states and 3 "associate members" – Hong Kong, Macao, and the Faroe Islands). The new global regulation puts a price on maritime greenhouse gas emissions and is aimed at setting a marine fuel standard to phase in cleaner fuels. The IMO is aiming to reduce carbon emissions from international shipping by 40% by 2030 and 70% by 2050.

The key part of the regulation is a pricing structure; ships that exceed the limits established will have to pay a fee. On the flip side, ships using low-emissions or zero-emissions technologies could receive credits or other compensation. The details are still being finalized, but the intent is to apply a cost to carbon emitted at sea.

The plan calls for a mandatory reduction in the carbon intensity of marine fuels, using a measurement approach that is intended to capture emissions from production to consumption. Large vessels - specifically those over 5,000 gross tons, which account for the majority of emissions - will be required to meet these standards or face financial penalties.

As noted above, the regulation is still in draft form. Formal adoption is scheduled for October 2025, and enforcement is not intended to begin until 2027. But the shipping industry will clearly need to begin exploring their options fairly quickly.

To help the industry achieve the intended goals, the IMO introduced plans for a global *Net-Zero Transition Fund*. The fund is intended to channel some of the revenue collected through the new emissions pricing to help shipping companies with their decarbonization efforts. This can include payments for vessels with low-emission levels, as well as payments to support efforts to reduce emissions - especially in developing countries. One of the goals of the program is to ensure that all regions and countries can participate in the transition to a cleaner maritime industry.

While many companies in the maritime industry had already begun looking at ways to lower emissions, they all need to begin looking at their options – and get started on implementing them within the next couple of years. So, what options does the maritime industry have for reducing emissions – and where is the industry today in making that happen?

Alternative Fuels for Maritime Vessels

First and foremost, there is already some progress happening in replacing diesel as the primary maritime fuel.

Hydrogen

One of the key options is Hydrogen, a totally clean fuel – although typically the process for creating hydrogen fuel relies on natural gas, so it is not an entirely green fuel. It is possible to create hydrogen fuel by using renewable energy rather than gas – but that process – which creates Green Hydrogen – is much more expensive. But even using standard hydrogen fuels results in significantly lower emissions than using diesel maritime fuel.

There are currently 2 approaches being pursued for hydrogen fuel for transportation:

- A *hydrogen internal combustion engine vehicle (HICEV)* uses an engine very similar to a gasoline or diesel engine – but fueled by hydrogen.
- *A fuel cell hydrogen vehicle (HFCEV)* generates electricity from hydrogen via a fuel cell and uses that electricity to power an electric motor, much like in an electric vehicle. Hydrogen fuel cells generate electricity through an electrochemical reaction between hydrogen and oxygen, which combine to generate electricity, heat, and water.

There is much more attention being paid to hydrogen fuel cell technology for maritime use. Fuel cell efficiency of over 60% has been demonstrated, and over 80% efficiency is believed to be possible under certain conditions. Fuel cells are quiet, have no moving parts, and are easily scalable for larger ships, since individual cells can be stacked.

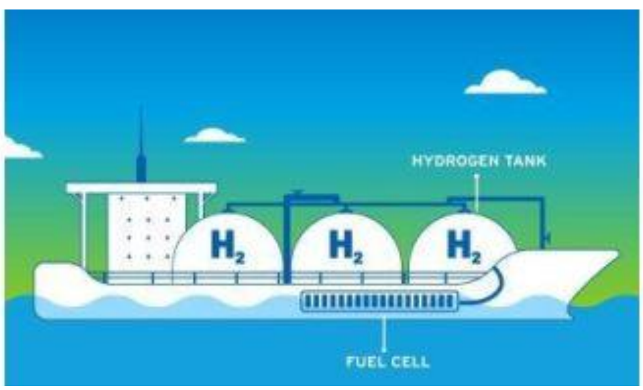

Image source: AMOT

The Global Maritime Forum (GMF) did a study in March 2021 that examined over 100 projects looking at zero emissions in maritime shipping worldwide and found that nearly half of them were focused on hydrogen as the low-carbon fuel source. (The Global Maritime Forum is an independent not-for-profit organization aimed at shaping the future of global seaborne trade and focused on decarbonizing the maritime industry.)

