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Maritime Decarbonization

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ABSTRACT

With increasing globalization and industrialization, world trade is experiencing significant growth. The maritime industry is the backbone of global trade, but it is a significant contributor to GHG emissions. This research paper delves into the negative impacts of the maritime industry on our environment, focusing on Heavy Fuel Oils (HFO's), which emit large quantities of CO2, exploring the alternatives to these fuels such as Ammonia, Hydrogen, LNG's etc. The study includes a case study of a company dominating market share in the maritime industry (Maersk) and another company which is a startup that has adopted environmentally friendly practices to achieve sustainability. Moreover, key obstacles such as fuel maturity, costs, technological limitations are examined and policies implemented by the international organizations and steps taken by the Indian government are also considered.

Keywords: *Decarbonization, Maritime, Sustainability*

1. INTRODUCTION

The oceans and seas cover more than two-thirds of the Earth's surface, serving as a highway for global trade, a source of food and minerals, a generator of oxygen and a sink for greenhouse gasses. The maritime industry is the backbone of global trade, with the international shipping sector responsible for the carriage of around 90% of world trade. The International Maritime Organization (IMO) is a specialized agency appointed by the UN, working with the responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. It predicts that maritime trade could increase between 40% and 115% by 2050 compared to 2020 levels. Despite the potential advantages associated with increased global trade such as significant economic growth, increased revenues, better quality goods, and increased employment, the expansion has a considerable tradeoff of environmental exacerbation, increased greenhouse gasses emissions, and greater strain on our ecosystem.

As the world struggles with the above mentioned issues, it is imperative that the maritime sector works towards the reduction of greenhouse gas emissions.

This study investigates current policies which work towards addressing such problems as well as assessing the sustainability approaches taken by big and small companies through the help of case studies.

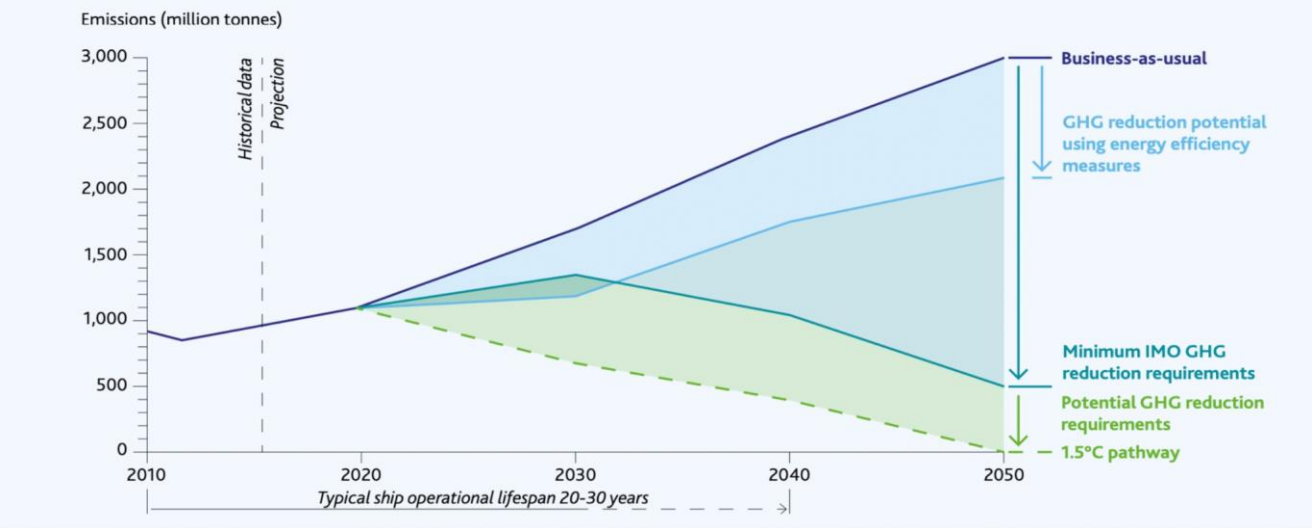
The importance of these policies is underscored by their potential to reduce environmental degradation by improving air quality, lower CO_2 emissions and protecting marine and human ecosystems. Lastly, the paper also focuses on how India is planning to encounter the unfavorable outcomes that the carbon emissions have and providing strategic recommendations.

This research delves into the significance of encouraging action to revolutionize the maritime industry and to review the present and future policies. As the world struggles with the above mentioned issues, it is imperative that the maritime sector works towards the reduction of greenhouse gas emissions. This study investigates current policies which work towards addressing such problems as well as assessing the sustainability approaches taken by big and small companies through the help of case studies. The importance of these policies is underscored by their potential to reduce environmental degradation by improving air quality, lower CO_2 emissions and protecting marine and human ecosystems. Lastly, the paper also focuses on how India is planning to encounter the unfavorable outcomes that the carbon emissions have and providing strategic recommendations.

2. ENVIRONMENTAL IMPACT

With a substantial increase in maritime trade, fuel demand is estimated to triple, resulting in a threefold increase in GHG emissions (from 31000 tonnes of CO_2 to 91000 tonnes of CO_2) by 2030. Ships use heavy fuel oil (HFO) which emits large quantities of carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter. Shipping is responsible for approximately 3% of global CO_2 emissions.

Figure ***1***



The aim to reduce GHG emissions by at least 50% by 2050 is not completely aligned with the Paris Agreement which focuses on bringing down temperatures below 2°C. Emissions of sulfur and nitrogen oxides are a contributing factor to ocean acidification. Acid rain, which is primarily composed of nitric acid and sulfuric acid, is caused by emissions which are produced when heavy fuel oils are burned during shipping. Acid rain has numerous disadvantages attached to it such as forest damage, soil degradation, crop damage and a myriad of health problems. IMO has reduced the allowable sulfur content in ship fuel, which has led to a reduction in sulfur emissions. Nonetheless, the sulfur content being produced is extremely high and therefore causes 150,000 deaths a year (13% of which is attributed to the maritime industry.)

The combustion of HFO leads to the production of primary and secondary particulate matter which is directly related to health issues such as cardiovascular and respiratory diseases.

Greenhouse Gas emissions such as CO_2, methane and soot and black carbon and other pollutants are a significant contributor to global warming. These compounds lead to increased absorption of sunlight and heat, accelerating the melting of ice caps and therefore leading to Arctic warming.

Warmer waters also lead to coral bleaching, disruption in ocean currents and food chains.

3. THE CHALLENGES OF DECARBONIZING THE SHIPPING INDUSTRY

Shipping decarbonisation faces numerous challenges. Some of these include high initial costs, limited infrastructure, technological readiness, international waters and energy density limitations.

i. **High Initial Costs:** Many shipping companies find it difficult to adopt new technologies as they often lead to higher costs of production which leads to a reduction in their supply.

ii. **Limited Infrastructure:** One of the major obstacles faced by shipping companies is the lack of infrastructure for alternative fuels such as LNG and hydrogen refueling stations. Many governments do not prioritize maritime decarbonisation, therefore reducing the provision of subsidies to important matters, such as this.

iii. **Technological Readiness**: Numerous decarbonisation strategies such as wind-assisted propulsion are still in pilot stages, making them unavailable for use at larger scales.

iv. **International Waters:** International waters are beyond the jurisdiction of one particular nation. This means that countries may have different regulations ranging from strict limits to lenient regulations.

v. **Energy Density Limitations:** Alternate fuels have varying energy density limitations which can cause problems. For instance, LNG has a lower energy density than HFO which impacts the vessel's range and efficiency.

