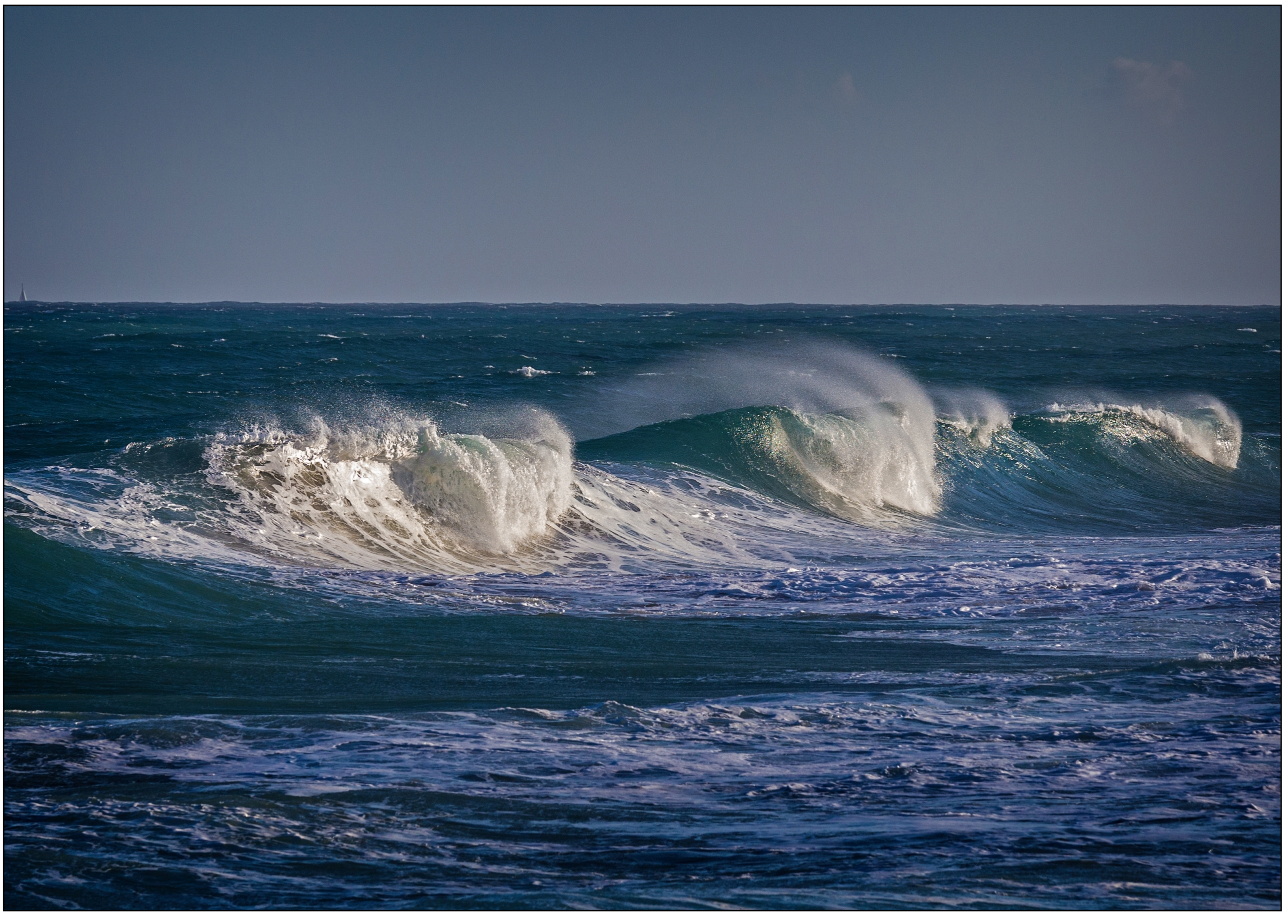
Periscope Network

Report

Power-2-X in Maritime



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POWER-2-X IN MARITIME

REPORT FROM THE NORTH SEA REGION

PERISCOPE
SEPTEMBER, 2021

Dear reader,

This report provides an assessment on the prospects for the use of Power-2-X fuels in the maritime transport segment, and the challenges facing the supply chain for uptake. Data for the report has been generated through interviews with 10 actors operating across the supply chain, providing perspectives on energy production, transfer, storage, demand, consumer, and policy. Survey instruments have been leveraged for additional input, and a workshop with actors from along the supply chain were engaged at Aarhus University in September, 2021.