A key advantage of hydrogen over other fuel alternatives is the relative ease of retrofitting existing ships with hydrogen fuel cells. The GMF estimated that hydrogen fuel could replace about 43 percent of trips between the US and China without requiring any changes, and perhaps as much as 99 percent of maritime trips with relatively minor changes.

Another upside of using hydrogen as a maritime fuel is that it is widely available, 70 million metric tons of hydrogen are produced for industrial use worldwide annually, with about 1/7 of that produced in the US. Hydrogen can be stored in large amounts for long periods of time, which is advantageous for the shipping industry.

But there are challenges to using hydrogen as a maritime fuel. Hydrogen is extremely flammable and has a larger ignition range than traditional fuels, meaning that hydrogen will burn at both low and high concentrations when combined with oxygen. There are safety measures that can mitigate this risk during storage, transportation, and ignition, but this still represents a challenge to the use of hydrogen.

In addition, hydrogen, even in liquid form, is less energy-dense than standard fuels, meaning that hydrogen fuel cells will take up more volume on cargo ships than diesel fuel, which could result in less room for cargo. However, this issue should be relatively minor.

And, hydrogen could be much more expensive, depending on the type of hydrogen. While standard hydrogen – known as Gray Hydrogen - is reasonably price competitive with traditional fuel sources, more sustainable hydrogen is not. Blue Hydrogen is produced via the same process as Gray, but its production plants are retrofitted with carbon capture and storage technology. Depending on the technology and the fossil fuel used, Blue Hydrogen plants can capture 50–90 percent of CO_2 emissions, but blue hydrogen is 30–80% more expensive than gray hydrogen. Green Hydrogen is produced through the electrolysis of water using electricity from renewable sources like solar or wind and is totally emissions free. However, it generally costs at least 4 times as much as Gray Hydrogen. These costs are expected to come down considerably in the coming years, but it does represent an issue currently for widespread adoption of hydrogen.

In an article I posted on the greening of hydrogen in 2023 I noted that the **H2Ports** project, funded largely by the European Union (EU), was beginning to demonstrate and validate two innovative solutions based on fuel cell technologies and a hydrogen mobile supply station. This has been conducted at the Port of Valencia, Spain. (In April 2023, the Port of Valencia also became the first port in the world to use a 4×4 truck tractor unit powered by Green Hydrogen to move containers within its terminals). The project was aimed at analyzing ways of improving the energy efficiency, performance, and safety of operations with fuel cell port equipment - and was the first to test the use of hydrogen technologies in port handling equipment in Europe. The Port Authority of Valencia (APV) has a goal to convert its docks into a zero emissions zone by 2030.

That article also noted that a German-based organization called DNV, which is focused on enhancing safety, quality, energy efficiency and environmental performance of the shipping industry, led a group of organizations in issuing a Handbook for Hydrogen-fueled Vessels in 2021 which created a roadmap towards safe hydrogen operations using fuel cells. The Handbook suggests that more testing is needed on the safety aspects of handling, storing and bunkering of hydrogen and that testing needs to address leakage, including the potential detonation risk if there is a leak. The Handbook addresses a range of other safety related issues as well, and notes that moving hydrogen as a fuel from land-based applications to maritime use will be challenging.

And the ports themselves will play a significant role in determining whether hydrogen is a usable fuel by controlling what fuels are available for the ships in the port to use - and when.

But shipping companies are beginning to get involved with hydrogen.

Viking very recently (April 2025) announced that it was building the *Viking Libra*, the world's first hydrogen-powered cruise ship, intended to operate with zero emissions. The ship is under construction at Fincantieri's Ancona shipyard and is scheduled for delivery in late 2026. It will have a gross tonnage of approximately 54,300 tons, with 499 passenger staterooms. The ship will have a hybrid propulsion system based on both liquefied hydrogen and fuel cells.

