



HOW HYDROGEN CAN HELP DECARBONISE THE MARITIME SECTOR

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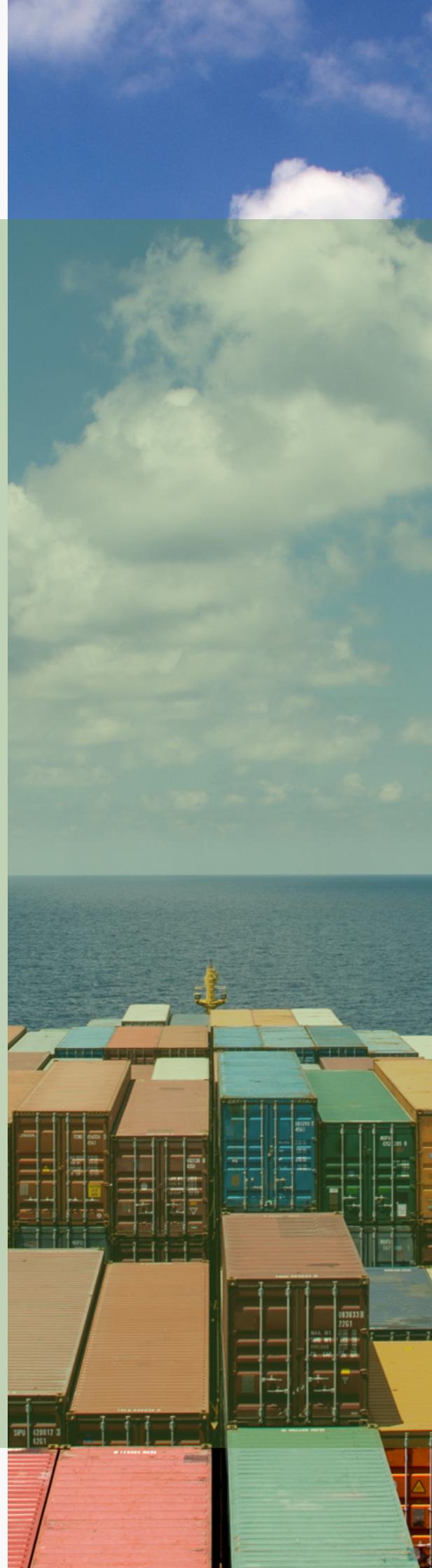
EXECUTIVE SUMMARY

Hydrogen Europe is the organisation representing the interests of the European hydrogen industry. It fully adheres to the European Union's target of climate neutrality by 2050 and supports the European Commission's objectives to develop and integrate more renewable energy sources into the European energy mix.

In December 2015 in Paris, a global climate agreement was reached at the UN Climate Change Conference (COP 21). The Paris Agreement is seen as a historic and landmark instrument in climate action. However, the agreement is lacking emphasis on international maritime transport and the role that this sector will need to play in contributing to the decarbonisation of the global economy and in striving for a clean planet for all.

Hydrogen, hydrogen-based fuels (such as ammonia) and hydrogen technologies offer tremendous potential for the maritime sector and, if properly harnessed, can significantly contribute to the decarbonisation and also mitigate the air pollution of the worldwide fleet. Hydrogen Europe will be the catalyst in this process the decarbonisation and also mitigate the air pollution of the worldwide fleet. Hydrogen Europe will be the catalyst in this process.

The pathway towards hydrogen and hydrogen-based fuels for the maritime sector does not come without technological and commercial challenges let alone regulatory barriers.





This paper aims at showcasing the importance of an ambitious maritime EU-policy to address those challenges and it **contains policy requests on EU initiatives such as the necessity to include the maritime sector in the European Emission Trading System as well as setting targets on the demand of hydrogen and hydrogen-based fuels and explain why even that is not enough.** The current state of International Maritime Organisation (IMO) discussions on the decarbonisation strategy are progressing slowly but there is no time.

Why should the EU take the lead? The IMO discussions on the decarbonisation strategy are progressing but this must be accelerated in order to meet the European Green Deal objectives of carbon neutrality by 2050. Measures to improve the energy-efficiency of the ship by 2030 will not be sufficient, we must act now. If the EU aims to reduce emissions overall by 55% in 2030 compared to 1990, a shift from fossil fuels to zero-carbon fuels for shipping will be required. **As the lifetime of ships is high, the introduction of zero-emission vessels must start now.**

In its communication on a sustainable and smart mobility strategy (SSMS), the European Commission has acknowledged the importance of taking the lead in decarbonising the maritime sector very clearly, laying down the priorities in the transport sector for the next ten years. This includes a target of zero-emission marine vessels market-ready by 2030, boosting the use of renewable fuels in the maritime sector as well as an emphasis on the creation of zero-emission ports.

In the face of inevitable climate change, Martin Stopford and eminent maritime economist describes the coming decade as “the 4th industrial revolution at sea”. It is in the EU's best interests to manage this revolution effectively over the decades to come.



GHG EMISSION - AN AGREED STRATEGY

While it is clear that the maritime sector is a critical enabler of global trade and an indispensable part of the world's economy it is also becoming increasingly clear that urgent action is needed to tackle the sector's ever-growing emissions. The global shift towards renewable and sustainable energy to limit the most severe effects of climate change is a challenge for every sector, including maritime. Maritime transport emits around 940 Mt of CO₂ annually and it was responsible for about 2.8% of global greenhouse gas (GHG) emissions in 2018 [1]. At EU level, CO₂ emissions of maritime shipping amounted to over 142 Mt in 2018 and 136 Mt in 2019. This equals to ~4% of total EU GHG emissions. These emissions are projected to increase significantly if mitigation measures are not put in place swiftly.

Ships are mobile entities having the biggest engines in the world on board and flying the flag of nations with different ideas and motivations on how to tackle GHG emissions. It is a global and a very competitive sector and being a first mover doesn't come without risks.

Agreed IMO ambitions set in 2018

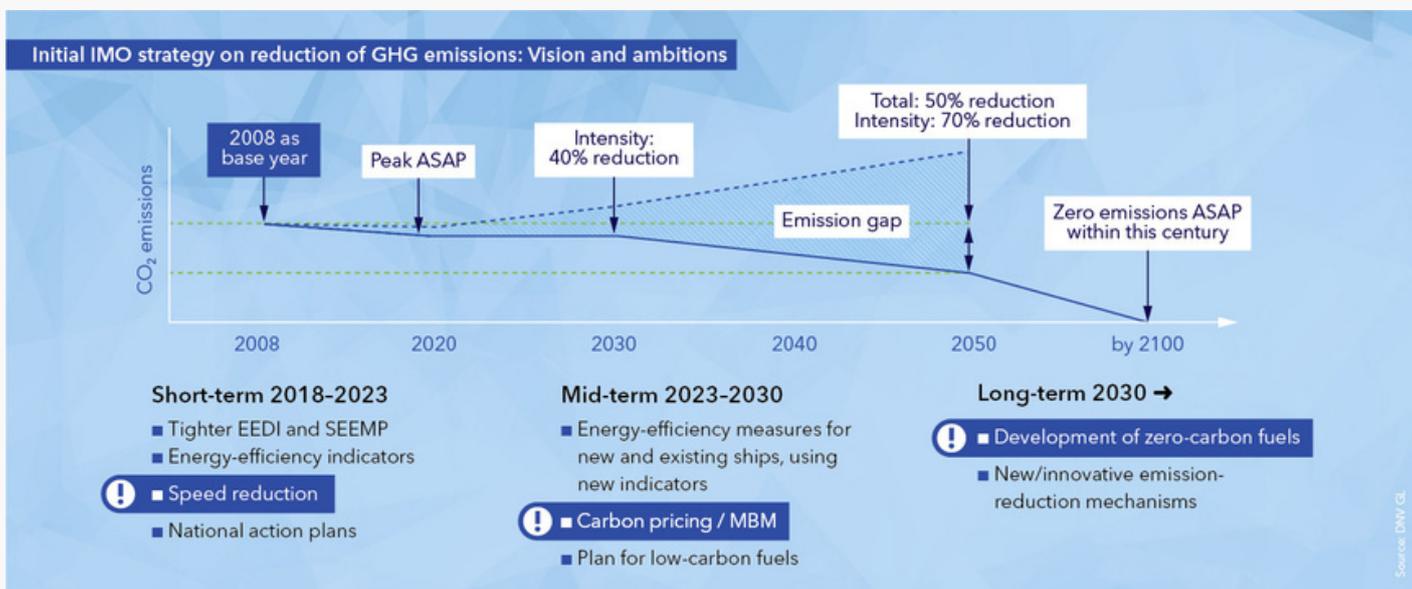
Reducing the GHG emissions from ships has been a major challenge for the IMO in the past 15 years because its members have very different opinions on the size and urgency of how the problem should be addressed. The IMO adopted its initial GHG emission reduction strategy in 2018 to be updated in 2023 where it sets a number of ambitions to reduce CO₂ emissions by 50% in 2050 and to reduce the carbon intensity of international shipping by at least 40% by 2030 both compared to 2008 [2] and to further improve the energy-efficiency of new vessels. As ships are generally in service for over 30 years, the maritime industry faces an enormous task to achieve this goal. Nevertheless, these targets constitute a remarkable achievement given the, at times, competing and diverging interests and visions among IMO members.

Hydrogen Europe fully supports these ambitions and wants to contribute to develop the building blocks that will ensure they are met. Hydrogen and hydrogen-based fuels will be an important piece of the puzzle, as they have 0% GHG emissions and can therefore contribute to a rapid decrease of the average GHG emissions for shipping.

[1] https://ec.europa.eu/clima/policies/transport/shipping_en

[2] <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx>

Figure 1: IMO strategy on reduction of GHG emissions (source DNV GL)



2050 target

To halve the GHG emissions by 2050 compared to the 2008 level is ambitious. To achieve the 2050 targets, alternative fuels and energy sources will be needed. The alternative fuels and technologies known at this time have limitations and no truly zero-carbon fuels are available on a larger scale. Although markets are powerful, they cannot, on their own, make the transition happen. An ambitious EU policy guiding this transition that includes clear goals as well as more research and innovation is needed. This effort also requires the building of a worldwide dedicated infrastructure network meeting the demand for various alternative fuels. The current state of IMO discussions on the strategy to achieve the target are progressing slowly but the introduction of zero-emission vessels needs to start now.

2030 target

The IMO 2030 reduction target to improve the carbon intensity of international shipping by at least 40% by 2030 compared to 2008 can be met with available technology, through a mix of short- and mid-term measures, including operational measures, such as lower speeds, improvements in operational efficiency through data analysis, limited use of low-carbon fuels, and energy efficient designs. In order to be able to achieve the 2050 target a somehow linear approach (by having a more stringent 2030 reduction target) would have been clearer. In this regard the EU is pushing for more stringent targets to be set by 2030 for all ships calling on EU ports and also to have a more robust system to measure the energy-efficiency of ships. Hydrogen Europe welcomes this move as we need to start building zero-emission ships now.

The adoption of the IMO 2030 target will not, in absolute terms, prevent GHG emissions from peaking in the years to come.

Prior to 2018 [3]

The IMO has been addressing GHG emissions from ships since 1997 when it adopted its “Regulations for the prevention of air pollution from ships” aimed at targeting SO_x, NO_x, ozone depleting substances, and other volatile organic compounds.