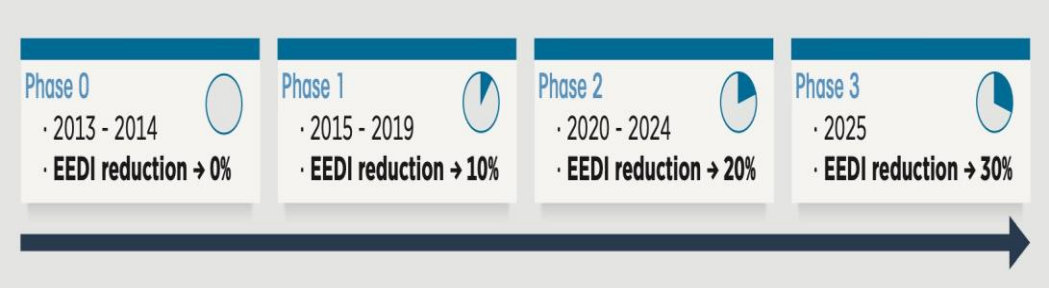
4. INNOVATIONS TO DECARBONIZE SHIPPING

In order to address the environmental impacts of the marine fuels that have been in circulation, International organizations like the IMO and UN alongside national governments are establishing strict policies and regulations. IMO is a specialized agency of the United Nations responsible for regulating maritime transport. Although it has received widespread criticism for its inactions, over the past few decades it has worked on various aspects of the industry.

1. In July 2023, the IMO revised their 2018 policy and set a target of achieving net zero carbon emissions by 2050. The new strategy aims to reduce 20-30% CO_2 emissions by 2030 and 70-80% CO_2 emissions by 2040, in comparison to the old strategy which aims to reduce total GHG emissions by 50% by 2050.
2. The 2023 IMO GHG strategy looked into the measure of global fuel standards as a technical element to reduce marine fuels GHG intensity. Global fuel standards are regulations which control the type and quality of fuels used in the maritime industry. It encourages the adoption of new renewable fuels such as ammonia, bio-fuels etc. This innovation increases confidence among investors, pushing the industry towards the development of a sustainable market.
3. The IMO has implemented 4 energy efficiency mandates which focus on improving energy efficiency across all vessels. These include EEDI (Energy Efficiency Design Index), EEXI (Energy Efficiency Existing Ship Index), SEEMP (Ship Energy Efficiency Management Plan), and EEOI (Energy Efficiency Operational Indicator).

EEDI: The EEDI was mandated by the IMO in 2011 and works towards the promotion of more energy efficient engines in order to decrease GHG emissions. It calculates a vessel's energy efficiency, which is measured in grams (g) of CO_2 per tonne-mile. In order to meet the EEDI requirements, ships need to have optimized engines, components and engine systems.

Figure 8 showcases the EEDI phases, implementation periods and reduction targets.



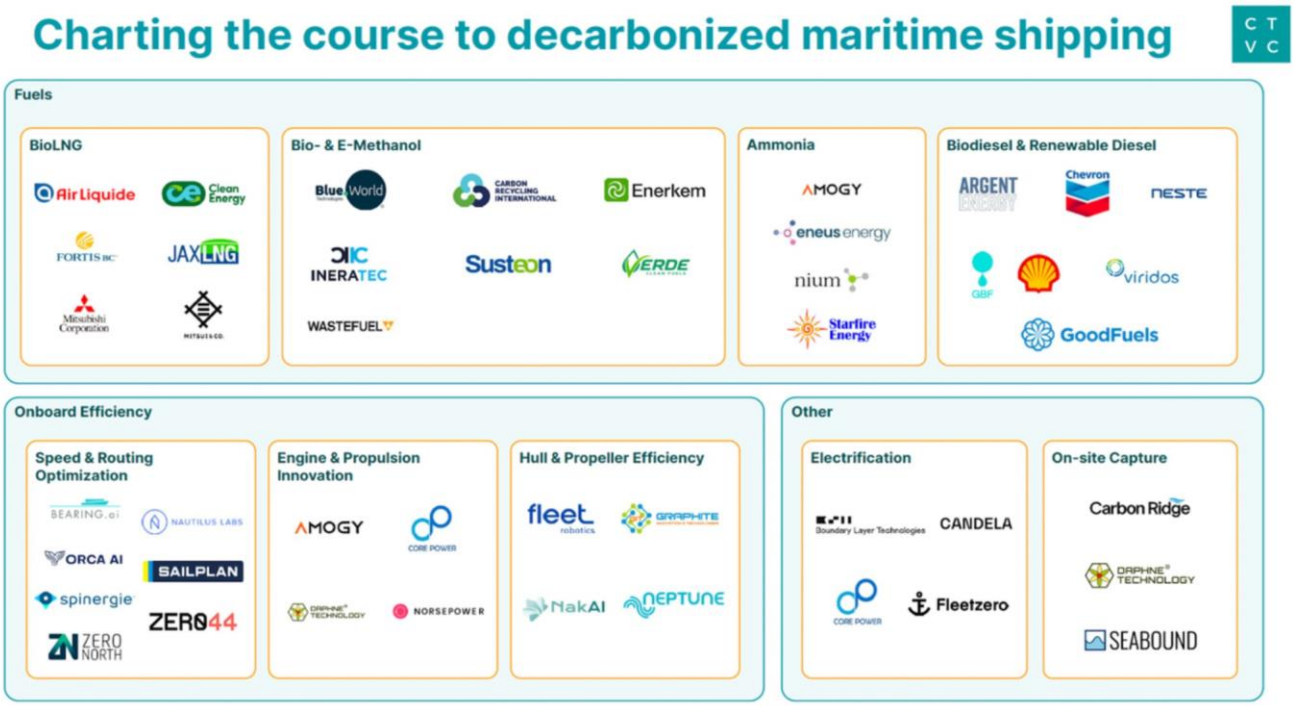
- **EEXI**: The EEXI mandate was proposed to the IMO by Japan in 2019. It was adopted by the IMO in 2021 and it aims to improve the energy efficiency in vessels through a technical approach wherein an index is created which compares the EE of the ship when it was developed to the baseline EE which has to be achieved. This mandate is an extension to EEDI.
- **SEEMP**: The SEEMP mandate works towards improving the energy efficiency of a vessel in a cost effective manner. It comprises three main operations to achieve its goals. Part 1: ship management plan to improve energy efficiency; Part 2: Fuel oil consumption data; Part 3: Ship operational carbon intensity plan.
- **EEOI**: EEOI is a mandate which measures the operational efficiency of a vessel.

Its purpose is to evaluate the environmental performance of vessels and encourage shipowners to adopt energy sources that produce less CO_2 emissions.

Efforts are also being made to research alternative fuels like hydrogen and green-methanol and innovative technological solutions which work towards lessening environmental degradation. Furthermore, considerable work is being done to optimize operations to cut down costs and increase efficiency, for instance how Maersk is decarbonising their terminals, executing electrification initiatives, like battery powered ships or hybrid vessels, and improving software systems to enhance logistics.