Viking also announced a second hydrogen-powered ship, the *Viking Astrea*, which is scheduled for delivery in 2027.

Viking Libra. Image source - Baird Maritime

Viking is working with Isotta Fraschini Motori, a subsidiary of Fincantieri's, that specializes in fuel cell technology. The ship's propulsion system is expected to produce up to 6 megawatts of power.

Viking and Fincantieri also announced that they have signed contracts to deliver 2 additional ships in 2031 and an option for 2 more in 2033.

So, there is clearly some movement to introduce hydrogen-powered ships – albeit fairly slowly. But this is not the only alternative fuel being deployed.

Ammonia

The article I posted on Green Hydrogen noted that a clear alternative to hydrogen as a clean fuel is ammonia – which is generally made from hydrogen. As an example of where this is happening in the maritime industry, the Maritime and Port Authority of Singapore announced back in 2023 that it believed that by some point in 2025 it would be ready to offer ammonia "bunkering", around the same time that the first ammonia fueled ships were expected to be delivered. (The Port Authority had stepped back from earlier expectations that ammonia fueling trials would happen by the end of 2023 – largely due to safety concerns).

More than half of hydrogen across the world is used to produce ammonia, the vast majority of which is used to make fertilizer. But, because so little of the hydrogen being used is Green Hydrogen, there are several companies around the world experimenting with technologies to create ammonia without hydrogen. For example, in the article I noted that a company based in Israel named Nitro Fix (which I also noted that I am a shareholder of) is generating ammonia from nitrogen and water only; bypassing the use of hydrogen that is the basis of the well-known Haber-Bosch process. The Haber-Bosch process converts atmospheric nitrogen to ammonia by a reaction using a metal catalyst under high temperatures and pressures. Nitro Fix is currently focused on using the ammonia for fertilizer but plans to expand to maritime transportation late this year or early next. If the approaches to bypass Haber-Bosch prove effective, the clean ammonia that is created can clearly be used for maritime transport – and will free up huge amounts of Green Hydrogen to be used for other purposes. Other companies involved in the production of Green Ammonia for transport include Statkraft, Aker Clean Hydrogen, and Yara International.

Several shipping lines are actively exploring the use of green ammonia as a fuel, as detailed below:

- **Yara Eyde:** Yara International, Yara Clean Ammonia, and North Sea Container Line have partnered to create the world's first ammonia-powered container ship, the Yara Eyde. It will be operated by *NCL Oslofjord* and operate on routes between Norway and Germany, specifically between Oslo, Porsgrunn, Hamburg and Bremerhaven. The joint venture intends to become the world's first line operator to focus exclusively on ammonia-powered container ships.

Image Courtesy of Yara International

- **[Höegh Autoliners](#):** Höegh Autoliners, which operates the world's most sustainable PCTC (Pure Car and Truck Carrier) fleet, is also involved in green ammonia initiatives, ordering new multi-fuel-ready vessels, including those designed for dual-fuel ammonia propulsion. A PCTC fleet refers to a group of specialized “roll-on/roll-off” vessels designed for the transportation of wheeled cargo, including cars, trucks, and other heavy equipment. Höegh is launching a green fleet program, including "ammonia-ready" vessels, with four vessels planned to have dual-fuel ammonia propulsion. Dual-fuel will include ammonia alongside a conventional fuel, such as diesel. So, these ships will not result in the same degree of emission reduction as pure ammonia vessels – but they will probably be less expensive. (Dual-fuel maritime vessels are equipped with engines that can run on either traditional marine fuels or alternative fuels like ammonia, methanol, or LNG (Liquified Natural Gas). This allows ships to reduce emissions while maintaining broader operational efficiency. The engine systems are modified to accommodate the different fuel types, including fuel tanks, fuel lines, and injection systems).