Additionally, in 2011 the IMO adopted a package of technical and operational measures for all ships. These regulations on energy-efficiency of ships entered into force on 1 January 2013. These measures represent the first GHG emissions reduction rule for a global industry and consist of two parts:

- Energy Efficiency Design Index (EEDI) requires new ships to perform above a certain minimum carbon intensity threshold with increasing mandatory improvements becoming stricter over time. The EEDI has put pressure on both shipowners and shipyards to find new ways to improve the energy-efficiency but has so far not sufficiently led to the uptake of alternative fuels.
- Ship Energy Efficiency Plan (SEEMP) establishes a mechanism to be used by shipowners to improve the energy efficiency of both new and existing ships. The guidance on the development of the SEEMP incorporates best practices for fuel efficient ship operation such as weather routing, trim and draught optimization, speed optimization, just-in-time arrival in ports, use of alternative fuels, among others. The SEEMP encourages the identification of opportunities to reduce emissions but does not mandate setting of improvement targets.



[3] The following section is based on information gathered from the IMO website, mostly <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx> and <http://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx>



AIR POLLUTION: THE SHIPPING SECTOR'S OTHER PROBLEM

Maritime shipping's essential role in our global economy is indisputable, but it is a significant contributor to global air pollution that harms both human health and the environment. The fourth IMO GHG study [4] estimates that international shipping emitted in 2018 approximately 17.1 million tonnes of NO_x and 9.6 million tonnes of SO_x.

According to the IMO international shipping is responsible for approximately 13% and 12% of global nitrogen oxides (NO_x) and sulphur oxides (SO_x) emissions respectively annually.

However, it should be noted that the maritime sector has in recent years undertaken some significant steps to reduce air pollution. To reduce SO_x emission, limits have been set on the sulphur content of the fuels. Emission Control Areas (ECAs) with stricter limits were established to minimize airborne emissions from ships. The SO_x emission limits apply to the existing fleet and NO_x emission limits were set for new build ships.

As of 1 January 2021, all ships built after that date and entering Europe Emission Control Areas (the Baltic, North Sea and English Channel) must comply to the Tier III standard set by IMO. This standard aims to reduce nitrogen oxide emissions by approximately 85% compared to the Tier II standard which currently applies. The only way to achieve this is with alternative fuels (e.g., hydrogen) with zero-emissions if fuel cells are used. NO_x abatement technology is required if hydrogen is burned in internal combustion engines.

Because of significant negative environmental and health impacts, decarbonisation efforts should also support the reduction of air pollution generated by the maritime sector.



PRACTICAL IMPLICATIONS OF THE IMO-TARGETS

Shipping emissions expected to continue to grow

The shipping sector share of global emissions has reached 2.9% in 2018⁴, surpassing the levels recorded the past decades with a peak in 2008 [4]. This shows, that even taking into account the ever-increasing energy efficiency of ships and though some improvement has been achieved, shipping is not on a trajectory to meet the 2050 ambition of reducing GHG emissions by 50%.

Assuming the COVID-19 pandemic has only a temporary effect on the world economy and trade, shipping is expected to continue to grow in the coming years and decades. As a result, although overall ships could improve their efficiency by a further 20% - 30% by technical and operational means – the growth in transport work will ensure that, even if those efficiency improvements are fully implemented, the absolute GHG emissions of the shipping sector will also continue to grow. The fourth IMO GHG study predicts that, in a business-as-usual scenario that includes only the continuation of efficiency improving actions, the absolute GHG emissions from shipping will remain stable at best but can potentially grow by more than 40%, depending on global GDP growth.

Only improving the energy-efficiency of the ship will not be enough. If the EU, in line with the European Green Deal targets, aims to reduce emissions overall by 55% in 2030 compared to 1990 and to have a climate neutral economy by 2050, a shift from fossil fuels to zero-carbon fuels for shipping will be required.

From fossil ships to zero-emission ships

The key questions are how to trigger the uptake of hydrogen and hydrogen-based fuels for shipping and how to step away from fossil fuels in the near term as widespread voluntary action by shipping stakeholders is unlikely due to significant cost penalties and IMO regulations mandating zero-carbon fuels are not on the horizon.

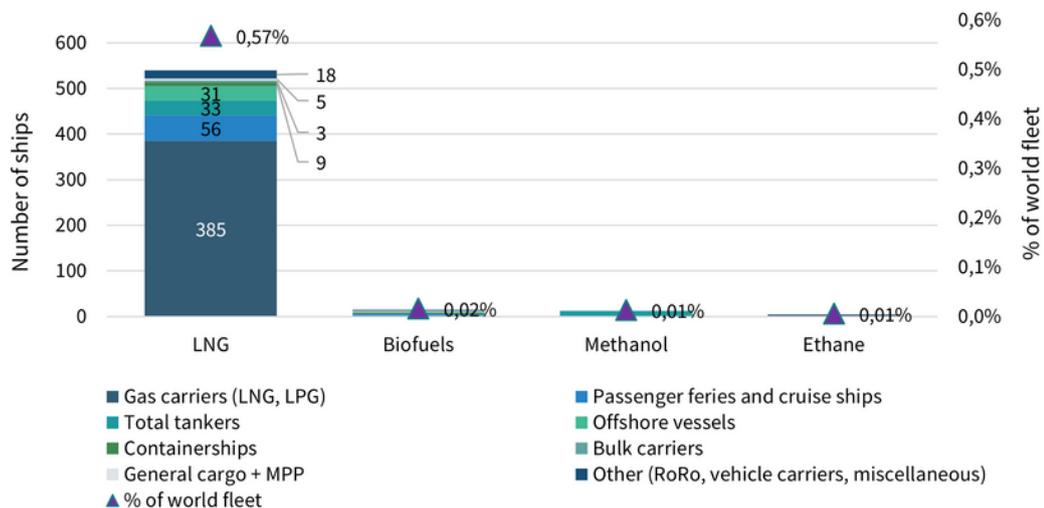
Heavy Fuel Oil (HFO) is the most used fuel in international shipping today and accounts for approximately 77% of all fuel burned in marine engines today, marine gas oil is the other main option. HFO is a residue from the refining industry and it has a very high energy density.

[4] <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx>

Before the 2018 IMO initial strategy to reduce GHG emissions was introduced, the maritime sector was focusing on selecting alternative fuels aimed at reducing air emissions, with GHG emissions more of an afterthought.

According to Clarksons Research [5], as of May 2020, the fleet of ships using alternative fuels consisted of 572 vessels, including ships using LNG, methane, ethane, or biofuel as a drop-in fuel. This amounts to a 0,6% of total vessels in operation.

Figure 2: Number of ships using alternative fuels (Source: Clarksons Research, Alternative Fuels Installations, May 2020)



From a more technical perspective, to succeed in the competition with currently used fossil fuels, alternative fuels will need to meet three characteristics:

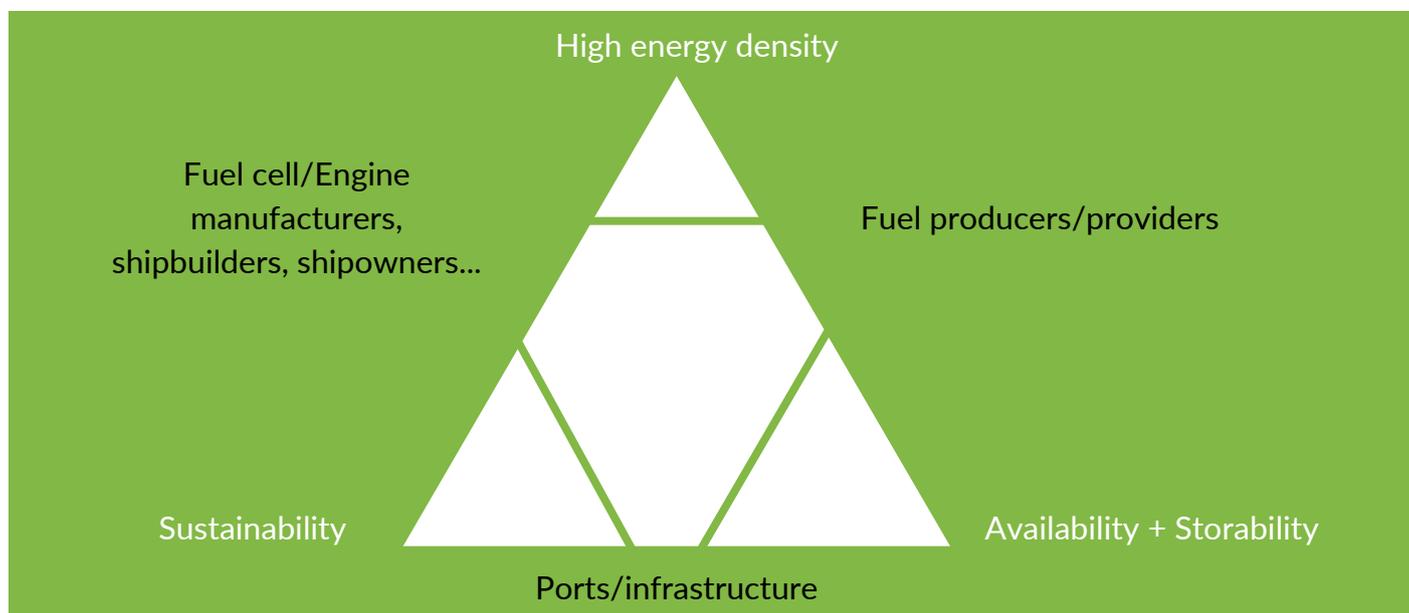
1. The first one is the **large energy density**. The energy density per volume unit of alternative fuel cannot compete with the energy density of existing marine fuels. As a matter of fact, it is the large energy-density of fuel oil (and the low price) that has made these fuels so successful in the past 100 years.
2. The second very important characteristic is the **availability and security of supply**. Because shipping is a worldwide industry, alternative fuels need to be available all over the world, which is the case for current fossil fuels. This requires the building of a worldwide dedicated infrastructure network meeting the demand for various alternative fuels. The regulatory framework on alternative fuels and the lack of demand might raise hurdles on the path to develop said supply network. When there is a significant degree of market development for a certain fuel or energy carrier, new EU infrastructure obligations should be developed.
3. Future alternative fuels will need to be **GHG-neutral from well-to-propellor**. Hydrogen Europe is convinced that there will be a need to consider the upstream greenhouse gas emissions. It is the only sensible way to tackle the decarbonisation of our society.

[5] <https://www.clarksons.net/wfr/>

Green hydrogen offers a perfect zero tank to wake emission solution and would benefit from a well to tank regulation. Too often, when considering decarbonisation of transport, the upstream emissions are not taken into account and this has also been the case for the maritime sector.

The IMO is currently considering how to take into consideration the GHG intensity of alternative fuels, not only from tank-to-propeller but also from well-to-tank. Hydrogen Europe would very much welcome the EU to take a leading role in those discussions.

Figure 3: Collaboration in order to meet the three characteristics (energy-density, sustainability, availability and storability) of the triangle



Collaboration: a critical success factor

Hydrogen Europe will have a coordinating role by bringing all the stakeholders (shipowners, shipbuilders, classification societies, fuel producers and providers, ports, ...) together to ensure the development of a coherent and robust maritime alternative fuels policy. A number of key questions need to be asked:

- What is further needed in terms of R&D, what are the technical constraints for using hydrogen, hydrogen-based fuels and hydrogen technologies (fuel cells, internal combustion engines, storage tanks, ...) on board ships?
- What regulation is needed to mitigate those constraints?
- What is needed to trigger the production of hydrogen-based fuels such as ammonia and what are the infrastructure requirements?

Cooperation between all stakeholders should ultimately be coordinated at EU level, where new obligations for fuel use and infrastructure could be introduced after a certain threshold is met.

Focus on zero-emission/low-emission ships

Although there is certainly a potential to improve the energy-efficiency of the existing fleet pure hydrogen as a fuel for existing ships is technically challenging. Hydrogen-based fuels (e-fuels) such as ammonia or methanol are more promising since they can be burned in internal combustion engines. The potential to use hydrogen-based fuels in existing ships needs to be further investigated but that is outside of the scope of this paper.