This report is produced by the PERISCOPE Group at Aarhus University for the PERISCOPE network.

Photographs
unsplash.com; pixabay.com; pexels.com

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PERISCOPE

PERISCOPE is an initiative of the Interreg VB North Sea Region Programme working to catalyse entrepreneurial discovery and promote trans-regional partnerships to unlock Blue Growth. We are supporting the combined maritime and marine innovation ecosystem in the North Sea region to accelerate innovation for sustainable business development in emerging blue markets.

The PERISCOPE network scouts for future business opportunities for the blue economy and supports planning activities with the intention to orchestrate action towards the realization of said opportunities, and, indirectly, to a transition to a more innovative and sustainable character of the blue economy.

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INTRODUCTION

The North Sea Region is a crucial area for Europe's blue economy with marine resources, technologically advanced industries, major port areas, global shipping companies, and vibrant offshore activities. With approximately 3000 ships sailing at any one time, the North Sea is one of the busiest shipping areas in the world.

The blue industries - often operating far from land - rely heavily on fossil fuels to power their activities. In particular, the maritime fleet for freight transport, the largest segment in global trade, has been carbon-based for over a century. Indeed, shipping emits 3% of all global CO2 emissions, and one very large container ship can burn 7,000 ton of fuel on a trip from Europe to Asia and back.[1] It will be a challenging industry to decarbonize and will require shared understanding and collaboration, shared risk taking and investments, technical agreements, and policy action to realize.

The transition of the blue economies and especially maritime toward a sustainable future is motivated by the desire to 1) unlock new growth areas, 2) develop, apply, and export new technologies, 3) increase productivity, and 4) decarbonize. To ensure the region's stability and long-term prosperity, the development and utilization of new energy sources provides an opportunity to support the accomplishment of these goals. While initiatives, cases, and projects are already emerging, questions of what's next, how, and when further applications of new fuels remain.

Interest in developing viable power-to-X fuels for use in vessels has been made clear in regional, national, sectoral, and company strategies for a green transition. These ambitions are strong: In Denmark, a target has been set for 70% emissions reduction by 2030.[2] For a successful transition to sustainable fuels for the blue economy, it is important that an integrated supply chain perspective is used as a starting point for informing and coordinating the network of actors. Collectively anticipating the practical challenges, potential bottlenecks, the provision-of-supply and customer-demand infrastructure dilemmas are needed to unlock the fuel technology transition

To inform this report, we have taken a mixed-methods approach that involved desk research, interviews, and workshops. We've interviewed 10 actors across the maritime supply chain network in order to broaden the perspective on the challenges that different organizations and entities are facing. We've spoken with shipowners, electricity conversion engineers and chemists, infrastructure providers, electricity market modelers, technology developers, policy experts, and class societies.

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[1] Sterling, J. 2021 Decarbonizing Mærsk. GSF presentation, Aalborg.

[2] https://um.dk/en/foreign-policy/new-climate-action-strategy/

Interviewees

This was followed by a hybrid workshop hosted by Aarhus University for knowledge exchange and a workshop in Aalborg Harbor. The outcomes of the report reflect the strategic priorities, policy positions, and issues that are distributed across the network.

The level of abstraction of this report has been designed for an executive audience in the decision-making capacity order to inform supply chain actors as well as policy-makers. However, this report remains a work-in-progress, and is drafted for informing the discussion on- and providing guidance for- modelling the decarbonized supply chain--rather than any attempt to bring it to closure. The green transition for the maritime and ocean economies is just in its infancy, and generating a greater understanding of the shared challenges is a core purpose of strategic foresight. Looking into the future comes with many uncertainties, and the case for Power-2-X's future applications in maritime is non-exempt.