- **Fortescue**: Fortescue, a global metal mining company headquartered in Australia, has also started using ammonia on a multi-fuel vessel, with the Fortescue Green Pioneer being the first vessel to do so at the Port of Singapore. The Green Pioneer is intended to demonstrate the viability of ammonia as a sustainable marine fuel in different ports around the world, with a stated goal of accelerating the adoption of green fuels in international shipping. The project is a collaboration between Fortescue and several other industry players. Fortescue and its partners have focused on safety and training for the use of ammonia as a marine fuel, hoping to ensure that the technology can be used responsibly. Fortescue has a broader strategy to decarbonize its supply chain and the Green Pioneer is part of the strategy to eliminate fossil fuels from its operations.

Green Pioner. Image courtesy of Port

- **Eidesvik Offshore*:*** Eidesvik Offshore is a supply and cable-laying shipping company. Their *Viking Energy* ship (which has nothing to do with Viking Cruises) has recently been retrofitted with a high-temperature solid oxide fuel cell powered by ammonia for zero-emission technology. The company's fleet has 10 supply ships - both platform supply vessels and anchor handling tug supply vessels - 5 subsea vessels, 5 seismic vessels, and 1 cable-laying ship. Viking Energy was the world's first LNG cargo vessel in 2003 and the first battery powered hybrid in 2016. (More on LNG later in this article). Eidesvic has partnered with Equinor to test the new propulsion solution with fuel cells running on emission-free ammonia. The companies are installing fuel cell modules with a total power of 2 MW. Other partners in the 5-year research project are Wärtsilä, who is supplying the power technology and systems for ammonia storage and distribution, Prototech, who is supplying the fuel cell system, and NCE Maritime CleanTech, which is coordinating the project with the European Union.

Viking Energy vessel. Image courtesy of Equinor

- **Amogy:** Amogy, a company that offers an ammonia cracking technology to enable ammonia to be used as a fuel, has recently demonstrated the *NH3 Kraken*, a carbon-free, ammonia-powered maritime vessel. Amogy provides carbon-free energy solutions to decarbonize hard-to-abate sectors like maritime shipping, as well as stationary power generation applications. Proven in real-world applications, its patented ammonia cracking technology appears to be a highly efficient method of splitting liquid ammonia and generating electrical power in combination with hydrogen fuel cells. The Kraken is a tugboat retrofitted with Amogy's ammonia-to-electrical power system. Originally built in 1957, the tugboat was initially powered by diesel generators and electric motors. The boat recently had its maiden voyage with the new fuel, sailing on a tributary of the Hudson River, upstream from New York City.

NH3 Kraken sailing on the Hudson River. Image courtesy of Supply Chain Brain

So there has clearly been significant progress in leveraging Green Ammonia as a maritime fuel, but there are still only a few ships on the seas fueled by ammonia – and only a few more known to on the way.

But there are other green fuels as well.

Methanol

Back in 2024 I posted an article about methanol, which included a discussion of the application of methanol to maritime transportation. The article noted that there are a variety of factors that make methanol a leading alternative maritime fuel choice. For example, because it is liquid at room temperatures it is much less costly to store and transport than gaseous fuels - and has the lowest carbon footprint of all liquid fuels. The article also pointed out that it can be used in both internal propulsion engines and to power fuel cells.

To date, the vast majority of methanol produced is generated from natural gas, which means it is not entirely free of greenhouse gas emissions. That being said, such "conventional" methanol reduces greenhouse gas emissions from combustion and is still cleaner than standard fuels, It can reduce Sulfur Oxides (SOx) and Particulate Matter (PM) emissions by more than 95%, and Nitrous Oxides (NOx) by up to 80% compared to conventional marine fuels.

However, *Green Methanol* is becoming much more common

Like the case with hydrogen, methanol is being classified according to the degree of sustainability of its production process. As with hydrogen, different "colors" are attributed to methanol based on that process, as described below.

As noted earlier, Green Hydrogen is generated through a chemical process known as electrolysis, which uses electric current generated by renewable sources to separate hydrogen from the oxygen in water. When the hydrogen is synthesized together with captured/recycled carbon dioxide – say from a biomass power plant after the pyrolysis process – the form of Green Methanol known as *e-methanol* can be distilled.