In order to tackle the biggest emitters, which are deep-sea ocean-going vessels, we will first need to further upscale hydrogen and hydrogen technologies through more research and innovation with inland and short sea shipping potential incubators for solutions in deep-sea shipping. There are still hurdles to overcome namely the price and the storage on board and the lack of consolidated and standardized solutions just to name a few.

In many cases, where the necessity to store large amount of fuel to ensure autonomy or where the power needs are significant, technological solutions are still to be identified and research and innovation will represent a significant enabler for the development of a zero-emission ship at cost competitive conditions. This is notably the case of highly specialised large vessels, large passenger vessels and long-route shipping vessels.

The greatest potential in the very short term lies in inland shipping and so-called vessels in ports and port areas such as urban ferries, tugboats and small dredging ships that maintain the depth of channels and rivers as these vessels have a relatively small fuel demand and can be supplied from a single location. Superyachts operating on hydrogen are also now early movers and show the potential of this fuel. Current projects depend on a patchwork of national legislation not designed for hydrogen maritime applications which slows down the process. A broader EU/IMO harmonised regulation will be necessary to enable the building of larger ships and to create the conditions for designing ships with innovative components at cost competitive conditions.

It should be recognised that these vessels have a range of options where some are not suitable solutions for deep-sea shipping, for example batteries or compressed hydrogen.

The focus on small zero-emission vessels now will lead to dedicated hydrogen supply chains for larger ships (short-sea-shipping) taking into account that the largest emitters, namely deep-sea vessels, will likely make use of hydrogen-based fuels (e-fuels) for their main engine power which will require different supply chains.

Hydrogen Europe is working on the deployment of hydrogen for all transport modes. The experience gained in other transport modalities may contribute to accelerate the learning curve of developing hydrogen and hydrogen technologies (e.g., trucks and buses) which are more developed than for maritime application. We do not need to start from scratch and can make use of those experiences and integrate existing technologies on board those relatively small vessels easily. These small vessels can make use of hydrogen refuelling stations (HRSs) on land.

It is likely as a first step that smaller ships in ports will be supplied with hydrogen from hydrogen tube trailers and/or fixed compressed hydrogen tanks and this will be done at HRSs on land where hydrogen for other applications (trucks, tractors, busses, ...) can be supplied as well. Such stations are currently being built but more demonstration projects are needed.

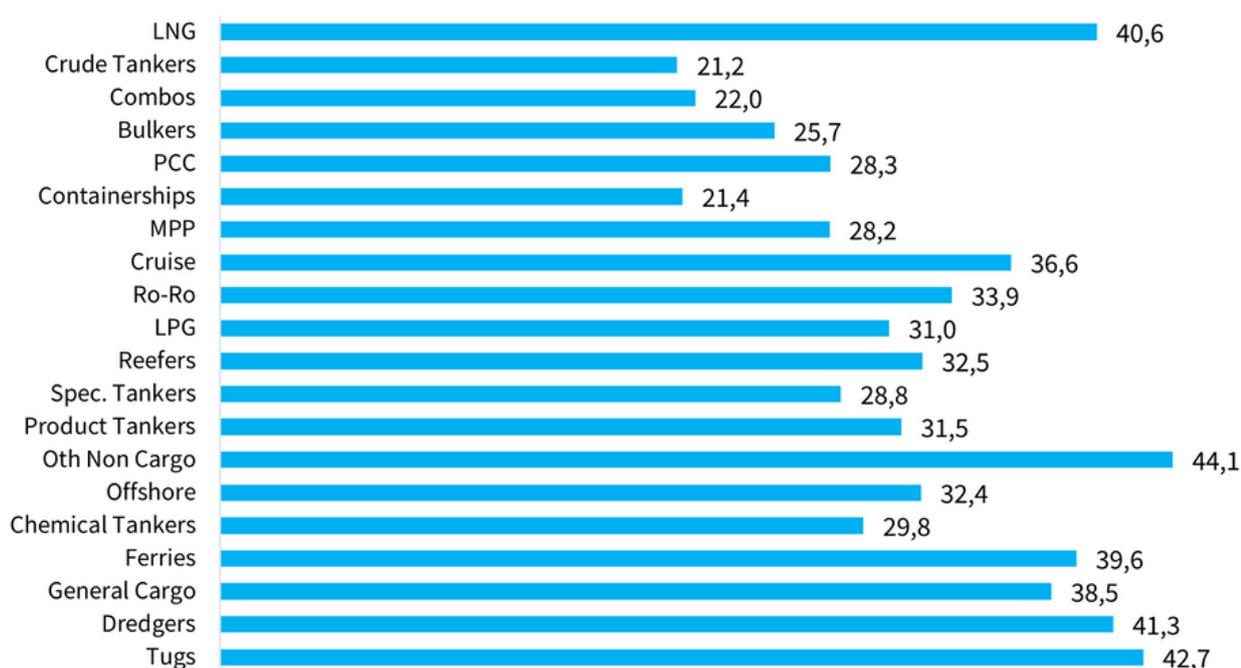
Our ambition is to develop the supply chain for smaller vessels in port areas and cities and to make those ships commercially viable by 2030. From there, the distribution, storage and bunkering of hydrogen and hydrogen-based fuels can be upscaled. This development will pave the way to hydrogen and hydrogen based-fuels and the required dedicated hydrogen infrastructure for the biggest emitters, ocean-going vessels.

Ships have a very long lifetime: it's time to act now

The lifetime of ships (on average 30 years) highlights the urgency of enrolling hydrogen as a fuel as soon as possible. Due to the long lifetime of vessels, fleet renewal takes a long time and therefore the transition to alternative fuels needs to start now in order to avoid that fossil fuelled ships will still service global trade and EU-trade for decades to come.

Around half of all ships in operation are more than 15 years old, with around 1/3 being more than 25 years old. The lifetime is even higher for smaller ships, such as general cargo ships, where the average is close to 40 years. The average age of inland ships is even higher. Ironically, these are the ships where the potential for hydrogen and hydrogen technologies is the highest in the short term.

Figure 4: Average age (in years) of 20 ship-types
(Source: Hydrogen Europe elaboration based on data from Clarksons World Fleet Register)



If the emission reduction targets of the EU are to be achieved, not only is decarbonisation of the shipping sector needed, it needs to start now, as ships ordered in the next years will impact emissions of the shipping sector for decades to come.

A transition to new net zero-emission fuels will be required to achieve the goals set out in the IMO Initial GHG Strategy and to put shipping on the pathway to decarbonisation. Therefore, to comply with the 2050 target we need to introduce as soon as possible zero-emission ships and ships with much lower emissions based on existing technologies and by investing in future proof technologies.

Concretely we believe that:

Before 2030: The greatest potential in the very short term lies in inland vessels and vessels active in ports and port areas such as urban ferries, tugboats and small dredging ships that maintain the depth of channels and rivers. Before 2030, the technologies will be ready so that all European new-build short sea ships and new build inland vessels can be zero-emission and pave the way for long distance ships.

By 2030: By 2030 many small ships will be running on hydrogen or e-fuels (dual and single fuel) depending on the chosen technology to power the ships. Technologies will be ready to already reduce substantially the emission of the rest of the ship fleets (existing ships and/or long-distance ships). Hydrogen-based fuels will have been tested for main engine propulsion for larger ships and the first ships running on these fuels (with both ICE and SOFC) will be built by 2025. Hydrogen and hydrogen-based fuels can already provide auxiliary power to larger ships which can significantly reduce emissions of air pollutants in ports and port areas.

Hydrogen Europe is of the opinion that by 2030 hydrogen and hydrogen-based fuels can provide auxiliary power to the majority of ocean-going vessels (build after 2025) in ports and that the EU should lay down the legislative pathway to make this possible.

By 2050: The worldwide fleet will have been even more hydrodynamically improved with highly automated machinery systems. The majority of ships with many of them fully autonomous will run on alternative fuels such as hydrogen and hydrogen-based fuels.



THE ROLE OF HYDROGEN

The choice of the fuel of the future is still uncertain (which is a risk of delay)

The discussion about the sustainable fuel of the future lies essentially in a trade-off between cost and the easiness to store energy on board which is the main challenge from a technical point of view. There are also questions regarding the powering of the ships. Hydrogen can be used in multiple ways either in fuel cells or via combustion in internal combustion engines. Pure hydrogen being the basic element of all hydrogen-based fuels is the cheapest fuel. It is, however, not the easiest to store compared with other fuels that are made from hydrogen (ammonia, e-LNG, e-methanol and e-diesel) which have a better volumetric energy density. The relatively low volumetric energy density of hydrogen is, next to production costs, the biggest techno-economical barrier for large scale adoption of hydrogen in maritime applications.

Hydrogen Europe has looked at the available technologies, their strengths and weaknesses, and their technology readiness levels (TRL), to propose deployment scenarios for ships and associated infrastructure. When it comes to fuel production costs alone, pure hydrogen options are always cheaper than fuels that require further 'transformation' - regardless of electricity price.

We found that for large ships, ammonia is the cheapest synthetic fuel (based on renewable hydrogen). The trade-off lies in the fact that as the energy density of the fuels increases the cost also increases as can be seen in the figure below.

Fuel cost increase and energy density improves



Even though the interest in hydrogen is growing, there are still some key barriers that need to be overcome before hydrogen can become a mainstream solution for shipping. One of the most important barriers is of course the high price of clean hydrogen and e-fuels as well as a lack of bunkering infrastructure. The regulatory framework is also lacking, both in terms of technical regulation as well as policies.

It is understandable that, given the long lifetime of ships, facing the risk of stranded assets, the shipowners are reluctant to invest in large vessels using alternative fuels. It is also understandable that, facing the same uncertainty, maritime ports are unwilling to invest in alternative fuels storage and bunkering infrastructure. Not to mention the fuel supplier that will need more demand/offtake security over a period of time.

Lack of consensus on what will be the future fuel of choice is one of the key barriers preventing hydrogen to move from R&D phase into wider adoption.

For short distance ships and inland vessels, it is clear that pure hydrogen is a convenient option and the cheapest one. These ships will kickstart the hydrogen transition. As indicated above, the necessary technologies are being developed and will make it possible to have zero-emission new built ships in these categories by 2030.

On a more general note, next to the obvious barriers such as price and infrastructure we should not forget the hydrogen production capacity. In this regard, it should be stressed that hydrogen has a much broader role to play in the decarbonisation of the economy than just as a zero-emission fuel. Hydrogen is the only sufficiently available and scalable technology for sector coupling, which is essentially energy system optimisation through production and consumption management in different sectors. Deep decarbonisation across all sectors of the economy would be improbable and prohibitively expensive without hydrogen. The role of hydrogen in the ongoing decarbonisation efforts has also been recognized in the EU Energy System Integration Strategy [6] and then in the EU Hydrogen Strategy [7], announced in July 2020, which set out a target of at least 10 million tonnes of clean hydrogen production in the EU by the end of 2030.

A lot of clean hydrogen will be needed

As can be seen in the figure below, of all the fuels that have the potential to be zero-emission or carbon neutral quasi all are based on hydrogen.

