# The Decarbonisation of Shipping amid Coronavirus and IMO Sulphur 2020: The cases of LNG and Ammonia

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## Introduction

The maritime industry plays an essential role in the global economy as it is responsible for the shipping of over 90 per cent of the world's total trade. Without it, the commerce of affordable food and goods would simply not be possible. In 2018, the transport volume of seaborne commerce amounted to 11 billion metric tons, some 2.7 per cent increase to 2017[1]. Maritime shipping continues to stand as the most cost-effective method of transportation for all sorts of goods, from raw materials and commodities such as fuel oils to end products. Currently, the world merchant fleet counts over 50.000 registered ships, of which about five thousand are container ships sailing oceans and seas to carry cargoes from one nation to another[2]. The vast majority of vessels run on dirty fuels.

Accordingly, the shipping industry is held up as a significant emitter of carbon dioxide (CO2) as well as other pollutants such as particulate matter (PM), nitride oxide (NOx) and sulphur oxide (SOx). These substances not only contribute to the concentration of greenhouse gases (GHGs) in the atmosphere but also are significantly toxic to humans and the environment. A report by the International Council on Clean Transportation (ICCT) estimates the world merchant fleet is directly responsible for around 932 million tonnes of carbon dioxide (CO2) emissions, or 2.6 per cent of the total global emissions every year[3]. Nonetheless, shipping has historically represented an exception to environmental policies and regulatory frameworks. As a result, their levels of pollution have remained substantially unchecked, and no incentives towards zero-carbon models of development have been laid out.

For this reason, in recent years, the International Maritime Organisation (IMO) has taken the lead in the effort to curb seaborne trade emissions. In this regard, the Sulphur 2020 initiative introducing a ban to dirty marine fuels lays out the basis for a more profound reform of the maritime sector likely to involve the switch to alternative fuels. Entered into force on March 1, 2020, the regulation is part of the 2018 IMO project to halve shipping emission by 2050, relative to levels in 2008. It is also the last of the three waves of turbulence affecting the marine fuels market since the beginning of this year. The other two originated from exogenous factors such as the COVID-19 pandemic outbreak and the Saudi-Russian oil price war, which combined have made the global petroleum demand plummet

[1] Statista Research Department, "Transport volume of worldwide maritime trade 2008-2018", *Statista* (23 March 2020), https://www.statista.com/statistics/264117/tonnage-of-worldwide-maritime-trade-since-1990/#:~:text=Transport%20volume%20of%20worldwide%20maritime%20trade%202008%2D2018&text=In%202018%2C%20global%20seaborne%20trade,ocean%20freight%20forwarder%20in%202018.

[2] UNCTAD, "Review of Maritime Transport 2019", *United Nations publication*, Sales no. E.19.II.D.20. (2019). Available at https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

[3] Olmer et al., "Greenhouse gas emissions from global shipping, 2013-2015", *The International Council on Clean Transportation* (October 2017), https://theicct.org/sites/default/files/publications/Global-shipping-GHG-emissions-2013-2015_ICCT-Report_17102017_vF.pdf

drastically. In light of the current downturn, many believe the time has come for the industry to adopt innovative solutions to curb emissions.

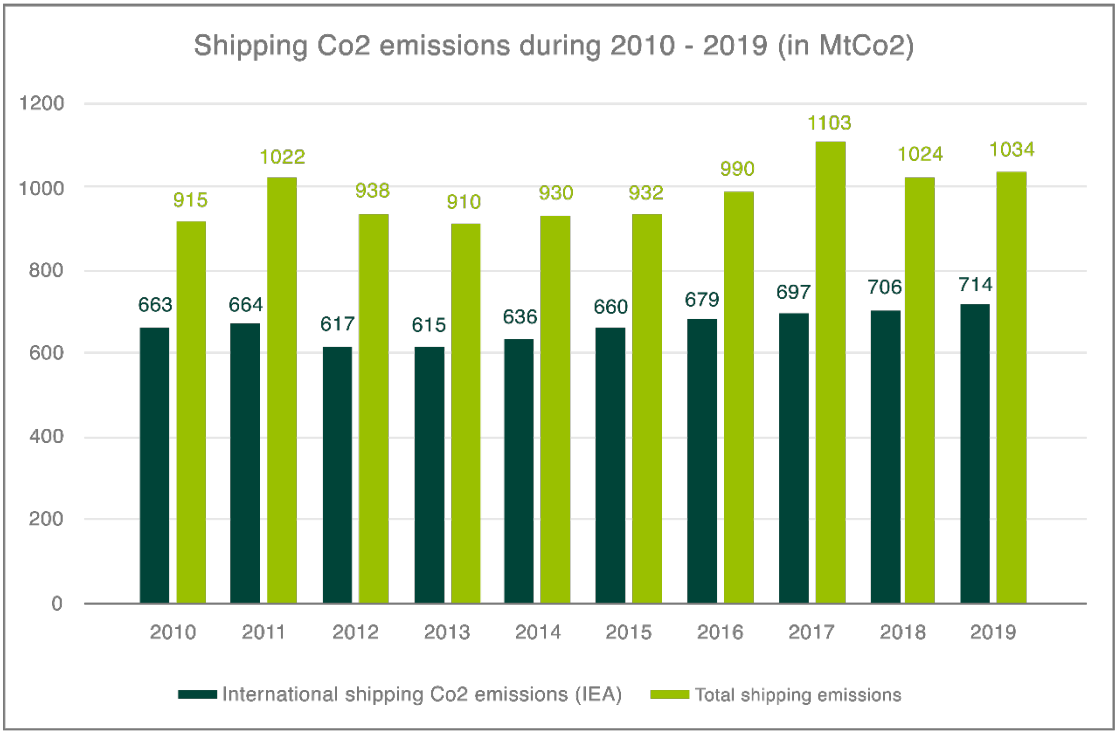
This report aims to shed some light on the international bid for the decarbonisation of the maritime shipping in light of the developments linked to the COVID-19 pandemic, the grim future outlook of the global economy and oil markets. It suggests the sector has a vast opportunity to re-design itself more sustainably. Notably, by investing in alternative bunker fuels such as Liquified Natural Gas (LNG) and carbon-free Ammonia which, over the years, are likely to demonstrate more competitiveness ever compared to conventional propellants.