The report will report on the state-of-play and the core concerns across the value chain, including energy production, energy transfer, energy storage, demand, customers, consumers, and policy. The report follows this structure. Of particular focus were the scenarios for the future uptake of e-fuels including green hydrogen, ammonia, and methanol, and their expectations for market penetration. In the end, this report provides more questions about how the green transition might occur, rather than answers on how it should occur. To this end, this report discusses the critical uncertainties that can be used to generate scenario data for modelling efforts for the green transition in maritime.

PRODUCTION

Green e-fuels boast advantages over current hydrocarbon-based fuels in that they can be: 1) sourced and manufactured from renewable energy, 2) can be produced “green” using carbon capture from the atmosphere or from biomass, 3) is not a greenhouse gas, 4) are easy to store as they are liquid at room temperature, 5) and in the case of methanol, is highly biodegradable, and 6) have relatively low or zero emissions. The production of green e-fuels such as green methanol and ammonia require the combination of few inputs: green electrons - or electricity generated from renewable sources, and carbon (in the case of methanol) or nitrogen (in the case of ammonia), and hydrogen. Other forms of e-fuels, coined as black or blue, are made from oil or coal, or natural gas, respectively. Current methods of production and combination of these elements are highly energy intensive, with energy losses starting already at the renewable energy production stage and then along the transport chain to usage. In order to produce the electricity required, substantial increases in green electricity generation will be required. See table 1

Table 1: Potential fuels (pros and cons)

Biodiesel (incl. advanced biofuels)	**Green methanol** (bio-methanol and e-methanol)	**Green ammonia** (e-ammonia)
☑ Biodiesel market already exists	☑ Can be produced from both biomass and renewable electricity	☑ Can be produced at scale from renewable electricity alone
☑ Can be used as drop-in fuel in existing vessels and engines	☑ Already in operation today	☑ Fully zero emissions fuel
☒ Limited availability of sustainable biomass feedstock	☑ Well-known handling	☒ Safety and toxicity challenges
☒ Price pressure due to competing demand	☒ Bio-methanol: biomass availability of biomass feedstock	☒ Infrastructure challenges at ports
	☒ E-methanol: Availability of biogenic CO2 source	☒ Future costs depends on cost of renewable electricity

Source: Sterling, J. 2021

These e-fuel types require, firstly electricity and secondly hydrogen, and requirements to meet the fleet’s demand is well beyond the current trajectory trend of newly installed capacity. Even though the cost of green electrons are rapidly decreasing, and demand will surely follow, major concern of the interviewees is the mass production of green electrons, which will require substantial investments in renewable energy generation. World energy demand will grow by 50% to 900 EJ/y by 2050.[3] And much of the e-fuel production is used as a storage alternative during times of excess wind: New parks are most profitable by selling directly to the grid. However, this gives rise to Power-to-X because when the wind blows strongly, this excess can be absorbed to lower the cost of the green electrons needed to produce the e-fuels.

In the case that insufficient production becomes problematic, interviewees are concerned that production of e-fuels will be accomplished with alternatives that use fossil fuels (the

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[3] Wenzel, H. 2021. Future marine fuels in the holistic picture. Presentation at GSF. Aalborg.

aforementioned black or blue types), which would essentially obscure the fact that the e-fuels are fossil fuels in another form, which would run the risk of coming under scrutiny from the public as a form of “greenwashing.” Greenwashing is a risky approach in public relations, and companies are concerned about being accused of this because of potential reputation damage and backlash.

Carbon, an element in the production of methanol, is widely abundant on Earth. Sources for carbon extraction include 1) plants (and other biomass) and 2) sequestering carbon from the atmosphere. The extraction method for the former means that agriculture, an energy-intensive activity in itself, is used to supply the carbon. Biomass availability is decisive for the fuel production scenarios in the shipping sector as it becomes a major component in biofuels, which are considered a transition fuel toward zero-emission fuels, but still require carbon to carry the energy. Criticism for sourcing carbon from agricultural activity for energy production revert to the fact that this agricultural land is also be used to produce food, and with global nutritional deficiencies and affordability of caloric consumption for many populations around the world leads to an ethical debate not easily overcome.