[6]<https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN>

[7]<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301>

Figure 5: Source: Zero-emission Vessels: Transition Pathways, Lloyd Register and UMAS

Table 1 - Energy source/zero-carbon fuels considered in this study

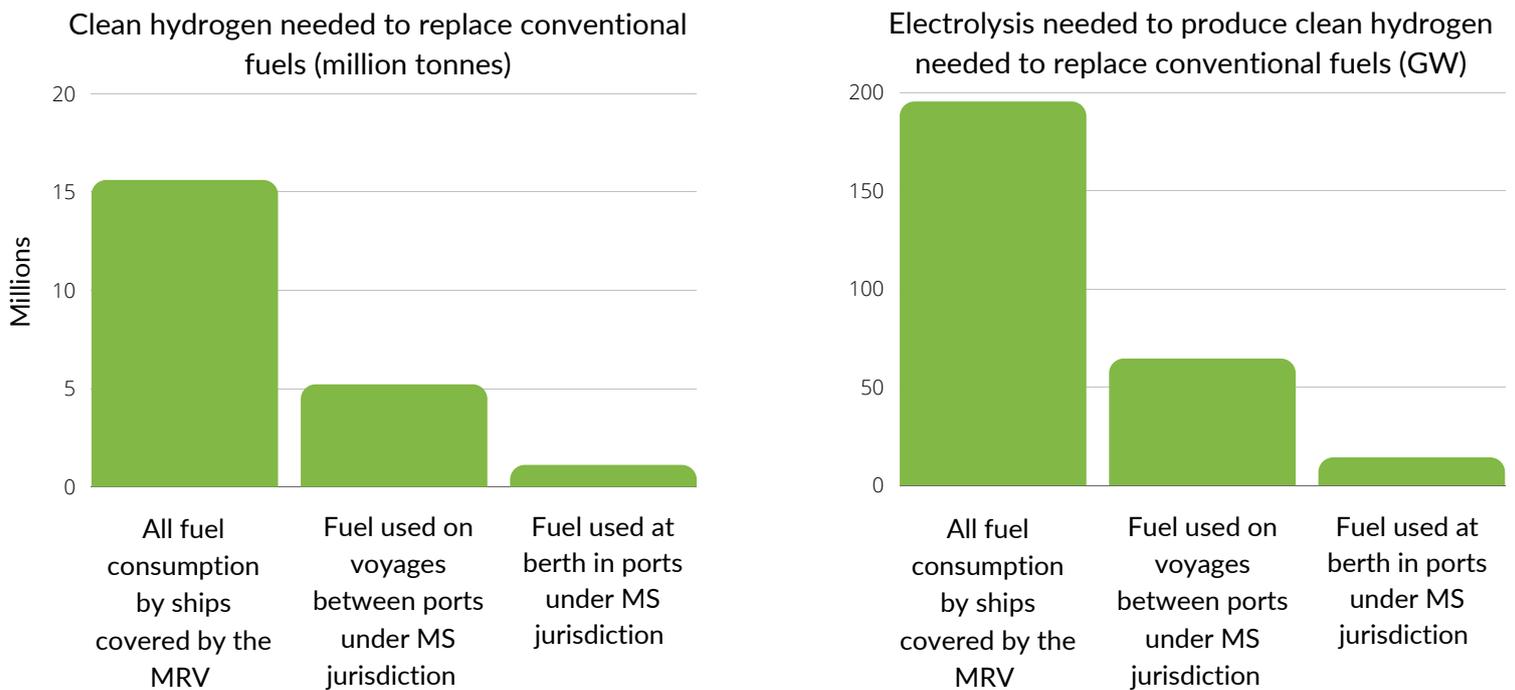
Energy source	Zero-carbon fuels				
	Methanol	Gas oil	Hydrogen	Ammonia	Electricity
Natural gas with CCS			NG-H ₂	NG-NH ₃	
Biomass	bio-methanol	bio-gas oil			
Renewable electricity	e-methanol	e-gas oil	e-H ₂	e-NH ₃	batteries

Note: Many types of biofuels exist depending on processes and feedstock (first, second and third-generation biofuels). In this study we considered only two cases that are regarded as representative for bio-methanol and bio-gas oil both as second and third-generation. Fuels produced from renewable electricity are referred to as electro-fuels.

Except for biofuels (and batteries), all zero-emission and carbon neutral fuels that are envisaged for shipping (hydrogen, ammonia, E-LNG, E-diesel, E-methanol) are made from hydrogen.

Hydrogen Europe has made a calculation on the amounts of pure hydrogen that could in theory be required by ships calling on EU-ports and intra-EU shipping in the longer term. The left bar in the left figure below shows the required amount per year for all ships covered by the EU Monitoring Reporting and Verification (MRV) Regulation. The bar on the right shows the annual amount from ships at berth in EU ports.

Figure 6: Clean Hydrogen needed to replace conventional fuels and electrolysis needed to replace these fuels (source: Hydrogen Europe own elaboration)





HYDROGEN AND HYDROGEN-BASED FUELS

Fuel cells (FC) and hydrogen have been implemented in submarines for many years. Several small vessels running on hydrogen have been built and more demonstration projects are underway to highlight the viability of hydrogen to power ships using FCs and dual fuel internal combustion engines up to a certain power. For certain use types (inland, near coastal), there is an emerging consensus that FCs, using hydrogen are the most promising zero-emission option. Several design projects are ongoing to test the applicability of FCs to larger vessels. However, due to the magnitude of energy storage and power required in these use cases, there is no consensus on the optimal strategy for fuel.

As there are still challenges to overcome with fuel cells for marine application, certainly for the larger ships, some consider that hydrogen dual fuel combustion engines could trigger the uptake of hydrogen for the maritime sector as a transitional pathway.

Pure hydrogen

Hydrogen is an energy carrier and a widely used chemical commodity. It is a colourless, odourless and non-toxic gas. For maritime use, it can be stored either in liquid form, as compressed gas, or chemically bound.

Hydrogen as a fuel can be used in multiple ways either in fuel cells, as a dual fuel mixture with conventional fuels, or as a replacement in combustion process [8]. Highest efficiency can be achieved in fuel cells (with efficiency ranging between 50% and 60% and potentially even higher with heat recovery), while adapted combustion engines have efficiency between 40% and 50%. For fuel cells the conversion of hydrogen into energy (Tank-To-Wake) generates zero-emission, only water. Total Well-To-Wake (WTW) emissions are therefore entirely dependent on the way that the hydrogen is produced.

If produced from renewable energy, hydrogen enables reduction of 100% Well-to-Wake GHG emissions.

In the case of dual-fuel internal combustion engines, blending with conventional fuels improves combustion and emission properties while reducing GHG emissions. Even a 50/50 mixture of heavy fuel oil and hydrogen could reduce CO₂ emissions by up to 43% per ton-kilometre. Single fuel hydrogen combustion engines are under development as well.

[8]<https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN>

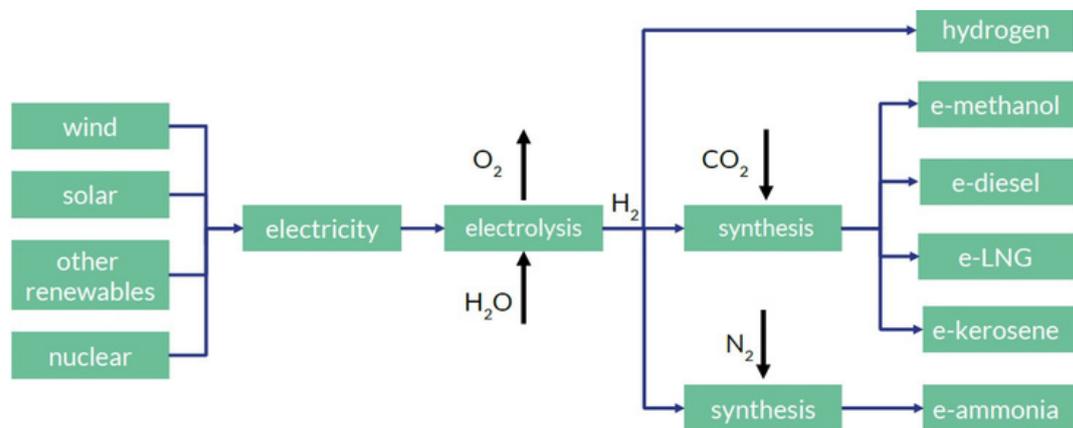
Unfortunately, as of 2019, over 90% of hydrogen produced in the EU is produced from fossil fuels without Carbon Capture and Storage (CCS).

Hydrogen has a high specific energy density, approximately three times the energy density of HFO, but because it is so light it has a low energy density in gaseous form. This can be improved by compressing it or liquifying it. The volumetric density of liquefied hydrogen is 71 times higher than hydrogen in its gaseous form but this is still only 16% of the density of marine gas oil. As a result, the liquified hydrogen energy density is approximately five times the volume of the same amount of energy stored as marine gas oil. If stored as a compressed gas at 350 bar, its volume is 7.5 times the volume of the same amount of energy stored as marine gas oil.

Other e-fuels: so-called hydrogen-based fuels

E-fuels are synthetic fuels which can be produced on the basis of electricity (from renewable sources), water and carbon dioxide or nitrogen. The figure below shows a simplified schematic representation of the production routes for the e-fuels.

Figure 7: Schematic representation on the role of hydrogen and relevant e-fuels (source TNO)



The most promising e-fuels other than hydrogen today are e-ammonia, e-methanol and e-LNG. Both ammonia and methanol are chemical commodities and many assume that it therefore should be fairly easy to roll them out for marine applications.

Ammonia

Ammonia is a hydrogen carrier that can be used in certain fuel cells or as a fuel for direct combustion in internal combustion engines. It has a high hydrogen content but does not contain a carbon atom. As a result, ammonia does not emit any carbon dioxide (CO₂) or sulphur oxide (SO_x) and it emits minimal amounts of nitrogen oxide (NO_x). According to the Hydrogen Europe comparison tool, it is considered a promising option for larger ships but there are still many issues to tackle (low flammability, N₂O emissions and ammonia slip from the incomplete combustion). Burning ammonia in large internal combustion engines is still in the research and development phase. It is currently being tested for use in ships by several engine makers. A significant challenge with ammonia is safety. It is highly toxic which is challenging, especially for use on board ships and on passenger ships. Ports that do currently not store ammonia will need to take this element into account and ports that already store it for the fertiliser industry will need to assess the likelihood of finding additional space.

The advantage of ammonia is that given its use as a fertiliser, it is a widely traded commodity with over 18 million tons of it traded internationally. As a result, there are transportation and storage technologies, port loading infrastructure, handling experience, and there is know-how on the safety aspects in the current supply chain. While future renewable ammonia can be technically produced anywhere with available renewable energy sources, most ammonia is currently produced in China (31%), Russia (9%), India (7%) and the USA (7%).

Methanol

Methanol is a mature technology with a potential to save significant emissions of pollutants as its combustion produces lower emissions during combustion. The life-cycle NO_x emissions are lower by 55% compared to conventional marine fuels and methanol SO_x emissions are 92% lower per unit of energy. Methanol is currently used by 11 tankers and one passenger ferry in Europe. It is a carbon-based fuel but if produced from direct air capture it is carbon neutral.

Due to its beneficial volumetric energy density and relatively high lower heating value only 2 to 3 more space is needed compared to current marine fuels. Moreover, no compression, nor cryogenic/low-temperature storage is needed to realize tank infrastructure on board or on harbours. An advantage of methanol is that existing infrastructure for liquid fuels can be used directly or modified easily and inexpensive. This is also the case for so called Liquid Organic Hydrogen Carriers (LOHC).

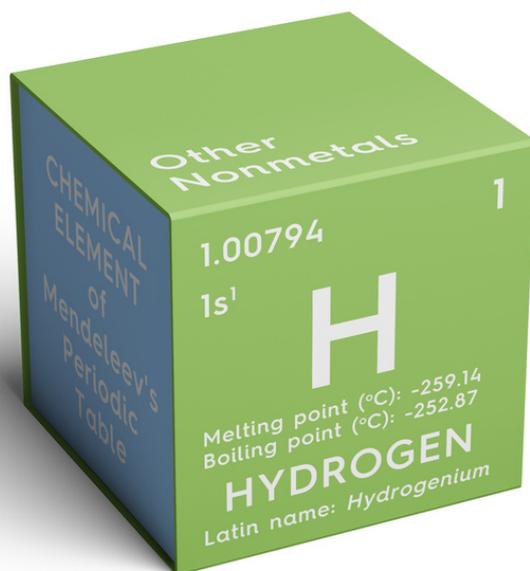
Biofuels: not future proof

There are many potential alternative fuels for shipping, but not all are equally promising. In most cases crop-based biofuels are more damaging than fossil fuels. And while some advanced biofuels could provide emissions reductions, they are limited in sustainable bio-feedstock availability. Therefore, the solutions, to be stimulated by FuelEU maritime (an initiative from the European commission to trigger the uptake of low-carbon fuels), need to be sought among technologies that can be both sustainable and scalable.