## The IMO and its efforts to reduce shipping emissions

The Marine Environment Protection Committee (MEPC) is IMO's senior technical body on marine pollution-related matters. Its primary focus revolves around the prevention of marine pollution by oil. In 1973, the MEPC adopted the International Convention for the Prevention of Pollution from Ships (MARPOL), the first-ever overarching antipollution convention. The MARPOL has undergone many changes throughout the last decades to incorporate requirements for ships to address pollution from other materials as well as, under an ANNEX VI adopted in 1997, air pollution and harmful emissions[4].

In 2018, the IMO adopted a strategy to reduce greenhouse gas (GHG) emissions from maritime shipping. By setting a series of milestones through 2050, the IMO envisages an overall emissions reduction of at least half by 2050, compared with 2008 levels[5]. Arguably, this strategy makes up for the policy gap at the international stage since governments had previously failed to bring aboutaction plans to reduce shipping emissions; even in specific fora such as the 2015 COP 21. As a result, emissions remained flat throughout the last decade.

[4] Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005)
[5] Schiutmaker et al., "International Maritime Organisation agrees to first long-term plan to curb emissions", *Reuters* (13 April 2018), https://www.reuters.com/article/us-maersk-emissions/worlds-largest-container-shipper-maerskaims-to-be-co2-neutral-by-2050-idUSKBN1O40QW#:~:text=Denmark's%20Maersk%20said%20on%20Wednesday,emissions%20to%20zero%20by%202050.




*Graph 1: CO2 Emissions from Shipping throughout the last decade (ICCS; IEA; IMO and author estimations, 2020)*

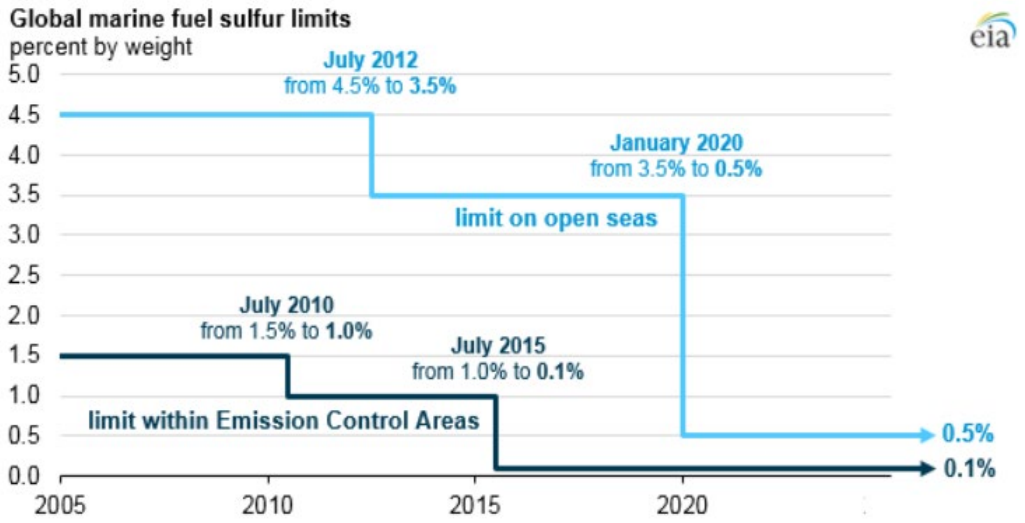
Concerning the European Union, seaborne trade was initially left out the notorious Emissions Trading System (EU ETS), the framework through which the EU aims to decarbonise large parts of its economy. Yet, the European Green Deal set out by the European Commission in December 2019 pledges to extend the EU ETS to the shipping industry along with other initiatives to further decarbonise the sector[6]. The EU and its Member States played an essential role in promoting the IMO strategy to halve GHG emissions from shipping. Notably, for vessels worldwide mainly rely on dirty fuels such as High Sulphur Fuel Oil (HSFO). According to Wood Mackenzie, seaborne trade burns about 3.5 million b/d of HSFO, accounting for some 6 per cent of global fuel demand[7]. This type of fuel consists of a fraction obtained from petroleum distillation and characterised by high viscosity and sulphur content of about 4.5 per cent m/m. For comparison, the sulphur content of fuels used in trucks or passenger cars does not exceed 0.001%[8]. It is, therefore, the densest fuel in commerce, yet the most suitable for medium