The figure below illustrates large companies like Shell, Chevron and Mitsibishi along with smaller companies and startups that are researching and developing products to overcome the carbon emissions produced by traditionals fuels used in the marine sector and progress towards climate change. Companies are not just looking into the fuel sector but also ways to increase onboard efficiency by focusing on factors such as speed and routing optimization, engine and propulsion innovation and hull and propeller efficiency.

Figure showcases startups and other companies looking into marine decarbonisation



5. ALTERNATE FUELS

Fuel is the largest expense for a shipping journey, making up 30-50% of a vessel's operating costs. Fuels used by marine vessels are known as bunker fuels. Those commonly used today are typically produced by refining crude oil. According to Mærsk Mc-Kinney Møller's Center for Zero Carbon Shipping (CZCS), alternative fuels have the disproportionate potential to reduce the entire industry's GHG emissions by over 80%. In maritime, alternative fuel pathways are really a suite of new technologies (such as engines) and ways of producing molecules (such as bio-methanol). Heavy Fuel Oils (HFO's), as mentioned before, are the workhouse of the maritime industry. HFO's have serious drawbacks despite their low costs. They contribute to a significant portion of the greenhouse gasses emitted causing acid rain, pollution and also pose serious health risks towards the marine and human ecosystem. The IMO has implemented several strategies such as the 2023 IMO GHG strategy which aims to reduce the emissions from international shipping. The Paris agreement is an international treaty which was adopted in 2015, providing a framework which works towards combating climate change by limiting global warming below 2°C. Both of these policies along with a myriad of other mandates influence the shipping industry to work towards finding alternative fuels. These fuels include LNG, Bio-fuels, hydrogen, ammonia and green-methanol.

Table 1 summarizing information about alternative fuels

FACTORS	LNG	BIOFUELS	HYDROGEN	AMMONIA	GREEN-METHANOL
Fuel Maturity 	Mature	Moderately Mature	Moderately Mature	Less mature	Less mature
Engine Maturity 	Highly mature	Mature	Advancing	Emerging	Mature and evolving
Availability at scale 	Commercially ready	Commercially ready	Limited availability for the marine sector	Commercially ready	Limited availability
Ease of Adoption 	Easily adopted due to established technology and regulatory incentives.	Can be easily integrated into current engines and can be used as a drop-in fuel.	Slightly challenging to use in areas like marine transport.	Easily adopted as used in the fertilizer industry as well.	Can be adopted
Emissions Impact 	Reduces emissions in the short term	Reduces emissions in the long term impact	Reduces emissions in the long term impact	Reduces emissions in the long term impact	Reduces emissions in the long term impact

Guide into few of terms in the table:

-Fuel maturity refers to how readily available and applicable a particular fuel is to be used in the world of commercial shipping
-Engine maturity refers to how developed and reliable the engine is for the usage of new fuels

6. LNG

LNG or otherwise known as liquified natural gas is produced by purifying natural gas and super-cooling it to -260°F to turn it into liquid. With the implementation of the sulfur cap scheme by IMO, LNG has gained momentum in recent years where important infrastructure developments have been completed.

Engine maturity refers to the degree of advancement, dependability and widespread adoption of engines designed to run on particular fuels in the maritime sector. In the case of LNG, it is highly mature, with intensive use in the industry due to its increased availability in recent years.

Dual fuel engines can operate on LNG with ease and have been adopted by numerous shipping companies. Companies like 'Wärtsilä and MAN Energy Solutions' have worked towards the adoption of LNG systems.

LNG helps significantly reduce the sulfur and nitrogen oxides emissions and also reduces the particulate matter emissions which help diminish the air quality degradation. The change of HFO to LNG guarantees an immediate carbon reduction of 21% on a well to wake basis. LNG already has a well-established infrastructure, with a robust global bunkering network and significant investments.

Since it is a liquid, it does not take up too much space, making it easier to transport.

With the global infrastructure for the use of LNG as a marine fuel expanding rapidly, there are no apparent issues with its scalability. As of 2023, there are 50 LNG bunker vessels in operation globally, with about 34 more to be included in the upcoming years. There is increased technological innovation with research focus on the integration of LNG with other renewable sources such as bio-LNG to work towards the further reduction of carbon emissions.

Despite its advantages, there are certain drawbacks associated with this alternate fuel. As a liquid, it vaporizes quickly if exposed to air. This increases the risk of vapor cloud explosion in ships. Essentially, this means that when LNG is exposed into the air, it turns into gas which when exposed to fire can explode, making it potentially dangerous on ships.

Another key risk in LNG facilities is the uncontrolled release of harmful, flammable or cryogenic fluid. Furthermore, there are significant economic costs attached to the use of LNG as an alternative fuel.

As part of the infrastructure itself the bunkering facilities and specialized equipment are quite costly. Although the price per unit of LNG is higher than the cost of traditional marine fuels, it can be overcome with operational efficiency and a stable supply of LNG.

7. BIO-FUELS

Biofuels are renewable fuels which are produced by the conversion of biomass and biogas from anaerobic decomposition of wastes. They are derived from natural, organic materials such as plant and animal waste and work towards the reduction of greenhouse gasses and reliance on non-renewable resources.

Similar to LNG, Bio fuels do have an established infrastructure due to its use in other sectors such as heating, aviation, road vehicles etc and are easily accessible. Since they are produced from diverse feedstocks such as corn, sugarcase, parm, rapeseed and cereals, there is a steady supply of input.

Biofuels can be easily integrated into current engines and can be used as a drop-in fuel. Unlike other fuel options, they also reduce the risks of environmental contamination and the amount of greenhouse gasses in comparison to fossil fuels.

The main issue that arises with the use of biofuels is that it becomes important to ensure that the resources being used to produce biofuels do not impact food security and land availability, Especially in developing countries. Biofuel production also involves excessive usage of water, along with high emissions of nitrogen oxides during their production

Many countries around the world have increased research and development on biofuels, increasing prospects for innovation and increased sustainability. Such R&D is supported by the Governments through support and incentives such as subsidies and grants

Biofuels may offer long term infrastructure, operational and regulatory costs, in the short run it is more costly than other fuels like LNG.

8. HYDROGEN

Hydrogen, using different technologies like fuel cells and internal combustion engines can be used as a shipping fuel. The fuel cells work by converting hydrogen in electricity by combining it with oxygen in an electrochemical reaction which produces heat and water as its by-products. Employing green H_2 as a fuel source for shipping will lead to almost zero carbon emissions. This process of electrolysis emits no CO_2, making it a clean fuel option in the maritime industry.

Hydrogen is a sustainable and non-exhaustible resource. Its availability causes no issue as hydrogen is the most abundant element in the universe. The potential for using hydrogen as a fuel has increased as there are increased advancements in research and development. Hydrogen fuel cell technology is transitioning from the planning stage to the deployment phase. The world's first hydrogen power ship by Toyota makes use of solar wind and wave generated power alongside hydrogen produced using the sea water. An example of this is that researchers from the University of science and technology in China have developed a less costly catalyst which is used as a material in the production of hydrogen in the electrolysis process.

MF Hydra is the world's first liquid hydrogen powered ferry which is equipped with 'Ballard's fuel cell modules.'

Looking into the disadvantages of hydrogen as a fuel, its production and storage is costly, requiring cryogenic storage. Hydrogen also has a low volumetric density, making it hard to compress and thus creating a requirement for a large amount of space. This would mean that ships would need to allocate a greater amount of space for storage, therefore reducing the cargo capacity and also increasing the storage costs. Additionally, the operational costs would increase as the handling of hydrogen would require maintained and skilled workers.