Hydrogen Europe will encourage the development of legislation that is future-proof. Biofuels can be either blended with conventional fuels or used as so-called drop-in fuels without changes to the existing infrastructure and assets. Therefore, blending biofuels to meet decarbonization targets risks postponing the uptake of hydrogen and hydrogen-based fuels. Biofuels are being used across industries and across countries, bear low capital costs, require minimal adjustments for machinery and storage of current assets, and are price competitive. As a result, they are often touted as the ideal replacement of fossil based marine fuels.

However, biofuels contend with two challenges: their availability and their sustainability.

According to the IEA, in 2016, the total biodiesel and bioethanol production amounted to 24.5% of total marine fuel demand [9]. Given the various competing industries (maritime, aviation, road transportation, and others) this amount is not nearly enough especially as some sectors, like aviation, can afford to pay premium for biofuels compared to the shipping sector. Any use of biofuels should take into account their effects on natural resources, food prices and social conditions.



[9] IEA defines advanced biofuels as “sustainable fuels produced from non-food crop feedstocks, capable of delivering significant lifecycle GHG emissions reductions compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts.”



PORTS AS HYDROGEN HUBS

It is important to point out the central role that the maritime ports have in the transition towards the hydrogen economy.

Already today a large portion of hydrogen industrial production and consumption takes place in ports or in close proximity to ports. The biggest hydrogen consumers come from the oil refining, ammonia and chemical industries, which combined use around 90% of all hydrogen produced each year in the EU, and quite a lot of those facilities are located in EU ports.

Five industrial hubs in the Belgian and Dutch ports (Antwerp, Zeeland, Rotterdam, IJmond and Delfzijl) have a combined local hydrogen demand of 1.7 Mt per year, which is equal to around 20% of total EU consumption today. Most of that hydrogen is also produced locally, usually from natural gas through steam methane reforming, the so-called grey hydrogen.

This opens up an important opportunity as this grey hydrogen will gradually need to be replaced with renewable or low carbon hydrogen. Having a large hydrogen demand centre in port, makes it possible to develop a clean hydrogen supply chain for shipping. This would be further strengthened by the fact that many port areas have industrial facilities from the hard-to-abate sectors, like the steel industry, which are also increasingly looking at hydrogen as an option for decarbonisation.

Furthermore, hydrogen can also be used as a fuel for most material handling vehicles used in ports' terminals to decarbonise port operations and further increase the demand for clean hydrogen.

The pace in which the maritime sector can decarbonise very much depends on how fast ports will be able to store sufficient amounts of green hydrogen.

Ports will become hydrogen hubs or “Hydrogen Valleys” where hydrogen can be produced or imported, stored and distributed for use in different applications such as:

- H₂ for trucks and rail (e.g., in port areas where the electrification of the railway is not possible),
- H₂ for inland waterways (for inland ports),
- H₂ for onshore power,
- H₂ for the decarbonisation of terminal and cargo handling equipment,
- H₂ for the industrial hinterland (e.g., refineries, chemicals...).

The revision of the directive on alternative fuels infrastructure (AFID) [10] will play a crucial role in this regard. As mentioned before, it is understandable that, facing the uncertainty on what the type of fuel shipping will use, ports will first need to develop a roadmap with the users of these fuels as well as with the fuel producers and with the storage terminal to come to an agreement on the timelines, conditions for use, quantities, etc. Hence our ask for a roadmap approach regarding the FuelEU maritime initiative and the revision of the AFID. Adding complexity to this, ports will also need to consider the triple-S criteria (sustainability, scalability and storability) when developing hydrogen infrastructure. Ports are also bound by local legislation and lack of space which can hamper the storage of fuels that are more hazardous such as ammonia. The storability of alternative fuels or the lack thereof could also hamper the development of the said supply chain.

Security of supply inter alia through interoperability, secure and reliable system operation and transmission of hydrogen to major demand centres and storage sites which ports will be is a prerequisite to develop supply chains.

To ensure that the different greening and energy transition pathways for ports do not get stuck in a discussion about the chicken-and-egg dilemma, coalitions or framework agreements should be developed by key stakeholders. Such coalitions could initially involve shipping lines, port managing bodies and energy providers at port level and could in a later stage evolve into a deeper cooperation with connecting ports. Such a bottom-up approach would see an individual port engage key stakeholders based on the port's individual roadmap, which provides a detailed plan of pathways for the greening of the shipping and takes into account each port's particular circumstances. The roadmap should be accompanied by a timeline which engages all relevant stakeholders: the port, the shipping lines, the energy sector (producers and providers), and other European ports where suitable.

The blue economy

It should also be noted that falling prices of offshore wind and solar are making renewable energy technology, potentially the cheapest source of renewable hydrogen, especially in northern parts of Europe, where solar is less competitive, making ports ideally placed to become large renewable hydrogen production hubs and demand centres. It is also increasingly likely that Europe will not be able to locally produce enough hydrogen to cover the entire future demand. A solution will be to import clean hydrogen by ships from North Africa, Australia, Chile or other countries with favourable wind/solar resources. Here too ports are set to benefit.

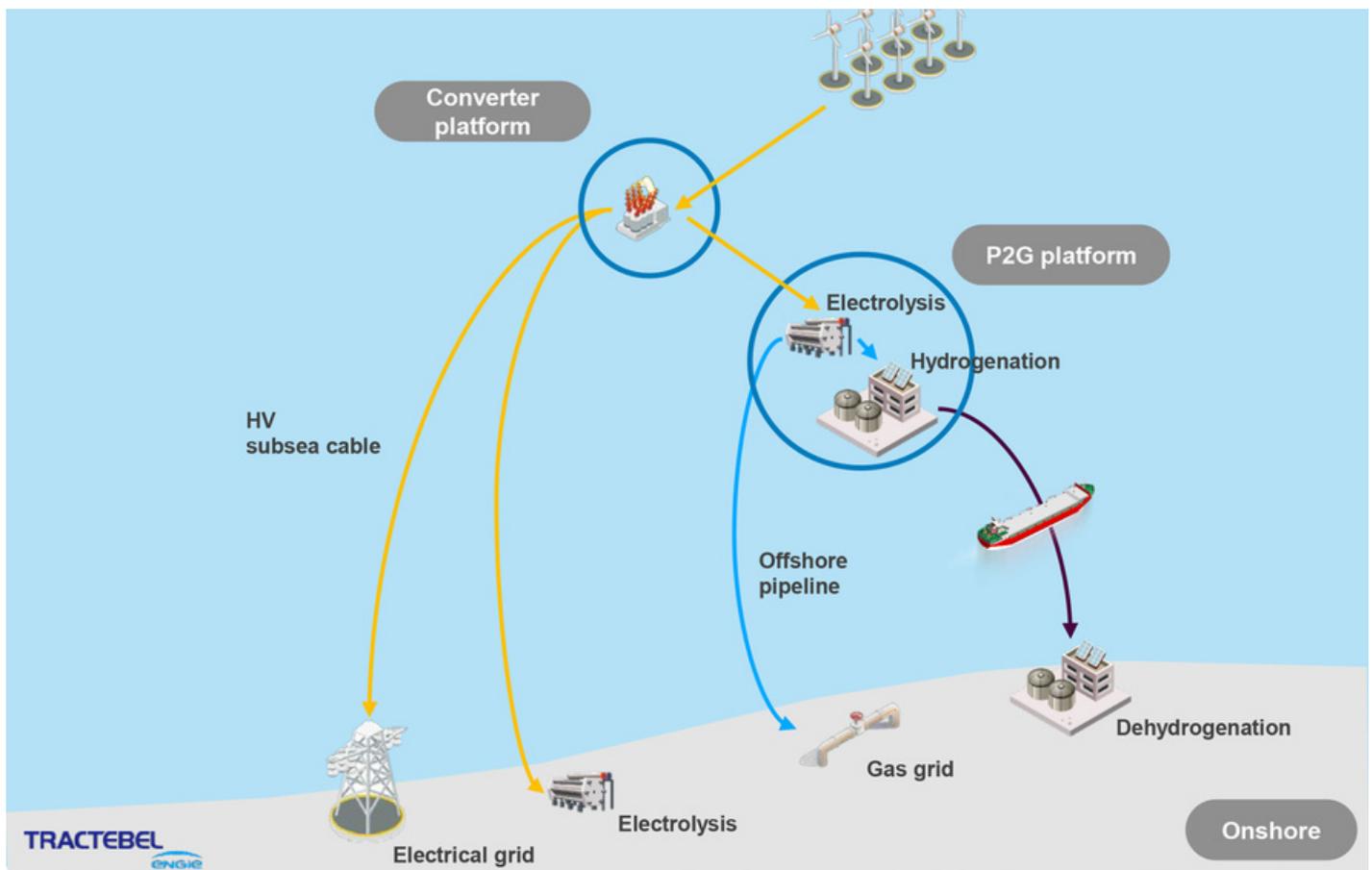
The maritime sector will also be a major enabling partner to materialise those synergies between offshore renewables and hydrogen. Namely, hydrogen produced offshore could be transported by ships to demand hubs such as ports. Hydrogen-fuelled ships will bring crew to offshore platforms and wind turbines (for maintenance). Besides, those platforms could become hydrogen hubs at sea supplying hydrogen to ships in transit. The Offshore Renewable Strategy [11] and the upcoming legislative initiative on FuelEU Maritime – Green European Maritime Space should therefore be consistent too.

[10] <https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/2111-Evaluation-of-the-Alternative-Fuels-Infrastructure-Directive>

[11] https://ec.europa.eu/energy/topics/renewable-energy/eu-strategy-offshore-renewable-energy_en

Maritime ports are set to become key hubs of the emerging hydrogen economy.

Figure 8: Production of renewable hydrogen offshore (source Tractebel) [12]



[12] <https://tractebel-engie.com/en/news/2019/400-mw-offshore-hydrogen-production-takes-system-to-new-levels>



AN AMBITIOUS, CLEAR AND STABLE POLICY FRAMEWORK TO PROMOTE EU INDUSTRY

We cannot wait

In the European Green Deal Communication [13], the Commission affirms its focus on the production and deployment of sustainable alternative transport fuels for the different transport modes. In parallel, the Commission wants to review the alternative fuels infrastructure directive and the energy taxation directive [14] and propose to extend the European emissions trading system to the maritime sector. In its resolution on the EU Green Deal, the European Parliament called for measures to move away from the use of heavy fuel oil and for urgent investments in research into new technologies to decarbonise the shipping sector, and in the development of zero-emission and green ships. In addition to that, as mentioned above, there is the FuelEU Maritime initiative aiming to increase the use of sustainable alternative fuels in European shipping and ports by addressing market barriers that hamper their use. This initiative is part of a package to bring the maritime transport sector in line with the EU's ambition of climate-neutrality by 2050.

Hydrogen Europe supports the policy initiatives of the EU aiming at decarbonising the maritime sector namely the:

1. EU-policy on decarbonisation of ships through **energy-efficiency improvements** and **direct carbon-pricing** through the EU regulation on Monitoring, Reporting and Verification of GHG emission of ships (EU MRV 2015/757) and the European Emission Trading system (EU-ETS 2004/87/EC).
2. Broader regulation to facilitate the **uptake of renewable and low carbon fuels** for maritime through the FuelEU maritime initiative.
3. The revision of the **EU-directive on the deployment of Alternative Fuels Infrastructure (AFID)** (2014/94/EU).
4. **The revision of the Renewable Energy Directive (RED II)** 2018/2001/EU.
5. The revision of the **Energy Taxation Directive (ETD)** to include maritime fuels as maritime fuels are currently exempt from taxes.
6. The revision of the **TEN-E regulation** (347/2013).