If carbon emission reduction is posed as the major motivating factor for the uptake in e-fuels, then Carbon Capture & Storage (CCS) could become a major method for offsetting emissions. Emerging technologies are becoming available to filter out carbon from the air and package it for storage. If carbon trading markets emerge in shipping, this could be a cost effective “solution” to reduce emissions: Packing it into cubes and disposing it rather than releasing it into the atmosphere. However, technological developments are needed to improve captured carbon from the atmosphere’s feasibility for re-purposed use in e-fuels.

Nitrogen is produced in industrial abundance, especially as an input for agricultural fertilizers. It is an energy-intensive production process, and the sourcing of such energy for its production for agricultural purposes is often from fossil fuels. Nitrogen is produced at scalable levels, but then again, is often scaled at the expense of burning more fossil fuels. Both the increase of the input of carbon from biomass and nitrogen from industrial production are predominantly sourced from fossil fuel energy inputs, and if the shipping industry is to attempt to avoid claims of “greenwashing,” then care is suggested as to further electrify the supply chain of inputs to the production of e-fuels.

One alternative that can supply electricity for industrial production and power agricultural activity is the production of electricity for nuclear energy. Indeed, interviewees have raised the question of the future of the public’s attitude, perception, and acceptance of nuclear energy in Europe. Many countries, such as Germany and France have signaled their intention to decommission nuclear power plants and shift electricity production to renewable energy sources. These ambitions are historically justified by the problem with the storage of nuclear waste and the dangers associated with operating nuclear plants. However, latest generation nuclear power plants have evolved since European countries have last taken up debates and have not reflected technological and safety improvements that could allow production--especially from newly built plants-- to occur at lower risk to disasters and waste storage. Such next-generation nuclear power seems to face an uphill battle for legitimacy and public acceptance.

In terms of e-fuel production, a major concern was raised as to where green electrons would be sourced. Shipping is a global market, and so while bunkering occurs all over the world, major ports located in high-traffic countries like China raise the question as to how much e-fuel China can produce. Their geographic location and industrial productivity provides a relative advantage to scaling production and thus benefiting from economies of scale over time. A secondary concern lingers over the licensing of e-fuel production technologies. There is a race on for patents in chemical energy production that favor developed countries with resources to acquire and recruit researchers. These patents and technologies then are developed into production techniques that are available through licensing agreements. However, if the global e-fuel is to occur at the scale to the demand of ship operators and the ambition of politicians, then the licenses for technologies may present a major barrier to widespread industrial production. If these licenses are costly, then they will not reach the market because industries in developing countries may face a cost barrier that limits their ability to produce them.

In sum, the major question in production is to whether these fuels will be supplied in quantities that satisfy the shipping industry's demand and to the degree which they are truly "green.".

TRANSFER

The transfer of e-fuels concerns the speed at which electricity can be converted, transferred or transported, and be made readily available to meet demand at infrastructure sites such as ports. The core concern from interviewees are the requirements for investment in infrastructure that can support e-fuels.

Existing energy infrastructure was primarily designed and built for the present fossil fuel-driven economy. The major question is in respect to the amount of infrastructure that can be re-purposed for e-fuels. Hydrogen and natural gas seem to be relatively compatible. Underground storage in depleted gas fields and caverns in Holland, for example, are able to accommodate and store hydrogen, and can even be re-extracted along with natural gas reserves and viable for use in existing infrastructure, for example, for residential uses such as in-home cooking and heating. Likewise, the gas pipelines are suitable for transporting hydrogen.

The European Union has considered plans to develop a "hydrogen backbone" that would develop a reservoir of hydrogen stretching from Spain to Holland and beyond that would provide infrastructure for increasing the accessibility to hydrogen that markets and industries can access. Producers of (green) hydrogen could deliver (sell) their hydrogen to the backbone at a price, and the users of hydrogen can make withdrawals at a price that pays for the production, storage, and the cost of maintaining the infrastructure. Such a "backbone" could increase the accessibility of (green) hydrogen for various residential and industrial markets, and would thus be available for more use cases. However, in order to make it available for the maritime sector it would need to be connected to port infrastructure, requiring last-mile pipeline and transport infrastructure investments. In such cases, increased infrastructure investments would likely price higher at ports, leading to slower uptake by maritime segments.