Lastly, hydrogen is a highly inflammable substance and explosive in nature. This means that the transportation process becomes a big hassle requiring increased upkeep as fires and explosions can happen if not handled properly.

9. AMMONIA

Ammonia has been produced in a safe and scalable manner for over a century through the Haber Bosch process wherein nitrogen and hydrogen are combined under a high pressure and suitable temperature to produce ammonia under the presence of a catalyst.

As there is no carbon atom in the production of ammonia, there are no CO_2 emissions which reduce the amount of greenhouse gasses produced when the fuel is burnt.

With ammonia being used in the fertilizer industry already, adoption of it as a fuel in the maritime industry does not pose too many problems. Furthermore, it can be used on a large scale in the long term since the cost of renewable energy is gradually decreasing.

The cost of implementation for ammonia is not significant either since the Haber process is efficient and scalable. The process requires less energy than methanol or e-methane in comparison, reducing the operational and production costs.
There are numerous safety concerns attached with the use of ammonia as a marine fuel. It is highly toxic which requires proper care and maintenance and appropriate standards and protocols to be set. It is also flammable and corrosive.
Although there is scope for innovation, there are significant research and development costs required to advance forward with ammonia technology. Most of the technology for ammonia powered engines is in the early phase, nonetheless, as of 2024 there are some ammonia-powered ships such as the Green Pioneer and the Yard Eyde.

10. METHANOL

Methanol is produced by steam-reforming natural gas. There are three different types of methanol; gray, blue and green. Gray methanol (what we typically call methanol) is not a clean or renewable energy source. Blue methanol is also produced using natural gas captures and stores the carbon produced during the process, making it a less polluting fuel. Green methanol is produced using low carbon and renewable energy sources, making it more environmentally friendly than methanol itself.
Green methanol has a much reduced carbon footprint which helps further reduce the GHG emissions. It contributes to improved air quality and plays a pivotal role in achieving maritime decarbonisation.
Green methanol can be adjusted easily within the existing engines, making the transition process easier and ensuring that the infrastructure costs remain low. Since green methanol can be adapted to the existing infrastructure, its production can be scaled up to meet the growing global demand. Government bodies and international organizations are increasingly opting and influencing the use of green methanol as an alternative fuel to HFO.
Green-methanol ships have already been introduced to the world., with Ana Maersk by the company Maersk being the first one. Project Air, which is an initiative in Sweden, is expected to bring down the GHG emissions by 123% compared to the conventional method of using gray methanol.
Methanol production does have safety risks since methanol is toxic, leading to possible health risks. It is also flammable which requires strict fire suppressions systems and overall protocols and standards to be set to mitigate any risks. Finally, green methanol has a low energy density, similar to hydrogen, which requires greater fuel tanks which take up more space and thus decrease operational efficiency.

11. CASE STUDY 1: MAERSK

Maersk, established in 1904, is an integrated container logistics company operating in 130 countries. It is a major player and a highly influential big time company in the maritime industry which is known for its extensive operations and strategies to expand its market state. Its activities include shipping, port operation, supply chain management and warehousing.
Maersk reported an impressive revenue of $51.5bn USD in 2023, underscoring the company's substantial scale. It also has a total market share of 17%, equivalent to MSC's (Mediterranean Shipping Company) market share.

Figure 2 represents the market shares of of shipping companies in 2024

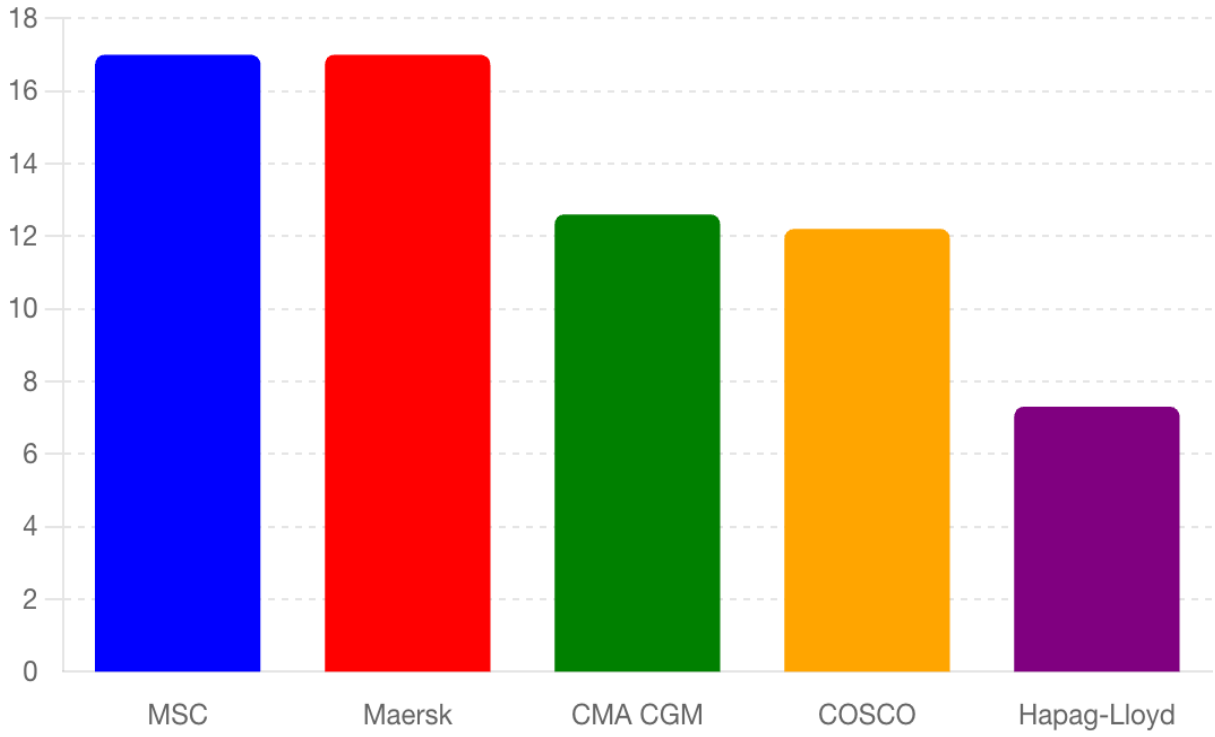
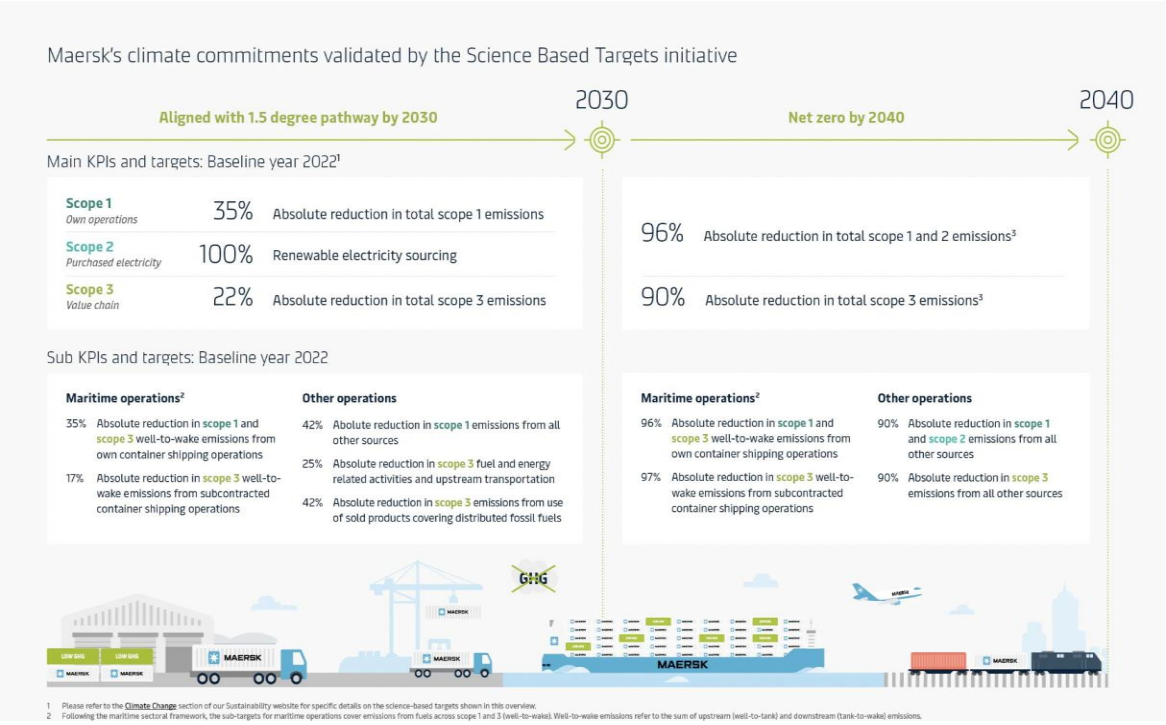