Green Methanol can really help the maritime industry meet the IMO's decarbonization goals. Since Green Methanol is chemically identical to conventional methanol, there are no compatibility issues or further engine investments required of shipping companies, allowing a seamless, gradual transition from conventional to Green Methane. Green Methanol is also compatible with current methanol dual-fuel engine technology.

Methanol also has a higher volumetric energy content than hydrogen and ammonia, making it a better choice for a wide range of vessel types and longer voyages, as it requires less frequent bunkering.

As a result of the above, the cost of converting diesel engines to methanol or dual-fuel vessels - and setting up land-based infrastructure to store and supply methanol - is significantly lower than other alternative fuels that require pressurization or cryogenics – like hydrogen.

Although ammonia can also be made from Green Hydrogen for use as a maritime fuel (or avoid hydrogen entirely as is done by several companies mentioned earlier), it is highly toxic and requires special storage. In contrast, methanol is biodegradable and therefore can be handled and stored much like gasoline, requiring fewer retrofits or infrastructure changes and making it much safer if it spills.

Interest in methanol as a marine fuel is rapidly growing, leading to commitments from some of the world's largest shipping companies to companies that offer methanol as a maritime fuel – such as ***Methanex***, which is the world's largest producer and distributor of methanol. Methanex has reported that 33 ships are now using their methanol. (Interestingly, they also note that 60% of these ships are dual-fuel). The Shanghai-based maritime company Cosco reported back in 2022 that it had ordered a dozen methanol-fueled ships.

And, since 2021 HD Hyundai has received orders for a total of 19 methanol-powered container ships from the major shipping line Maersk. Last year, Hyundai successfully delivered the world's first methanol-powered ultra-large container ship to Maersk. Maersk has also agreed to buy half a million tons of hydrogen-based and biogenic Green Methanol per year from Chinese wind farm Goldwind.

Methanol is currently available at more than 125 of the world's largest ports.

World's largest Methanol-powered Container Ship – operated by Maersk.
Image courtesy of Bloomberg News

Another interesting development related to methanol maritime fuel: in 2023 **Advent Technologies** released several *Serene Power Systems*, fuel cell-based battery units using methanol or biomethanol to power marine vessels. Advent intends to shortly add e-methanol.

Serene Power Systems can be used to replace conventional diesel generators. The system uses a compact battery and a small fuel cell configuration, which makes it appropriate for smaller vessels, including sailboats, ferries, and river vessels. For larger vessels, the systems may support auxiliary loads and supply shore power solutions for vessels at ports. Advent has stated that their product eliminates the need for deploying a heavy onboard battery

The Advent system operates at high temperatures, generating electricity while producing heat. The batteries also function effectively at extreme temperatures, from minus-60 degrees Fahrenheit to 122 degrees Fahrenheit.

In addition to the Serene Power Systems' ability to use green fuels and operate at extreme temperatures, Advent also notes other system benefits. For example, they point out that customers have the ability to customize systems to each vessel's specifications, and they require minimal maintenance once installed. The batteries also operate with little-to-no noise.

One Green Methanol hurdle is cost – it can be 3-4 times as expensive as diesel-based marine fuels. (The expected drop in the cost of Green Hydrogen will clearly help lower the cost of Green Methanol). The International Energy Agency (IEA) warned in a recent report, entitled *The Role of E-fuels in Decarbonizing Transport*, that methanol could be 25-100% more expensive than ammonia.

This is largely because of the need to provide captured CO_2 — from biogenic sources or direct air capture — to ensure that the Green Methanol produced is carbon-neutral over its lifetime. The IEA calculates that equivalently optimized plants, located on sites with high-quality renewable resources and low-cost biogenic CO_2, would produce low-emission e-methanol today at a cost of $47/GJ (gigajoule), compared to e-ammonia at $40/GJ - with these costs respectively falling to $35/GJ and $30/GJ respectfully by 2030.