[13] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[14] <https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-Revision-of-the-Energy-Tax-Directive>

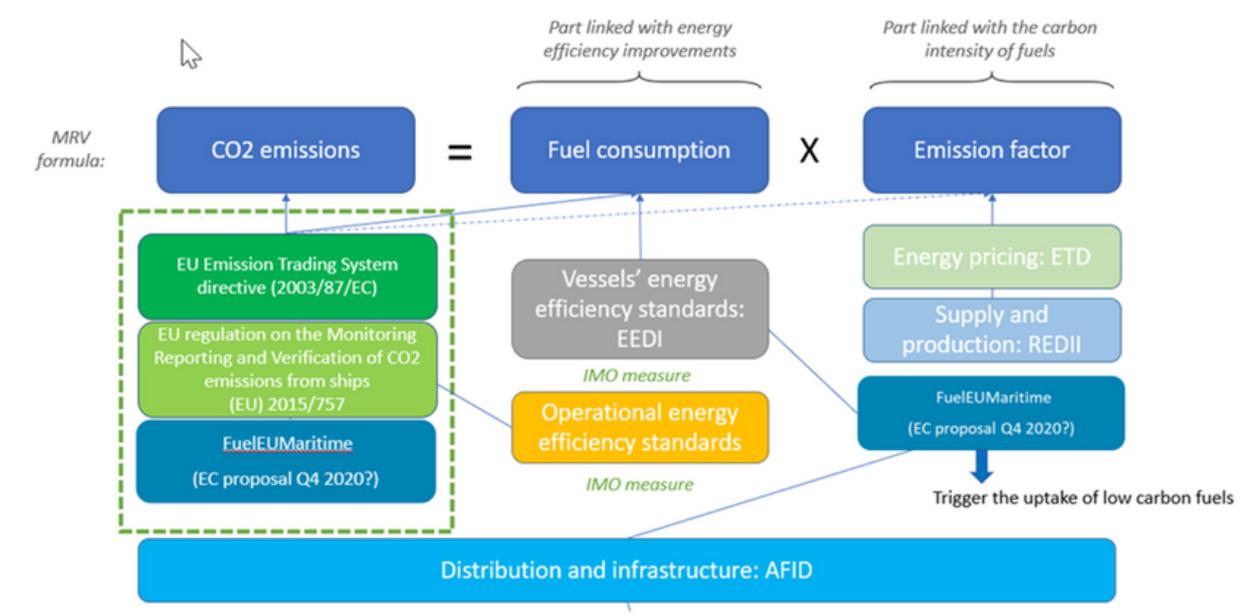
The policy initiatives are all connected one way or another. Although there is no silver bullet to decarbonise the maritime sector, we cannot afford to have a patchwork of legislations and regulations. We need a European regulatory framework with clear and ambitious obligations for the use of hydrogen and hydrogen-based fuels by 2025 and 2030 in the maritime sector.

There is no silver bullet to decarbonisation

There is no silver bullet regulation to decarbonise the maritime sector nor any other sector. The EU regulation should create a supply and demand for hydrogen and hydrogen-based fuels at a pace where the shipowner has the option to actually choose this technology. At the same time, the EU should develop regulation that accelerates the pace at which the hydrogen technology for the maritime sector is developed. As is the case for other transport modes there is a tension field between both. Adding complexity to this is the storage and distribution of hydrogen and hydrogen-based fuels. The review of the EU Green Deal offers an excellent opportunity to analyse the interdependence between hydrogen production, distribution and infrastructure, and demand.

On top of this, the FuelEU Maritime initiative will focus on ramping-up the production, deployment and uptake of sustainable alternative marine fuels. The initiative will have direct implications for alternative fuel infrastructures and must therefore be well-aligned with existing legislation also under review, specifically the revised AFID will need to take this into account, as it will require targeted and effective investments in ports.

Figure 9: EU Maritime decarbonisation policy initiatives



ETS is useful but not enough

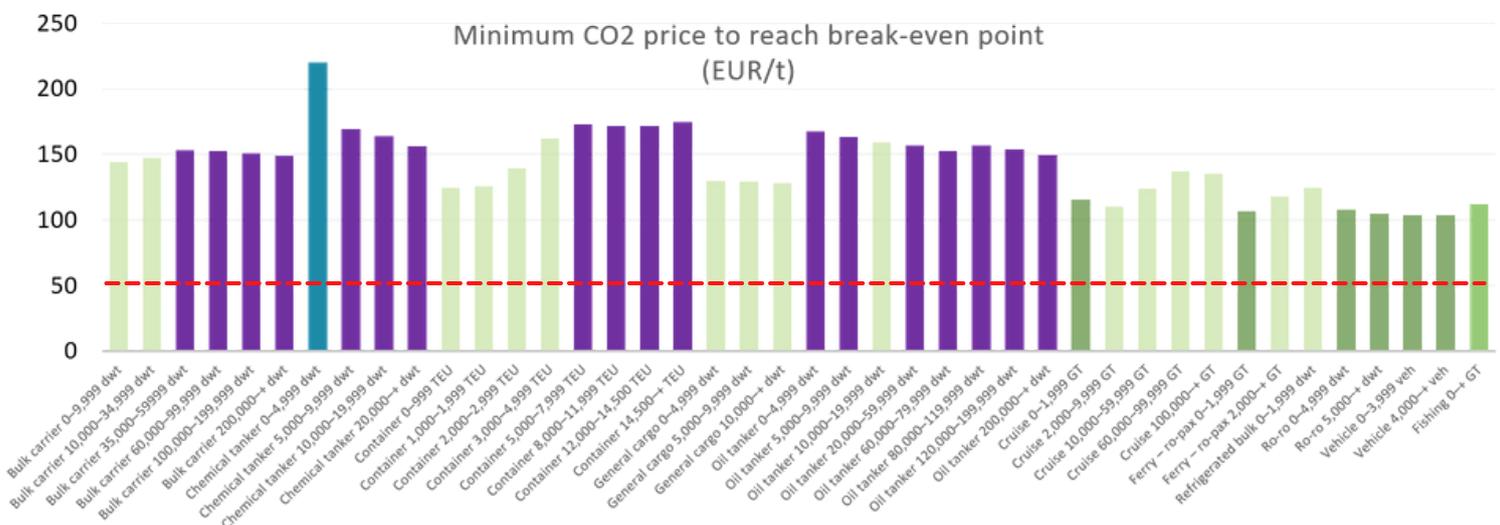
There have been many attempts to develop a market-based measure at IMO but all in vain.

Several industry organizations that are member to the IMO and Member States submitted a proposal to establish an IMO GHG emission reduction R&D programme to accelerate the introduction of low-carbon and zero-carbon technologies and fuels. The sponsors propose that funding would be provided via a mandatory R&D contribution per tonne of fuel oil purchased for consumption. A levy of 2\$/ton of CO₂ is proposed to fund innovation.

Putting a price on carbon emissions of shipping would be a welcome first step in establishing a regulatory framework for the decarbonisation of this sector, but only provided that the revenues flow back to the maritime sector where it can act as an important driver for necessary investments in sustainable fuels, innovative techniques and retrofiting.

Carbon pricing through an Emission Trading System (ETS) seems straightforward but the current ETS has shown to have limited effect. Hydrogen Europe is in favour of including maritime in the ETS but this is only a part of the solution. The figure below is a calculation that Hydrogen Europe made showing the price of emission allowances that would be needed per ship type in order to trigger the uptake of hydrogen which is much higher than the current price of emission allowances. The red line shows the price of emission allowances at 50€ t/CO₂. The bars show the price that would be needed per ship type to have a real impact. Even including shipping in the ETS will not be enough to drive the technology revolution needed to achieve the IMO 2050 target.

Figure 10: EU Maritime decarbonisation policy initiatives



Hydrogen Europe supports including maritime in the ETS

On 16 September 2020 the European Parliament voted in favour of including maritime shipping under the EU ETS Directive starting in 2022. It calls for an ocean fund for the 2022-2030 period, financed by revenues from auctioning ETS allowances, which would be used to make ships more energy-efficient, to support investment in innovative technologies and infrastructure for decarbonising maritime transport, and to protect marine ecosystems impacted by climate change. The Commission would be required to assess any new global market-based emission reduction measures adopted by the IMO with respect to their ambition and environmental integrity.

Hydrogen Europe welcomes the vote in the European Parliament to include shipping in the EU ETS. The ocean fund is what is needed to trigger the uptake of hydrogen and boost hydrogen technologies. An extension of the EU ETS to maritime shipping should result in CO₂ reduction, limit carbon leakage, acceleration of the transition towards clean fuels, and not hamper the competitive position of the EU market.

An operating emission standard applying to all ships entering in EU ports

The European Parliament also adopted amendments requiring shipping companies to reduce on a linear basis their annual average CO₂ emission relative to transport work, for all their ships, by at least 40% by 2030 compared to 2018 levels, with penalties for non-compliance. In order to obtain data on transport work, the reporting of 'cargo carried' per voyage would remain mandatory. In addition, the amendments introduce environmental performance labelling of ships, and calls for inclusion of methane and other greenhouse gases besides CO₂, and better supply of shore-side electricity in ports.

Since the numbers tell the tale, Hydrogen Europe welcomes the initiative to have more robust data on emissions of all ships calling on EU ports in order to develop an emission standard.

FuelEU Maritime: not a black and white situation

Hydrogen Europe welcomes the initiative from the European Commission to accelerate the uptake of alternative fuels for maritime transport through the FuelEU Maritime initiative, which will lead to goods being delivered in the most sustainable way. Hydrogen has a significant role to play not only for maritime transport but also for other transport modes, industry, and energy consuming sectors.

Regarding the pathway to sustainable alternative fuels, Hydrogen Europe prefers goal-based performance requirements based on the carbon intensity of the energy used over mandating the use of specific sustainable alternative fuels.

The more open performance requirements are technology neutral which will lead to innovation. We acknowledge this could lead to uncertainty for sustainable fuel suppliers leading to investment uncertainty. Thus, while we prefer the performance requirement, it is not a black and white choice and very much depends on the details of the two options.

Requirements on the share of specific sustainable fuels could be an interesting tool if they include also zero-carbon non-blendable fuels such as hydrogen and possibly ammonia. The minimum share of sustainable fuels should therefore not be limited to a blending requirement, as that would exclude some alternative fuels (like ammonia or hydrogen) and would therefore not be truly technologically neutral. Furthermore, the requirements should be defined on a fleet level and not at individual ship level – as that would enable to fulfil the obligation more smoothly by introducing a number of zero-emission vessels.

Renewable energy sub-targets and multipliers are essential instruments to incentivise the uptake of renewables in the energy system and to close the financial gap between the cleaner yet more expensive option and its cheaper fossil alternative for end-customers. However, both instruments are interlinked. Sub-targets will result in an obligation to produce Renewable Fuels of Non-Biological Origin (RFNBO) and create a “push” in supply. In an emerging market, multipliers will create a stronger demand for RFNBO relative to the fossil alternative and create a “pull” effect. As such we advocate for an integrated framework, within the RED II whereby both instruments are aligned with each other and are mutually reinforcing.

Through the FuelEU Maritime initiative specific targets regarding the share of hydrogen and hydrogen-based-fuels in the total fuel demand for maritime sector can be set leading to more certainty for producers, distributors and infrastructure providers and consumers, therefore it is expected to be a strong piece of legislation.