Figure 3 is a pictorial representations of the upcoming plans of Maersk

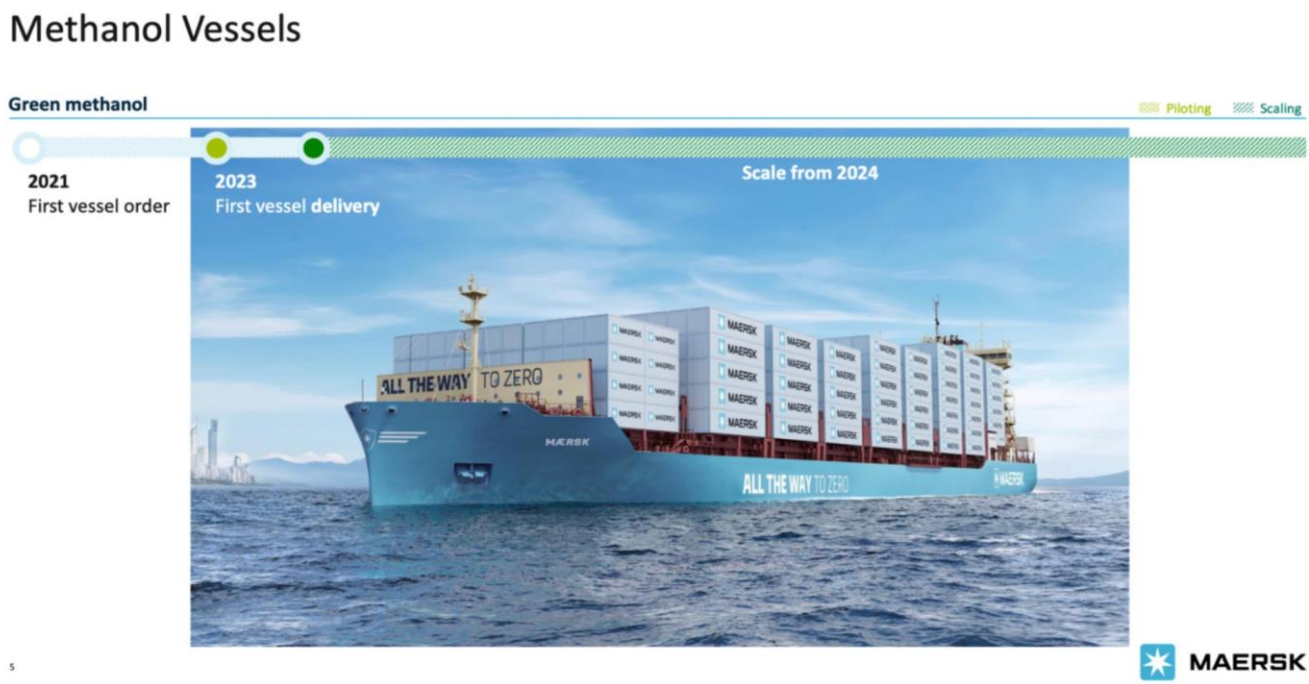


As a world leader in shipping, Maersk has implemented a strategy of achieving net-zero CO_2 emissions by 2050 and therefore complying with the IMO's regulations.

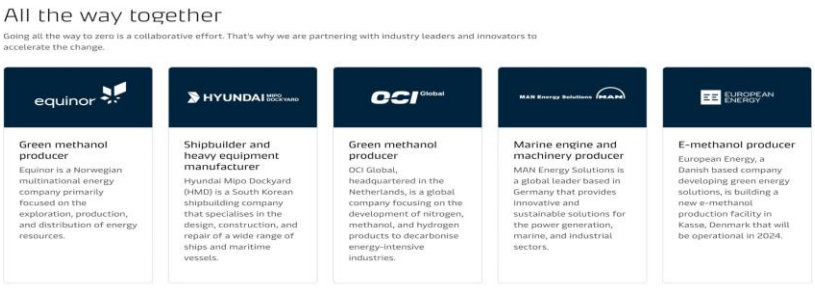
Maersk's unique selling propositions include its move towards vertical integration, its leadership in the aspect of sustainability and inclined focus towards technological innovation. It is working towards designing carbon neutral vessels, building carbon neutral products, driving innovation in new fuels and pushing for regulatory frameworks.This strong commitment to sustainability and research and development is likely to ensure a larger market share in the long term.

Maerks fleet comprises a total 740 ships, including Triple E Class, E Class, Edinburgh Class, Handysize Tankers and the recently included Methanol-Enabled Vessels. Maersk's Eco Delivery initiative aims to offer customers with sustainable shipping solutions by replacing the traditional fuels that produce GHG emissions with cleaner fuel options such as biodiesel and green methanol. Maersk has signed a large-scale offtake agreement for green methanol, securing 500,000 tonnes annually starting in 2026.

Figure 4 showcases Methanol-Enabled Vessel Timeline



Figures 5 and 6 represent the partnerships Maersk has agreed upon to switch to greener fuels



Maersk's commitment to achieving sustainability measures is also reinforced by their collaboration of the LEO forum with other companies. Collaborations with major companies such as H&M in the fashion industry and BMW in the automobile industry underline the commercial benefits of their green initiatives.

Maersk has also added the 'Ana Maersk' and 'Laura Maersk' into their fleet collection. Both these vessels, along with the 16 others as part of their 18 large green methanol-enabled vessels that will be delivered between 2024 and 2025, In 2021 Maersk emitted a total of 33 million tons of CO_2. These new additions will contribute to the removal of 3% (1 million tons) of CO2 from their fleets.