But shipping companies appear to be opting for methanol over ammonia. A major reason for this is the cost of addressing safety. While both ammonia and methanol are hazardous chemicals, ammonia is toxic at much lower concentrations, necessitating extra costs for corrosion-resistant tanks and on-board safety measures which might include double piping and dedicated ventilation systems. So, while methanol is more expensive to produce, ammonia is more expensive to handle.

Furthermore, methanol is currently covered in the IMO's *Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel,* and engines capable of running on the fuel are already commercially available. (The IMO has not yet updated its guidance for ships using low-flash-point fuels or those carrying liquefied gases in bulk to allow for ammonia to be used as a fuel).

Source: Vessel Finder

The bottom line is that methanol appears to be ready to take off as a meaningful clean fuel for the maritime industry.

Ethanol

Ethanol is a renewable fuel made from various plant materials collectively known as “biomass”. It is generally produced from renewable sources like corn and other plant materials

Raízen, an integrated energy company with a broad portfolio of renewables, and ***Wärtsilä***, a global leader in power system technologies for marine and energy markets, signed a Decarbonization Agreement relating to the marine sector. By studying the effects of ethanol application as a marine fuel, the new initiative aims to reduce GHG and provide some novel options to shipping companies seeking sustainable fuel alternatives.

Wärtsilä, under its fleet decarbonization program, has been conducting technology tests with ethanol as a primary fuel in its Wärtsilä Sustainable Fuels engine laboratories. It has been supporting Raízen in discussions with ship designers and shipowners, and also on regulations and compliance requirements for the use of cellulosic ethanol as fuel.

According to Raizen, replacing diesel with sustainably produced ethanol in marine transportation can reduce CO_2 emissions by up to 80%.

Apparently, Maersk has started to look at ethanol as well.

Are There Other Alternative Maritime Fuels?

There are several other types of less polluting fuels that are being explored by shipping companies.

Hyundai and Maersk are also collaborating on joint research to examine the feasibility of the Solid Oxide Fuel Cell (SOFC) system. SOFC is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. The SOFC has a solid oxide or ceramic electrolyte.

Advantages of this class of fuel cells include high combined heat and power efficiency, long-term stability, fuel flexibility, low emissions, and relatively low cost. The largest disadvantage is the high operating temperature, which results in longer start-up times and mechanical and chemical compatibility issues.

And there are also other more standard fuels being adopted in the maritime industry. While definitely not a green fuel, **Liquified Natural Gas (LNG)** generates much fewer emissions than diesel fuel – including as much as 99% less sulfur oxide (SO_x), up to 90% less nitrogen oxide (NO_x), and 20-30% less carbon dioxide (CO_2). It is gaining popularity in the maritime industry. Interestingly, many modern LNG tankers use LNG as their fuel for ship propulsion and auxiliary power generation; these are often referred to as LNG-fueled LNG carriers. It has been estimated that there were over 2,400 LNG fueled ships at the end of 2024 with another 1,000 on order.

LNG is natural gas that has been cooled to -162°C (-260°F), turning it into a clear, odorless liquid that is easy to ship and store. LNG is typically 85–95% methane and also contains small amounts of ethane, propane, and other hydrocarbons. LNG as fuel for ships is generally produced from natural gas extracted from underground reserves, including both onshore and offshore gas fields.

LNG engines are quieter than diesel engines. However, LNG has a lower energy density than diesel, so using LNG as an alternative fuel for shipping requires more fuel and therefore larger fuel tanks to achieve the same range.

While LNG generates fewer emissions overall, it can release methane, which is a potent greenhouse gas. This "methane slip" can reduce some of the overall greenhouse gas emission gains. (Dual-fuel engines can significantly reduce methane slip)

BioLNG is LNG produced from biogas, which is generated from organic waste including food scraps, agricultural waste, sewage sludge and more. BioLNG is generally considered a renewable fuel and can further reduce the carbon footprint of ships. That being said, the production and combustion of BioLNG still emit some greenhouse gases.