Similar to the hydrogen backbone is the question as to the development of an international electricity grid that can intelligently move green electrons across borders to enable the production of e-fuels. The grid would need to be strengthened and increasingly standardized to accommodate the large increase in electricity, and also indicated that supplementary infrastructure investments would be required if licensing agreements for technology become inaccessible due to patent protections and local operations.

A third concern of the interviewees in terms of transfer is the speed of bunkering. The amount of electricity for battery-driven vessels and hydrogen transfer to power an ocean going vessel would take long periods of time. In the case of transferring sufficient hydrogen to power an ocean-going vessel with a refueling hose using current technology would take days. Hence the preference to develop e-fuels that can imbue the hydrogen with power-to-X in on-shore facilities and then be able to transfer faster into the vessel. The transfer mechanisms for hydrogen thus require research and development in order to make them able to recharge their tanks, or improved methods and ship design to make bunkering a modular process. In such a case, the option to swap fuel tanks at ports carries additional concerns of how such swapping can be done safely and how much ships would need to be redesigned and/or retrofitted in order to accommodate such swapping.

STORAGE

The storage of green e-fuels concerns storage at the site of production, on transportation vehicles such as lorries, but also at ports and on vessels. The storage of different e-fuels at these different sites requires investment across geographies.

The problem is exemplified in the challenges in the historical case offered by Liquid Natural Gas (LNG). LNG, which is a fossil fuel but burns with relatively low emissions as compared to traditional Heavy Fuel Oil (HFO) and derivative diesel fuels, has been denoted as a so-called “transition fuel.” Such fuels are (temporarily) supported by policy in order to reduce emissions such as carbon dioxide, nitrous oxide, sulphur oxide and black-carbon. Policy for increasing the use of transition fuels can offset short-term emissions while “buying time” for developing new decarbonized fuels and the required enabling technologies. Even though LNG has received policy support, LNG is still only available at relatively few ports.

In order to utilize LNG at a large scale, it would need to be made available in many more ports, and many more vessels would need to be able to burn it as a fuel. As the world trade of LNG has grown substantially over the previous decades, many new vessels are able to utilize it as a propulsion fuel, but many of the vessels that burn it as a fuel source are primarily limited to those that transport it. In other words, LNG carriers are, today, essentially the only ones that also use it for propulsion. This reality calls into question the future of e-fuels: Will they suffer the same fate that LNG has? This, in turn, begs another question, what is the future of e-fuels, if it is much more costly to produce-if it is not merely a process of underground extraction as LNG is?

Methanol, currently and primarily derived and produced from fossil fuels, already has the capacity to be produced at 100 million metric tons per year, is available in over 100 ports worldwide with established logistics and infrastructure for storage and bunkering.[4] Other alternative energy storage methods to e-fuels are emerging, for example batteries. Battery technology is advancing rapidly in other contexts such as mobile phones. However, given that mobile phone batteries are designed and innovated in that particular context, leveraging the technology for large ocean-going vessels is much slower given that technological generations are fewer and further between. Other battery technologies on the horizon, such as solid-state batteries for maritime purposes, remain speculative. While such batteries sidestep loss-in-conversion challenges from electricity to liquid storage and combustion heat (which is the case in e-fuels), questions remain, again, as to the redesign of propulsion systems, bunkering speeds, and availability of infrastructure at ports.

Meanwhile, concerns over bunkering on ships of fuels such as ammonia should be concerning. Ammonia dissolves in water, and sea water, and does not decompose. A large ammonia spill will kill all of the marine life in a large vicinity, and so just one spill would be significantly disastrous to potentially halt all usage of ammonia and put ammonia on a blacklist.

Another speculative option is liquid hydrogen. This fuel could bunker much faster and would require much less volume than hydrogen gas, but is limited by current technology because it requires significant energy to maintain a low enough temperature to retain a liquid form. However, advances in cooling technology could make it a viable option in the future. In the end, e-fuels burn considerably slower and with less intense heat release, making tank storage much larger.