Figure 7 showcases the newly introduced green-methanol powered vessels

In order to continue on this pathway towards maritime decarbonisation, Maersk has an immediate target of reducing emissions by a significant amount by 2030, alongside its original plans of achieving net zero emissions by 2050. Furthermore, with the introduction of the two new vessels Ana Maersk and Laura Maersk, the company hopes to modernize their entire upcoming fleet with vessels that solely work on green-methanol. It has also created a seed investment with C2X, an independent company that will provide resources to own and operate assets to produce green-methanol at scale. It has also entered into a partnership with Ørsted to upscale their production of green fuels, particularly green-methanol. Furthermore, they also aim to work with institutions and industry partners in the research and development area in order to advance their development and innovation in the maritime sector. Ultimately, their strategies like fleet modernisation, increased innovation, decarbonisation of terminals and logistics and services to reduce inland emissions, operational efficiency and regulatory frameworks help strengthen Maerks position in the market as well as guide them towards a leading role in maritime decarbonisation, becoming a model for sustainability.

12. CASE STUDY 2: STARFIRE ENERGY

Starfire Energy was founded in 2007 with an aim to focus on solar energy systems. However, in 2016, they shifted their focus on developing patented technology for the clean synthesis and use of ammonia. They scale up technologies to make and use carbon-free ammonia fuel.

Starfire Energy was founded by Joe Beach (CEO) who has an and Jennifer Beach. an M.S. and Ph.D. in Applied Physics from the University of Alaska andJennifer Beach(COO)who has a Master of Science degree in technology management.

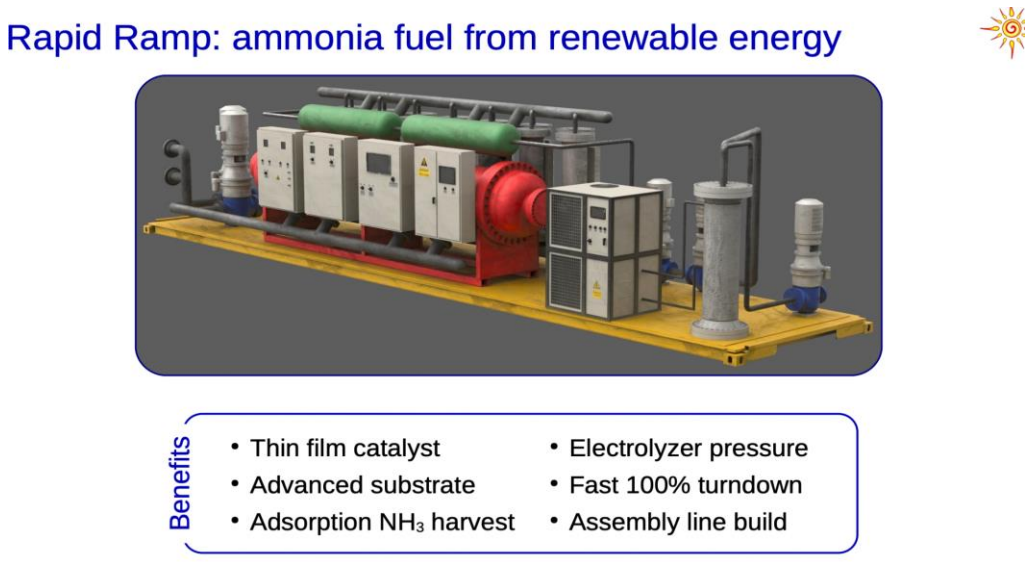
Figure 9 is a comparison between the competitors of Starfire Energy

	Starfire Energy	Avina Clean Hydrogen	Ammpower	Tsubame BHB
Description	Developer modular systems to produce carbon-free NH3	Green Hydrogen and Ammonia production	Manufacturer of batteries	Manufacturer of ammonia and its related products
Founded Year	2007	2022	2019	2017
Location	Denver (United States)	New York City (United States)	Vancouver (Canada)	Tokyo (Japan)
Company Stage	Series B	Series A	Public	Series C
Unicorn Rating	Minicorn	Minicorn	-	-
Total Funding	$39.6M	$10M	-	$35.3M
Funding Rounds	9	1	2	2
Latest Round	Series B, $3.03M, Dec 28, 2023	Series A, $10M, Nov 09, 2022	Post IPO, $1.1M, Sep 26, 2022	Series C, $35.3M, Feb 21, 2024
Investor Count	15	-	-	15
Top Investors	Chevron, Greentown Labs & 13 others	-	-	Mitsubishi UFJ Capital, Energy & Environment Investment & 13 others

Starfire Energy has raised about $39.6M of venture capital funding till date. Their investors include Samsung Ventures, Mitsui O.S.K, AP Ventures, Chevron Technology Ventures amongst others. The CEO of MOL Switch, which is an US based investment arm of Mitsui O.S.K. Lines, Tomoaki Ichida, commented that “Ammonia is a leading candidate for next-gen marine fuel, but more investments should be made into technologies to build a cost-effective and robust supply chain. This investment aligns with our focus, and we believe this technology will make green ammonia more affordable and available.”

With increased scope to enter the maritime industry with alternative fuel ideas, Starfire Energy carbon free-ammonia can play a huge role in achieving the policy of net zero carbon emissions by 2050. Starfire Energy’s Rapid Ramp NH_3 system is a variable-rate ammonia production process which is engineered into a modular plan design. This modular and scalable technology uses renewable energy sources to produce ammonia.

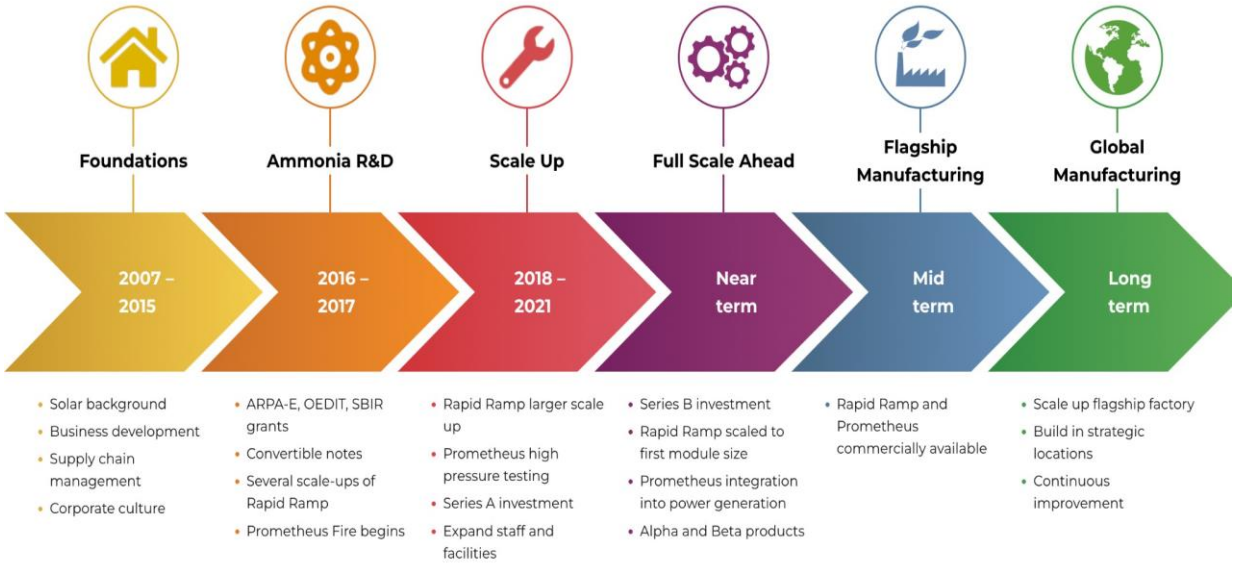
Figure 10 illustrates the Rapid Ramp NH3 technology system and its advantages



The systems use nitrogen from air and hydrogen by splitting water, wherein the reaction takes place under high pressure and temperature, facilitated by a catalyst. The traditional Haber process relies on natural gas whereas Rapid Ramp NH_3 makes use of renewable energy sources. The electrolysis process of splitting water to get hydrogen and oxygen does not directly produce any CO_2 emissions. The plants are built in modular shipping containers which help ensure ease of adoption and interconnection on the sites.