The revision of the directive on alternative fuels infrastructure

The revision of the directive on alternative fuels infrastructure will play a crucial role for ports to become hydrogen hubs. We need to understand that clean hydrogen has to be produced and then transported affordably. The infrastructure is the backbone of our energy system; we need to ensure that the EU infrastructure policy is aligned with the EU Green Deal and creates an enabling framework for hydrogen infrastructure.

Ports will first need to develop a roadmap with the users of these fuels but also with the fuel producers and storage terminal to come to an agreement on the timelines, conditions for use, quantities, etc. Hence we ask for a roadmap approach regarding the Fuel EU maritime initiative and the revision on AFID.

We call for the establishment of a common regulatory framework to provide for the rapid expansion of hydrogen refuelling stations (HRSs) network across Europe. These HRSs will be used to supply hydrogen to small ships in ports, where these ships are being developed/used, and set the seeds for a dedicated hydrogen infrastructure.

There can be no chicken-and-egg dilemma: the deployment of infrastructure must occur alongside the deployment of ships. We should also think of conversion parks and required infrastructure in ports where electrolyzers convert renewable energy into green hydrogen for the supply of industrial plants and facilities to use the “waste streams”, heat and oxygen power-to-gas facilities for the conversion of electricity to hydrogen and if applicable further to synthetic gas in so far as they perform network-related functions.

A special effort on port operation

Air emissions stemming from auxiliary engines on ships in ports lead to local air pollution. There are several alternative ways to provide auxiliary power to ships in ports, the main one being cold-ironing which is the process of providing electrical power to a ship at berth while its main and auxiliary engines are turned off. This can be done through electricity from the shore which puts a heavy burden on the electricity grid since the power required is very high. Moreover, climate efficiency (CO₂-reduction per euro invested) of shore power depends strongly on the local circumstances of the port and the type of vessel (cruise ships, ferries, container ships or crane vessels, to name just a few).

Another way is to supply auxiliary power with fuel cells or dual-fuel hydrogen internal combustion engines that can be put on mobile barges or on shore. This is a much more flexible way to deliver auxiliary power to ships and is also an excellent way for ports to develop hydrogen refuelling infrastructure.

Hydrogen Europe is of the opinion that by 2030 hydrogen can provide auxiliary power to the majority of ocean-going vessels (build after 2025) in ports and that the EU should lay down the legislative pathway to make this possible.

The revision of the TEN-E regulation

The Trans-European Networks for Energy (TEN-E) regulation governs the development of energy related infrastructure. Since the adoption of the previous regulation, the EU energy policy has evolved and has set more ambitious 2030 and 2050 targets. The EU's infrastructure policy needs to become better aligned with the overall energy and climate ambitions of the Union.

The revised TEN-E should provide an enabling framework for the development of a hydrogen economy and hydrogen backbones. The retrofitting/conversion of existing gas infrastructure to transport hydrogen from production sites to demand centres such as ports, in particular, brings with it significant societal savings for the energy transition. It also offers a cheap and cost-effective option for transporting renewable energy.

Hydrogen Europe recommends the introduction of “clean hydrogen networks” as a new thematic area under the TEN-E regulation. Both new infrastructure projects as well as hydrogen transport (including pipelines, maritime, road and other) solutions, intermediate storage and associated infrastructure projects should be encompassed in the framework of TEN-E.

The synergies between the Trans-European Transport Networks (TEN-T) and the Trans-European Networks for Energy (TEN-E) should be explored further to make a direct link between the fuel source, the optimisation of the production, the use and transport of large quantities of hydrogen and the increase of hydrogen demand for the transport sector through the development of a hydrogen infrastructure network. When TEN-T and TEN-E corridors are aligned geographically, the HRS network should be strengthened. The goal of the TEN-T network should be a safe and sustainable EU transport system that promotes the seamless movement of goods and people.

The revision of the renewable energy directive (RED II)

The RED II should promote further development of renewables, and especially renewable hydrogen. However, the current iteration of the directive was drafted and agreed on in a different context and spirit to that of today. The EU Green Deal has set a clear pathway towards climate neutrality, and firmly underlines the importance of a well-balanced RED and a concerted regulatory environment that enables a positive investment environment for existing players and market challengers, to enable the scaling-up and deployment of hydrogen and hydrogen technologies.

Under RED II, each Member State must set an obligation on fuel suppliers to ensure that renewable energy makes up at least 14% of the energy used in that Member State in the transport sector. Specific sub-targets for hard to abate sectors (e.g., steel production, aviation and maritime) may also be considered in the upcoming revision of the RED to further incentivize and speed-up deployment and adoption of renewable energy in specific sectors and industrial segments.

When developing legislation and proposing targets and incentives, it is important to avoid duplication of efforts, as such if specific sectoral targets for maritime are proposed within the context of the RED II revision, they should always be coherent with any other targeted sectoral legislative initiatives e.g., FuelEU Maritime.

The current RED II directive does not acknowledge green hydrogen imports. In the absence of a system on guarantees of origin, the Commission should provide certainty for ports on how to deal with green hydrogen imports, otherwise this will represent a barrier. The same goes for import of hydrogen carriers.

We should ensure that an ambitious EU decarbonisation policy does not disadvantage EU industries but favours them!

In the past a lot of the shipbuilding has been transferred from Europe to Asia due to unfair competition rules and this process needs to be stopped. Fortunately, the EU still has a solid position in building complex ships and a strong value chain of shipping equipment suppliers. It also aims at being a champion of hydrogen technologies.

The EU maritime technology sector is strategic for Europe. It ensures access to trade at sea and enables the EU into the blue economy. Europe is a worldwide leader as far as complex ships are concerned and in the production of the required maritime equipment, systems, and technologies. This worldwide leadership has been maintained by continuous investments in R&D&I and professionalization of the workforce, against a strong competitive Asian pressure supported by state aid policies.

EU shipbuilders and maritime equipment companies are at the edge of innovation on greening technologies, thus abating GHG emissions and other air and water pollution. The competitive advantage is based on a knowledge-based economy that spans from industrial know-how to excellent research infrastructure and centres. Maritime operations are safely ensured by highly professionalised and skilled sea operators, thus representing a complex European ecosystem that may ensure the transformation towards a green economy occurs.

The European industrial network composed by shipbuilding and maritime equipment companies has the capability to address the challenge of decarbonising waterborne shipping, taking a world leadership on those components of the maritime value chain which will have the highest marginality on the medium/long term. For this reason, this EU ecosystem has to be supported against non-EU companies, whilst taking the lead of green technologies for maritime.

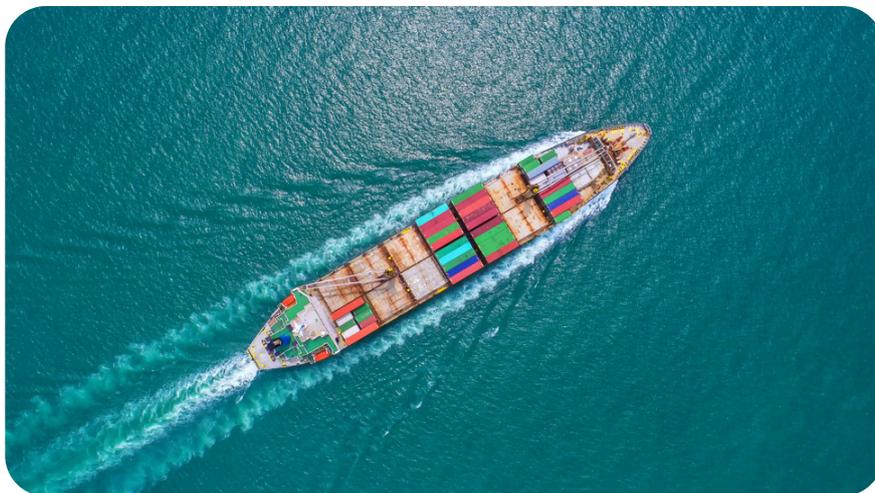
The rules that will trigger the uptake of hydrogen must be designed in such a way that they do not disfavour ships made in the EU but rather encourages the promotion and production of EU made zero-emission ships for which the EU industry has a competitive advantage. This is a win-win situation.

Immediate EU regulatory focus on decarbonising short-sea-shipping would be preferable in order to smooth the transition to zero-emission shipping.

The European short-sea-shipping industry possesses many strategic advantages over other regions because of its extensive coastlines. This brings opportunities for the European hydrogen industry. In Europe, market mechanisms are highly developed, there is an after-market for ageing vessels, and the technology is impressive. Short-sea-shipping in Europe faces challenges but it has proven to be innovative and viable with vigorous competition in most of its sectors.

In Europe many fast ferries are constructed and operated by European-based companies. This focused interest originates from the ever-increasing value of time to deliver goods from A to B and the funds needed for such investments. Faster and greener short sea ships can bring new opportunities for the hydrogen sector in Europe.

We are moving into an era where globalisation is no longer the issue. We will see more short-sea-shipping and local manufacturing short sea is the perfect way to test new forms of technology as they do not spend as much time at sea as deep-sea ships.





SUPPORTING INNOVATION

Ambitious R&I programmes are not enough

As presented, the shipping sector encompasses a wide range of ship types each with their advantages and disadvantages for hydrogen technology. This variety highlights the importance of defining different strategies for hydrogen as a fuel for each vessel type. The most crucial bottleneck with hydrogen as a fuel is not the production of renewable hydrogen or the end-point use but rather the storage both onshore and onboard the vessels. Power and autonomy are the key determining factors in this regard. Two joint undertakings will cooperate on this: the Clean Hydrogen for Europe (CHE) will focus on hydrogen technology building blocks, which will be then used by the Zero Emission Waterborne Transport (ZEWT). CHE will research, develop and demonstrate technologies to incorporate operational experience, but will do so for applications which are suitable for first movers and create synergies with for instance mobility and stationary sectors to increase the impact.

Europe's diversity offers enormous strength if it can be harnessed and strategically guided, but European policy, research and development are presently fragmented both within and across the different countries.

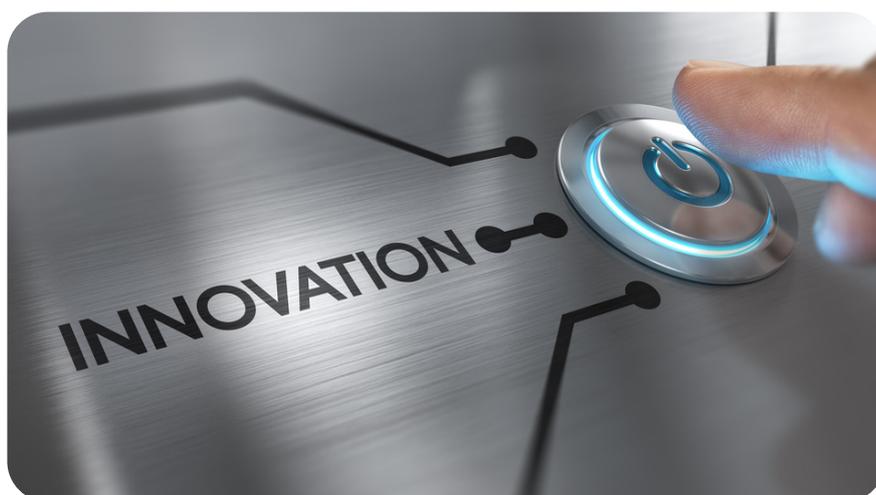
ETS to fund first movers

Without action first movers are disadvantaged by paying and taking the risk without any rewards while others wait for a reduction of cost and of investment uncertainty before investing in the technology. We believe shipping should be incorporated into the EU ETS and that 50% of the income generated should be channelled back to the sector to finance innovation and first movers. It will be necessary to generate a fund, such as the green ocean fund under the EU-ETS, as soon as possible that rewards first movers and that allows the maritime sector to benefit from the allocation of sufficient funds to innovate. The revenues of the fund could be used to finance the uptake of energy saving technologies on ships, bunkering/charging infrastructure for zero-carbon fuels/energy in European ports and subsidising the uptake of zero-carbon fuels by ships via carbon contracts for difference.