Image source – Shell Global

And, finally, in addition to LNG, **Liquified Petroleum Gas (LPG)** is being used for maritime transport

LNG and LPG are both hydrocarbons, but they differ in composition, production, and storage. As noted earlier, LNG is primarily methane cooled to a liquid state, while LPG is a mixture of propane and butane and often a byproduct of natural gas processing or crude oil refining. LPG is highly flammable and composed of a mix of hydrocarbon gases but it's readily available around the world and is lauded as a clean, energy efficient and portable fuel with an affordable price tag. Major differences been LNG and LPG include the fact that light pressure is used to liquefy LPG, while LNG is liquefied cryogenically - through exposure to extremely low temperatures. In addition, while LPG is stored, shipped and transported in tanks or cylinders, LNG must be stored and shipped in purpose built cryogenic tanks. (Pipelines are usually used to transport LNG). The need for cryogenic storage, coupled with infrastructure requirements such as production plants, dispensing stations and pipeline transport facilities, make LNG not a much less viable option in developing nations.

What Other Approaches can Maritime Fleets Adopt to Reduce Energy Usage?

There are a variety of other things that maritime fleets are exploring as a way to reduce energy consumption, and hence emissions – particularly on ships that are operating with conventional fuels.

Maritime Navigation Systems

Maritime navigation systems can reduce fuel usage by analyzing weather conditions and expectations as well as sea conditions to determine the most fuel-efficient routes

HD Hyundai and Maersk plan to conduct a 6-month trial of Avikus' HiNAS (Hyundai intelligent Navigation Assistant System) - an advanced navigation solution intended to deliver more energy-efficient vessel operations - and HD Hyundai Marine Solution's OCEANWISE route optimization system. These are being installed on a Maersk container vessel built by HD Hyundai Heavy Industries. HiNAS Navigation shows navigation information in an augmented reality (AR) view. HiNAS Control provides autonomous navigation, maneuvering, and collision avoidance.

HINAS Navigation System – Image source Avikus

The purpose of the trial period is to validate the fuel-saving and GHG emission-reduction impacts of navigation systems.

There are a range of other maritime navigation systems on the market. Here are several of the companies and their products:

- **Wärtsilä – Navi-Planner:**
  Wartsila is a Finnish company, referenced earlier, which manufactures and services power sources and other equipment in the marine and energy markets. Their onboard system is designed for route planning, optimization, and monitoring – while also reducing crew workload.

- **Nautilus Labs** - **Voyage Optimizer**
  Nautilus Labs, which is based in New York City, describes itself as a deliverer of maritime decarbonization systems. This Voyage Optimizer is intended to optimize routes and speeds to reduce emissions – and enhance profitability.

- **ABB – Ship Performance Optimization System (SPOS):**
  ABB (Asea Brown Boveri) is a Swiss company focused on electrical and automation technologies, including robotics and power generation. SPOS is a decision support tool for onboard voyage optimization that uses weather forecasts, sea conditions, vessel profiles and advanced algorithms to make better-informed decisions that help optimize routes, reduce trip costs, and improve crew safety.

- **NAPA – Voyage Optimization**:
  NAPA is another Finnish-based company (with offices around the world) – that delivers maritime software and data services. Voyage Optimization offers weather-based routing and aims to optimize arrival times and achieve emission and cost reduction along with enhanced safety.

Cruise Ship Smart Rooms

Cruise ships are beginning to install smart room technologies, similar to those used in hotels, to reduce energy consumption and improve guest comfort. These technologies include temperature control, smart lighting, and automatic setting adjustments based on occupancy. Smart room technologies can also incorporate other energy-saving features, such as automatic blinds, smart curtains, and energy-efficient appliances.

Cruise ships are using smart thermostats and air conditioning systems that can be adjusted remotely or automatically based on guest preferences and room occupancy. Eco-mode settings automatically turn off heating or air conditioning when guests leave the cabin and return to pre-set levels when they return. Some systems learn guest preferences over time and automatically adjust the temperature and humidity accordingly.