This reduces the overall cost of implementation while also allowing for incremental scaling.
Starfire Energy also uses Prometheus Hydrogen to crack ammonia back to nitrogen and hydrogen for fuel cell applications. This process is essential for utilizing ammonia as a hydrogen carrier. This is useful in several aspects as ammonia has a higher energy density, making it easier to transport on ships. It can also be installed on ships directly which ensures a continuous supply of the fuel on the ship. The hydrogen which is produced using the cracking process is then fed into the fuel cells which generate electricity to power the ships propulsions without producing any GHG emissions.

Figure 11 is the roadmap for further progress for Starfire Energy



In early 2024, Starfire Energy announced a major collaborative agreement with one of the largest manufacturing companies in the world and one of the leading engineering companies driving EPC projects for ammonia in Asia. This would accelerate new green ammonia project identification in the region.

13. GLOBAL POLICIES TO FIGHT AGAINST CLIMATE CHANGE

The Paris Agreement is a legally binding treaty which was established on 4th November 2016. The agreement works towards reducing greenhouse gas emissions in order to bring down temperatures below 2°C and even pursue efforts to limit it to 1.5°C above pre-industrial levels. It periodically assesses the progress towards achieving this goal in the long term and provides finance to developing countries in order to mitigate climate change. This is encouraging countries to look into carbon free fuels which aligns with the IMO's strategies of maritime decarbonisation.
Carbon pricing reduces greenhouse gas emissions by putting a fee on the amount of carbon emitted. This has the effect of shifting the burden that the public has to pay towards the producers/shipping companies to reduce the amount of pollution they create by switching to less pollutive energy/alternative energy sources. An emission trading systems (ETS) cap exists which defines the maximum amount of greenhouse gasses that can be emitted under the system.

14. OTHER INITIATIVES

Alongside the implementation of policies, there are a significant number of emerging software systems that are also focused on maritime decarbonisation.

- An emission tracking software was launched by Yxney maritime which makes it possible to plan initiatives which are helpful in reducing emissions in particular vessels. The application also measures the current and future emission trajectories which can be used to improve the ships overall performance and efficiency.
- ShipManager is a marine fleet management software and ship management system. Systems like these are responsible for collecting all types of data regarding the vessel such as its performance, fuel consumption, efficiency, carbon emissions etc. The collected data can be analyzed to identify where electrification is needed and how shipowners and companies can optimize energy efficiency for their vessels.
- Maress is a digital management system for data-driven decarbonisation. Similar to 'ship manager', it is a leading provider of maritime communication and digital solutions for increased emissions. It offers various services such as Fuel Quality Testing, Bunker Quantity Surveys, Oil Condition Monitoring and Transformer Oil Testing. The system can integrate various decarbonisation technologies such as alternative fuels, energy efficient devices and hybrid propulsion systems.

15. INDIA'S POLICIES

With several countries taking steps to work towards maritime decarbonisation and a sustainable lifestyle, we will now look into the policies and initiatives taken up by India. India has been gradually increasing its focus on maritime decarbonisation and is working towards reducing GHG emissions and thus bringing about climate change.

1. India, as a member state of the IMO, is also instructed upon adhering to their net zero carbon emission by 2050 initiative. India is committed to reduce these GHG emissions, adhering to the IMO's global strategy

2. The government has implemented various initiatives like the Sagarmala Programme, National Waterways Act, and Inland Vessels Bill to develop the waterways sector and enable a modal shift. The National Waterways act supports the use of cleaner fuels by providing a regulatory framework which encourages the implementation of eco-friendly technologies. The national waterways act and the inland vessels bill, together, support the transition to LNG as a cleaner alternative to current heavy oil fuels (HFO's) for cargos.

3. With an increased growth witnessed in the marine decarbonisation sector globally, India has been seen to be making movements as well. The investments in renewable energy will help to pave the way towards a clean energy sector as they have substantially increased from nearly $9 billion in 2023 to $16.5 billion in 2024.

4. The National Maritime Perspective Plan (NMPP) aims to reduce logistics costs and develop a sustainable maritime infrastructure and promote greener practices. There are also Green Port initiatives which encourage sustainability in port operations.

India has significant potential to research and innovate in this sector. With its skiller labor force, growing demand for green ships, the Indian government's support for shipbuilding and India's abundant natural resources, alternative fuels can be looked into and used for vessels in order to reduce our reliance on fossil fuels and reduce GHG emissions.

16. CONCLUSION

The Shipping industry plays a pivotal role in world trade, and has been a difficult industry to decarbonize. It remains a large contributor of greenhouse gasses and thereby, air pollution. It often gets overlooked in the overall climate change conversations and hence, the current efforts are not in-line with the targets set by the Paris 2050 agreement. Various companies, including global leaders such as Maersk and also new startups such as Starfire Energy, FleetZero etc are leading the decarbonisation movement through various innovations such as alternate fuels, digitization, energy efficiency, fleet management etc. These, coupled with stronger implementation of policies can pave the way for the shipping industry to better coexist with global climate goals. India is gearing up to play a major role in this transformation by revamping its port infrastructure, with innovations in shipping also expected to follow.

REFERENCES

"About." Starfire Energy, https://starfireenergy.com/about/. Accessed 8 June 2024.
"About A.P. Moller - Maersk." Maersk, https://www.maersk.com/about. Accessed 1 June 2024. "Ammonia as a shipping fuel." Global Maritime Forum, 14 March 2022, https://www.globalmaritimeforum.org/news/ammonia-as-a-shipping-fuel. Accessed 29 May 2024.
Booth, Oliver. "Charting a course to curb maritime emissions." CTVC, 17 August 2023, https://www.ctvc.co/maritime-decarbonization/. Accessed 28 may 2024.
"Decarbonising Ocean Shipping | Sustainability & ESG." Maersk, https://www.maersk.com/sustainability/our-esg-priorities/climate-change/decarbonising-o cean-shipping. Accessed 2 June 2024.
"Decarbonizing shipping – why now is the time to act." The World Economic Forum, 27 May 2021, https://www.weforum.org/agenda/2021/05/decarbonising-shipping-the-time-to-act-is-now /. Accessed 3 June 2024.
"EEXI and CII - ship carbon intensity and rating system." International Maritime Organization, https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx?ref=ctvc.co. Accessed 9 June 2024.
guide, step. "Electrification of Things: By Sea | by Cantos | Cantos Ventures." Medium, 19 July 2022, https://medium.com/cantos-ventures/electrification-of-things-by-sea-9d6a2d7ba998. Accessed 1 June 2024.
Hakirevic, Naida. "Maersk CEO shares three imperatives for shipping's decarbonization to succeed." Offshore Energy, 14 March 2024, https://www.offshore-energy.biz/maersk-ceo-shares-three-imperatives-for-shipping-decar bonization-to-succeed/. Accessed 10 June 2024.
"Harnessing GREEN HYDROGEN." NITI Aayog, 29 June 2022, https://www.niti.gov.in/sites/default/files/2022-06/Harnessing_Green_Hydrogen_V21_DI GITAL_29062022.pdf. Accessed 8 June 2024.
"IMO's GHG Strategy." IMCA, https://www.imca-int.com/imos-ghg-strategy/. Accessed 19 July 2024.
"Improving the energy efficiency of ships." International Maritime Organization, https://www.imo.org/en/OurWork/Environment/Pages/Improving%20the%20energy%20e fficiency%20of%20ships.aspx. Accessed 9 July 2024.
Jørstad, Tommy Stokmo. "Hazards in LNG Facilities: What should we be aware of?" Gexcon AS, 16 March 2021, https://www.gexcon.com/blog/the-7-essential-hazards-in-lng-facilities/. Accessed 5 June 2024.
Kapoor, Kamna. "Global initiatives shaping the future of green methanol production." S&P Global, 20 April 2023,