DEMAND

Critical to demand is the availability of supply. Critical to the provision of supply is the demand from the market. In order to burn Power-2-X fuels in maritime, ships must have the proper propulsion systems. Before the systems are established, ship operators need to know that there is ample supply. In energy markets, this is known as the chicken-and-egg problem: That suppliers won’t produce without demand, and customers won't build or convert their systems without reliable supply.

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[4] Friis-Jensen, M. 2021. Methanol fuel cell: The key to decarbonizing. GSF conference presentation. Aalborg.

The lack of a market explains why the production of Power-2-X fuels has been slow to develop and scale. One effort to overcome this problem has been to build ships that are capable of burning multiple fuels - such as Mærsk's recent announcement that they will build ships that can run on--or switch between--diesel and methanol. This was announced in conjunction with the planning agreement with a production facility to scale production of green methanol. However, since much of the technologies are still being developed and producers have yet to achieve economies of scale, price forecasts indicate that e-fuels will be substantially higher in the short- and medium-term. Complicating this picture is the price of crude oil, the current main source of marine fuel, which is notoriously difficult to forecast as it is subject to complex geo-socio-political driving forces.

In order to create economies of scale, many stakeholders are curious about the so-called "fuel mix" of the future. Which fuels will become widely available? Which one will dominate the maritime segment that will drive innovation investments in ship propulsion? At the moment it is not clear which e-fuel(s) will emerge as dominant, making investment decisions opaque. Ships are ideally optimized and often built-for-purpose, but without fuel availability, this becomes a risky investment if they are under-specialized, as is the case in flexible (dual-purposed) engines.

Pressuring shipowners to "go green" occurs through the general public's consciousness of global warming and climate change, which manifests in the statements and actions of pressure groups and politicians. These pressures are present on many companies and industries. While companies and industries can and do convert their production systems, a core shared element of the global supply chain is that of maritime transport. Thus, all companies and industries (cargo owners) can also collectively pressure maritime carriers, ship operators, and charterers toward sustainability, thus creating sufficient pressure to convince maritime transporters to implement solutions. The results of such pressures have relatively little impact on the final prices that consumers pay. For instance, a car may cost 2% more, a mobile phone may cost 1% more, and a pair of jeans may cost 2% more.[5]

Recent initiatives have witnessed the collective interest and action of cargo owners to pressure the maritime transporters to this end. Over 150 of the world's largest shipping companies, maritime companies and NGOs have signed on to collectively pressure shipping companies.[6] Also among the Danish signatories are shipowners such as TORM, Norden, DFDS and Maersk.

Yet the political agenda depends to a large extent on the continued appetite for sustainability. Concerns that sustainability is following a "hype cycle" indicate that this pressure can and might change. A global recession could have an impact on priorities, where economic concerns once again take primacy. In such a scenario, sustainability may turn out as a "nice to have" but

[5] Source: BCG https://www.bcg.com/publications/2021/fighting-climate-change-with-supply-chain-decarbonization

[6] Exemplary signatories include Cargill, Dow, Holcim, and Tata Steel. For more, see https://www.seacargocharter.org/signatories/

secondary to a “return to growth” agenda. This is certainly still the mantra for much of the developing world, who are hesitant to sign onto international agreements such as the Paris Agreement because of the economic implications and resulting higher energy costs to maintain forward economic momentum.

Another issue for the e-fuel supply and demand conundrum is the competition for e-fuels by other industries such as housing, plastics, agriculture, aviation, and manufacturing. Airlines, for example, are also under pressure to decarbonize, but lack a fuel such as a green e-kerosine that can accomplish this. If airlines or other industries begin to receive subsidies to purchase e-fuels, then that will put pressure on supply and lead to higher prices, squeezing maritime transporters’ ability to pay. National governmental policies, for example in Germany and Japan, are uncertain, uneven, and unilateral, making price forecasting difficult, and in turn, could lead to suboptimal investment decisions. A similar effect could come from establishing taxes on diesel fuel or HFOs or carbon emission taxes, that, in industries where it makes most sense to reduce tax burden, would witness the first movers to pay the price to switch to e-fuels, and only once that transition has taken place, then other industries will have their turn.