Smart lighting systems allow guests to adjust lighting levels remotely. And lighting can be integrated with occupancy sensors to automatically turn off lights when no one is in the cabin – and back on when they return.

Some systems can also monitor energy usage in real-time and provide feedback to guests, encouraging more energy-conscious behavior.

Smart room technologies help cruise lines reduce their overall energy consumption, therefore lowering GHG emissions. They can also create a more comfortable and personalized guest experience by allowing guests to adjust lighting, temperature, and other settings to their individual preferences.

Cruise lines – including Virgin - have begun installing smart room technology – from multiple vendors. (Another transparency alert: a Hotel Smart Room Technology vendor that I am on the board of – CIRQ+ - is in discussions with a cruise ship company about piloting their technology).

Carbon Capture

One final approach to reducing emissions on ships is not aimed at reducing energy usage. Carbon Capture and Storage (CCS) technologies have been used by a variety of industries across the world for years. Now there are CCS products being offered that can capture CO_2 from a vessel's exhaust for future use or safe storage.

Shoreside CCS involves the capture of carbon emissions from industrial processes, such as steel and cement production, or from the burning of fossil fuels in power generation. This carbon is then transported from where it was produced, via ship or in a pipeline, and stored deep underground.

The same technology is now being applied to reduce the carbon footprint of ships operating on fossil fuels. For example, back in 2022 Value Maritime's *Filtree* system was installed on two of **Eastern Pacific Shipping's** ships – Pacific Cobalt and Pacific Gold. These are the largest ocean vessels to be fitted with carbon capture technology to-date.

The Filtree system is connected directly to the exhaust and is designed for small to medium sized vessels. The technology allows vessels to capture up to 40% of CO_2 emissions, with the potential of exceeding 90% in the future. The technology does not liquefy the gas – it uses a CO_2 absorber (monoethanolamine). The solvent mixture is stored in tank containers that can be offloaded in port or kept in onboard tanks for pumping ashore. Value Maritime takes responsibility for extracting and liquefying the CO_2 which can be used for a variety of purposes, such as fertilizer or biodiesel production.

There are potentially three types of CO_2 capture systems for the maritime industry: post-combustion, pre-combustion, and oxyfuel combustion. Oxy-fuel and pre-combustion remove carbon from the fuel before use. These systems typically require complete engine redesign, because they need to be integrated into a fuel supply and power generation system of a vessel. They are costly and time-consuming and therefore may therefore be less suitable for the shipping industry.

The post-combustion process captures CO_2 from flue gas produced *after* combustion and can be added to traditional engine design without the need for large changes. Value Maritime's Filtree is an example of this method, making CCS technology less costly and more attractive for ship owners.

Once carbon is captured by CCS technology the CO_2 needs to be stored. Vessels are limited by space and power, making storage and liquification an issue. At present vessels need to make frequent stops to offload the CO_2.

(Final transparency alert: another company I am on the board of – RainIons – has developed a set of materials and coating that breaks up all greenhouse gas emissions – CO2, NOx, SOx, and more – from transport and industrial exhausts, dramatically reducing emission levels. This is not the same as carbon capture, and there is no need to store the CO2. The company just started a pilot with a trucking fleet and is in discussions about testing out the technology on a ship).

There are, of course, safety issues associated with the discharge of carbon dioxide from vessels which will need to be carefully managed. The industry has experience in offloading other hazardous materials from vessels. Updating mandatory regulations for the handling of CO_2 and other hazardous materials will be the key to ensuring best practice when it comes to the lifecycle of captured carbon.

So, What is the Future of Emissions in the Maritime Industry?

The shift to a more sustainable maritime industry is still in the very early stages, but there are clearly a slew of options that shipping lines can take to avoid being charged by the new IMO fee program. This includes a wide range of options for replacing the fossil fuels that power virtually all ships, along with a number of other approaches to reducing energy consumption on board the vessels or capturing the carbon. This wide range of options – along with the IMO's intentions of trying to help make things happen – should enable shipping companies to move relatively quickly towards a maritime future with significantly fewer emissions.