https://www.spglobal.com/commodityinsights/en/market-insights/blogs/chemicals/04202 3-global-initiatives-shaping-the-future-of-green-methanol-production. Accessed 30 May 2024.
Keller, Peter. “The Outlook for LNG as a Marine Fuel.” The Maritime Executive, 2 February 2021, https://maritime-executive.com/editorials/the-outlook-for-lng-in-2021. Accessed 3
June 2024.
“Maress | VPS.” Veritas Petroleum Services, https://www.vpsveritas.com/maress. Accessed 2 June 2024.
“Marine fleet management software | ShipManager.” DNV, https://www.dnv.com/services/marine-fleet-management-software-and-ship-management- systems-shipmanager-114260/. Accessed 6 June 2024.
Mc-Kinney, Mærsk. “Explore our history.” Maersk,
https://www.maersk.com/about/our-history/explore-our-history. Accessed 1 june 2024. “MEPC 80-17-Add.1 - Report Of The Marine Environment Protection CommitteeOn Its
Eightieth Session (Secretariat).” International Maritime Organization, 7 July 2023,
https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/annex/ME
PC%2080/Annex%2015.pdf. Accessed 1 June 2024.
“Moving forward climate action – Maersk perspective.” Moving forward climate action – - Maersk perspective,
https://wwwcdn.imo.org/localresources/en/About/Events/Documents/Regional%20Confe
rence%20in%20Asia%20and%20the%20Pacific/presentation%2013%20-%20Gungor%2 0-
%20Maersk%20Decarbonising%20Shipping.pdf. Accessed 11 July 2024.
“National Green Hydrogen Mission.” National Portal of India, 6 March 2023,
https://www.india.gov.in/spotlight/national-green-hydrogen-mission. Accessed 9 July 2024.
“National Perspective Plan Ministry of Shipping, GOI, Government of India.” SagarMala,
https://sagarmala.gov.in/about-sagarmala/national-perspective-plans. Accessed 4 June 2024.
“Oceans Economy and Fisheries | UNCTAD.” unctad,
https://unctad.org/topic/trade-and-environment/oceans-economy. Accessed 3 June 2024. “The Paris Agreement | United Nations.” the United Nations,
https://www.un.org/en/climatechange/paris-agreement. Accessed 9 June 2024. “Path to IMO 2050 and the role of LNG as a marine fuel.” Wärtsilä, 6 August 2020,
https://www.wartsila.com/insights/webinar/path-to-imo-2050-and-the-role-of-lng-as-a-ma rine-fuel. Accessed 1 June 2024.
Peters, Stephen, and Susann Roth. “Climate Solutions: Three Paths to Expanding Investment in Green Hydrogen Energy | Asian Development Blog.” ADB Blog, 8 December 2023, https://blogs.adb.org/blog/climate-solutions-three-paths-expanding-investment-green-hyd rogen-energy. Accessed 13 June 2024.
“Press Release Ifrma Page: Press Information Bureau.” Press Release Ifrma Page: Press Information Bureau, 2 February 2024,
https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2002021. Accessed 8 June 2024. “Reducing emissions from the shipping sector - European Commission.” EU climate action,
https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en. Accessed 5 June 2024.
“Renewable energy investments in India to jump 83% to $16.5 bn in 2024.” Business Standard, 26 December 2023,
https://www.business-standard.com/industry/news/renewable-energy-investments-to-incr ease-83-to-16-5-billion-in-2024-123122600251_1.html. Accessed 4 June 2024.
Schuler, Mike. “Maersk Signs Largest Green Methanol Offtake Agreement for Low Carbon Shipping.” gCaptain, 22 November 2023,
https://gcaptain.com/maersk-signs-largest-green-methanol-offtake-agreement/. Accessed 10 July 2024.
Sideri, Olga, and Dimitrios Papachristos. “Green shipping onboard: acceptance, diffusion & adoption of LNG and electricity as alternative fuels in Greece - Journal of Shipping and Trade.” Journal of Shipping and Trade, 13 July 2021, https://jshippingandtrade.springeropen.com/articles/10.1186/s41072-021-00089-z.
Accessed 3 June 2024.
Sivadas, Lakshmi. “LNG - A future fuel for the maritime industry?” Wärtsilä, 29 March 2017,
https://www.wartsila.com/insights/article/lng-a-future-fuel-for-the-maritime-industry. Accessed 9 September 2024.
Sonowal, Shri Sarbananda. “Propelling India's Maritime Vision: Impact of Government Policies.” Research and Information System for Developing Countries, 30 October 2023,
https://www.ris.org.in/sites/default/files/Publication/CMEC-Book.pdf. Accessed 7 June 2024.
“Starfire Energy announces MOL Switch investment.” Starfire Energy, 28 February 2024,
https://starfireenergy.com/2024/02/28/starfire-energy-announces-mol-switch-investment/. Accessed 2 June 2024.
“Starfire Energy - Company Profile.” Tracxn, 14 July 2024, https://tracxn.com/d/companies/starfire-energy/HCl91eT3HoEk9sKJhwKQSex7X7GI
9RjIY9dE_p65jBI. Accessed 3 June 2024.
“Starfire Energy Raises $24 Million Series B Funding for Modular Carbon-Free Ammonia Fuel Technology.” Starfire Energy, 2 November 2022, https://starfireenergy.com/2022/11/02/starfire-energy-raises-24-million-series-b-funding-for-modular/. Accessed 1 June 2024.

Trump, Donald, et al. “Three Recent Advancements in Fuel Cells Suggest Economic Breakthrough.” Axiom Technology Headhunting, https://www.axiomsource.net/blog/Three-Recent-Advancements-in-Fuel-Cells-Suggest-Economic-Breakthrough. Accessed 2 June 2024.

“The Vital Role of the Maritime Industry in Shipping.” Northeast Maritime Institute, 19 January 2024, https://nmi.edu/the-vital-role-of-the-maritime-industry-in-shipping/. Accessed 4 June 2024.

“What is the shipping industry?” Clarksons, https://www.clarksons.com/glossary/what-is-the-shipping-industry/. Accessed 5 June 2024.