A final concern on the demand side comes from the business model approach, which has developed thinking around pay-for-propulsion, or propulsion-as-a-service, where technology providers are paid a service fee for propulsion rather than fuel, incentivizing propulsion providers to accelerate innovation in order to rapidly advance technology and ensure optimal operational performance, of which they would share in the savings. While such schemes have existed in the airline industry, they have yet to gain footing in maritime.

Shipbuilding must make significant investments to incorporate new e-fuels. In some cases fuel cells may provide the major mechanism for energy conversion, but using combustion engines is also possible. Power systems have been optimized for HFO and marine diesel for generations, and incorporating new fuels brings with it a new learning curve to start up on.

POLICY

Power-to-X fuels are still more expensive than their fossil counterparts. Implementation of a carbon tax based on a carbon intensity index would absorb the harmful externalities and create an enhanced market with global carbon pricing mechanisms.

Key policy concerns have arisen over the level of public sector investment for the production of green electrons. While the trajectory for installed production capacity has grown every year, concerns are raised over the current rate of growth. Options suggested for improving the provision of green electrons include the reduction of power taxes on renewable electricity and using grid fees to encourage producers to locate production where there is better grid capacity.

In order to meet the cross-sectoral demand, investments and incentives must be in place, yet in order to drive global production, incentives must establish a level playing field across geographies and industries. Otherwise, risks of localized production and loss due to long-distance transmission ensue. This would risk result in a local, or at best, regional green transition.

At the International Maritime Organization (IMO), changes in regulations that will evaluate the energy efficiency of a ship from well-to-wake from tank-to-wake are on the table. Such changes imply that the energy efficiency would take into account the sourcing of fuels for the vessel, not only the efficiency of the vessel given its type. For the maritime industry, established indexed calculations for the energy efficiency of ships promise to improve transparency in the second-hand market for ships. Ship prices are, however, volatile due to the time-lag in capacity (shipbuilding time), leading to intermittent price spikes of cargo freight rates. Such calculations and the fines and/or fees that accompany them are not foremost on the buyers' mind when speculation for wild profits are present. Increasing regulations, however, do require ships to undergo expensive upgrading and retrofitting to bring them into compliance.

New builds are a crucial element if an energy transition is to happen in maritime. Policies that encourage the greening of the public sector fleet, for example the coast guards, are often used to test the performance of new technologies since they are less price sensitive and operations are outside of many market forces. Public procurement can thus be an entry point for many new vessel types and technologies. Likewise, implementing so-called "green corridors" in which designated shipping lanes mandate zero-emission shipping would drive infrastructure development and allow first-movers to adopt new zero-carbon technologies.

Looming unresolved issues include current subsidies for fossil fuel producers and the absence of taxes on diesel fuel and HFOs for the ocean-going fleet. Taxing emissions accordingly is difficult because of the requirements of achieving a majority of shipowners who flag, register, and class their ships in many different contexts.

Incentives must be in place so actors can implement new solutions and begin learning from their research and innovation in order to improve the efficiencies of new fuels.

CONCLUSION

Shipping has adopted aspirational targets for decarbonizing the global merchant vessel fleet, for example Denmark's goal of CO2-neutral shipping by 2050. However, such plans for implementation have yet to be established and agreed to in the IMO. Frameworks that make zero-emission ships the obvious choice need in-phasing soon if targets are to be met.

While the decarbonization agenda and accompanying concerns across the supply chain overlap to a great extent, the problem-solution space will require shared understanding and collaboration, shared risk taking and investments, technical agreements, and policy action to realize.

In order to reach such ambitions, large investments large-scale projects are required for producing green electrons in an enormous supply. Furthermore investments and innovation in energy transfer, port infrastructure, conversion technologies, shipbuilding, propulsion, and new fuels are required.

This report has done more to air the concerns and the criticisms of Power-toX as a maritime fuel. It does this not to thwart development, but to rather make the concerns addressable for the community of stakeholders that need to drive the transition.

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