The European Commission should adopt an integrated approach in EU funding instruments to make sure that new bunkering infrastructure, as well as technology on board and vessels, can be stimulated simultaneously, preferably in the same subsidy call. Only in this way can we overcome the chicken-and-egg problem and stimulate the commercial scale up of low carbon fuels, clean energy and energy carriers.

The moderate price level of the EU ETS and the uncertain price development does not provide sufficient incentives for significant investments in innovative climate-friendly options. Carbon Contracts for Differences offer the opportunity to guarantee investors in innovative climate-friendly technologies and practices a fixed price that rewards CO2 emission reductions above the current price levels in the EU ETS.

Climate targets can only be achieved with a shift to new technologies. Putting a price on shipping carbon emissions would be a welcome first step in establishing a regulatory framework, provided that the revenues flow back to the maritime sector where it can act as an important driver for necessary investments in sustainable fuels and innovative techniques on board.





TECHNICAL REGULATION ALLOWING THE INTRO OF NEW FUELS AND ENERGY CONVERTERS

In the absence of IMO regulation on how to build hydrogen fuelled ships safely, classification societies currently approve the use of other low flashpoint fuels including hydrogen-based on alternative design. The alternative design is the process by which the safety, reliability and dependability of the systems must be demonstrated to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery. The development of specific rules allowing for the type approval of hydrogen and fuel cell vessels at international level as well as for inland transport in EU waterways is needed in order for this sector to develop. Classification societies should group common practices for approval at a certain stage and use these as a standard development route for fuel cell systems in ships. In this regard standardisation of hydrogen storage is also considered a key element.

Regarding bunkering and infrastructure, the development of national regulation has proven to be a barrier to the uptake of alternative fuels. Especially for short sea shipping harmonisation of regulation/guidelines on e.g., bunkering (the ship-shore interface) needs to start now. A robust and sound alternative fuel framework both at IMO, European, national and local level is a prerequisite for the uptake of hydrogen in shipping.

Many lessons can be learned from the introduction of LNG as a fuel for ships prior to the implementation of the 0.1% Sulphur limit in the Emission Control Areas (ECAs) in 2015. Back then the mitigation of pollutants (SO_x, NO_x and PM) was the main focus of EU member states and ports, while CO₂ has now become the key element to tackle.

In this context LNG was regarded as a promising alternative fuel for the transition towards more sustainable shipping. The IMO focused on developing a code (IGF-code) allowing ships to burn LNG safely but could not consider the ship-shore interface (bunkering) and issues such as safe loading and unloading of ships while bunkering, standardisation of connectors, methane slip, etc. In order to give certainty to shipowners that they could bunker LNG in a similar way to HFO/MGO (Heavy Fuel Oil/Marine Gas Oil) the EU published bunkering guidelines for LNG-fuelled ships in 2018. Port authorities have welcomed this but are bound by own local stricter regulations. Uncertainty about the availability of LNG in ports led to more uncertainty.

Hydrogen Europe would like to highlight the lessons learned from the experiences of LNG as a fuel for ships in developing a faster, new and effective harmonised frameworks at EU level (e.g., on standardization, harmonization of local rules) and robust regulation on SAF (Sustainable Alternative Fuels) infrastructure for alternative fuels where hydrogen is given a prominent role. We encourage the IMO to start developing technical regulations for ships powered by hydrogen and hydrogen-based fuels such as ammonia.



OUR POLICY RECOMMENDATIONS

The IMO discussions on the decarbonisation strategy are progressing but this must accelerate in order to meet the Green Deal objectives of carbon neutrality by 2050. If the EU aims to reduce emissions overall by 55% in 2030 relative to 1990, a shift from fossil fuels to zero-carbon fuels for shipping will be required. As the lifetime of ships is high, the introduction of zero-emission vessels must start now.

The European Commission has acknowledged the importance of taking the lead in decarbonizing the maritime sector very clearly in its communication on a sustainable and smart mobility strategy (SSMS), laying down the priorities in the transport sector for the next ten years. This includes a target of zero-emission marine vessels market-ready by 2030, boosting the use of renewable fuels in the maritime sector as well as an emphasis on the creation of zero-emission ports. In the European Green Deal Communication, the Commission affirms its focus on the production and deployment of sustainable alternative transport fuels for the different transport modes. The SSMS is a unique opportunity to illustrate how hydrogen technologies can support, in a cost-effective manner, the achievements of the EU Green Deal ambitions to reach carbon neutrality by 2050.

Hydrogen Europe has developed this maritime policy paper aiming at showcasing the importance of an ambitious maritime EU-policy to address those challenges. This paper contains policy requests on EU initiatives such as the necessity to include the maritime sector in the European Emission Trading system as well as setting targets on the demand of hydrogen and hydrogen-based fuels. This paper does not only contain policy requests. An ambitious EU maritime decarbonization policy can succeed if the known and unknowns that are inherent to the energy transition are identified.

In order to identify the gaps Hydrogen Europe will have a coordinating role at EU level by bringing all stakeholders (including shipowners, shipbuilders, classification societies, fuel producers and providers, ports authorities) together to ensure the development of a coherent and robust maritime alternative fuels policy. Cooperation between all stakeholders should ultimately be coordinated at EU level, where new obligations for fuel use and infrastructure could be introduced after a certain threshold is met.

The fuels of the future need to be future-proof. There are many potential alternative fuels for shipping, but not all such as biofuels are equally promising. Therefore, the solutions, to be stimulated by the FuelEU Maritime initiative, need to be sought out among technologies that can be both sustainable and scalable. **Hydrogen Europe will encourage the development of legislation that is long-standing.**

The role of ports will be pivotal. The pace in which the maritime sector can decarbonise very much depends on how fast ports will be able to store sufficient amounts of green hydrogen and hydrogen-based fuels. **Ports will become hydrogen hubs or “hydrogen valleys”** where hydrogen can be produced or imported, stored and distributed for use in different applications to ensure smooth sustainable transition pathways for ports, coalitions or framework agreements should be developed by key stakeholders to develop roadmaps and timelines.

In order to speed up the process of ports become zero emission ports, **Hydrogen Europe is of the opinion that by 2030 hydrogen can provide auxiliary power to the majority of ocean-going vessels (build after 2025) in ports and that the EU should lay down the legislative pathway to make this possible.**

Hydrogen Europe supports the policy initiatives that different DGs of the European Commission are working on aiming at decarbonising the maritime sector. A word of caution: **although there is no silver bullet to decarbonise the maritime sector, we cannot afford to have a patchwork of legislation and regulations and need a European regulatory framework with clear and ambitious obligations for the use of hydrogen and hydrogen-based fuels by 2025 and 2030 in the maritime sector.**

We find the FuelEU Maritime initiative which will focus on ramping-up the production, deployment and uptake of sustainable alternative marine fuels very promising. **The initiative will have direct implications for alternative fuel infrastructures and must therefore be well-aligned with existing legislation also under review,** specifically the revised Alternative Fuels Infrastructure Directive will need to take this into account, as it will require targeted and effective investments in ports.

Through the FuelEU Maritime initiative specific targets regarding the share of hydrogen and hydrogen-based-fuels in the total fuel demand for maritime sector can be set leading to more certainty for producers, distributors and infrastructure providers and consumers, therefore it is expected to be a strong piece of legislation.

Hydrogen Europe also welcomes the vote in the European Parliament in September 2020 to include shipping in the EU ETS. Putting a price on carbon emissions of shipping through the EU-ETS would be a welcome step in establishing a regulatory framework for the decarbonisation of this sector, but only provided that the auctioning revenues flow back to the maritime sector through the Ocean fund which can act as an important driver for necessary investments in sustainable fuels, innovative techniques, and retrofiting.

An extension of the EU ETS to maritime shipping should result in CO2 reduction, limit carbon leakage, accelerate the transition towards clean fuels, and not hamper the competitive position of the EU market.

We call for the establishment of a common regulatory framework to provide for the rapid expansion of hydrogen refuelling stations network across Europe. These hydrogen refuelling stations (HRS) will be used to supply hydrogen to small ships in ports, where these ships are being developed/used, and set the seeds for dedicated hydrogen infrastructure. **There can be no chicken-and-egg dilemma: the deployment of infrastructure must occur alongside the deployment of ships.**

The synergies between the Trans-European Transport Networks (TEN-T) and the Trans-European Networks for Energy (TEN-E) should be explored further to make a direct link between the fuel source, the optimisation of the production, use and transport of large quantities of hydrogen and the increase of hydrogen demand for the transport sector through the development of hydrogen infrastructure network. **When TEN-T and TEN-E corridors are aligned geographically, the HRS network should be strengthened.**

When developing legislation and proposing targets and incentives, it is important to avoid duplication of efforts; as such if specific sectoral targets for maritime are proposed within the context of Renewable Energy Directive (RED) revision, they should always be coherent with any other targeted sectoral legislative initiatives e.g., RE Fuel Maritime.

The current RED2 directive does not acknowledge green hydrogen imports. **In the absence of a system on guarantees of origin, the commission should provide certainty for ports on how to deal with green hydrogen imports,** otherwise this will represent a barrier. The same goes for import of hydrogen carriers.

The European Commission should adopt an integrated approach in EU funding instruments to make sure that new bunkering infrastructure, as well as technology on board and vessels, can be stimulated simultaneously, preferably in the same subsidy call. Only in this way can we overcome the chicken-and-egg problem and stimulate the commercial scale up of low carbon fuels, clean energy and energy carriers.

Hydrogen Europe highlights the lessons learned from passed attempts to accelerate the uptake of alternative fuels in developing new and effective harmonized frameworks at EU level (e.g., on standardisation, harmonisation of local rules) and robust regulation for alternative fuels where hydrogen is given a prominent role. **We encourage the IMO to start developing technical regulations for ships powered by hydrogen and hydrogen-based fuels such as ammonia.**



FINAL REMARKS

Hydrogen, hydrogen-based fuels (such as ammonia) and hydrogen technologies offer tremendous potential for the maritime sector and, if properly harnessed, can significantly contribute to the decarbonisation and also mitigate the air pollution of the worldwide fleet. Hydrogen Europe will be the catalyst in this process.

The pathway towards hydrogen and hydrogen-based fuels for the maritime sector does not come without technological and commercial challenges let alone regulatory barriers. Hydrogen Europe has developed this maritime policy paper aiming at showcasing the importance of an ambitious maritime EU-policy to address those challenges. As the lifetime of ships is high, the introduction of zero-emission vessels must start now.

Without action first movers are disadvantaged by paying and taking the risk without any rewards while others wait for a reduction of cost and of investment uncertainty before investing in the technology. It will be necessary to include the maritime sector in the ETS and generate a fund, such as the green ocean fund, as soon as possible that rewards first movers and that allows the maritime sector to benefit from the allocation of sufficient funds to innovate. Finding first mover will not be enough. Through the FuelEU Maritime initiative specific targets regarding the share of hydrogen and hydrogen-based-fuels by 2030 in the total fuel demand for maritime sector will need to be set.

The scale of investment needed on the side of infrastructure is huge. The pace in which the maritime sector can decarbonise very much depends on how fast ports will be able to store sufficient amounts of green hydrogen and hydrogen-based fuels. Ports will become hydrogen hubs or “hydrogen valleys” where hydrogen can be produced or imported, stored and distributed for use in different applications to ensure smooth sustainable transition pathways for ports, coalitions or framework agreements should be developed by key stakeholders to develop roadmaps and timelines.



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