[6] Morgan, "EU starts to chart shipping's new green course", *EURACTIV*, 13 February 2020 (27 February 2020). Available at https://www.euractiv.com/section/shipping/news/eu-starts-to-chart-shippings-new-green-course/
[7] Thompson, "IMO 2020 is about to get real", *Wood Mackenzie* (2 December 2019), https://www.woodmac.com/news/opinion/imo-2020-is-about-to-get-real/
[8] European Commission, "Cleaner Air in 2020: 0,5% sulphur cap for ships enters into force worldwide", *European Commission* (3 January 2020). Available at https://ec.europa.eu/transport/modes/maritime/news/2020-01-03-sulphur-cap_en

and low-speed ship engines. Although ships usually use blends of heavy fuels and distillates, also referred to as marine diesel oils (MDOs) or "intermediate fuels oils", these cannot be processed by larger vessels. For their bulk necessitates heavier fuel oils with a higher energy density. More in general, the combustion of HSFOs and high sulphur-content MDOs releases not only more copious quantities of CO2 but also emits treacherous Nitride oxide (NOx) and Sulphur oxide (SOx). The latter is extremely toxic for the human body and the environment as they cause acid rains, a phenomenon often occurring in the proximity of vulnerable coastal areas such as seaports. To cut these emissions, on January 1 2020, the International Maritime Organisation issued a regulation named "IMO Sulphur 2020".

## The IMO Sulphur 2020 regulation

The IMO Sulphur 2020 lies on resolution MEPC. 305 (73) bringing about amendments to the IMO MARPOL Annex VI on the "Prohibition on the carriage of non-compliant fuel oil for combustion purposes for propulsion or operation on board a ship"[9]. The resolution was first adopted on October 26, 2019, and officially entered into force on March 1, 2020. It imposes requirements for vessels to limit the sulphur content of fuel oil to 0.50 per cent m/m (mass per cent concentration) down from 3.5 per cent m/m. Besides, it further reduces the limit from 0.5 per cent m/m to no more than 0.1 per cent m/m for ships operating in the four IMO-designated Shipping Emission Control Areas (SECAs): the Baltic Sea, the North Sea, North America and the US Caribbean.




*Graph 2: Marine Fuel Sulphur Limits (U.S. EIA, 2019)*[10]

[9] International Maritime Organisation, Resolution MEC.305(73) (adopted on 26 October 2018). Available at http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-%28MEPC%29/Documents/MEPC.305%2873%29.pdf

[10] U.S. Energy Information Administration, "The Effects of Changes to Marine Sulfur Limits in 2020 on Energy Markets", U.S. Energy Information Administration (March 2019) Available at https://www.eia.gov/outlooks/studies/imo/pdf/IMO.pdf

The IMO expects the Sulphur 2020 regulation to bring about several beneficial changes to maritime shipping. Notably, by helping curb some 8.5 million metric tons of Sulphur Dioxide (SO2) emissions on an annual basis, thus reducing the negative impacts that these emissions have on human health and the environment[11]. However, compliance with the Sulphur 2020 undoubtedly carries some challenges for the industry in general. Not only shipowners are called to change their business models, but also upstream refineries and infrastructures would have to accommodate changes in the bulk feedstock particularly when alternative and carbon-free bunker fuels are expected to gain momentum out of this regulation. To partly address these concerns, the IMO issued guidance on best practices for flag and port States with regards to the actions they would need to take to make sure ships are compliant[12].

## The compliance with IMO Sulphur 2020 and the use of "scrubbers"

Earlier this year, experts predicted that higher shares of Very-Low Sulphur Fuel Oils (VLSFOs), Ultra-Low Sulphur Fuel Oils (ULSFOs) and low-sulphur content MDOs in the market would translate into higher costs and therefore higher prices for goods[13]. Accordingly, significant suppliers started to clean out their storage tanks and barges from HSFO to free space up for VLSFOs[14]. However, even though IMO's regulations specifically intend to reduce the sulphur content of fuel oils used or carried on board ships, it does not unequivocally ban the use of HSFOs. Hence, shipowners could continue to burn it provided they fit “scrubbers" on their ships. Scrubbers are Exhaust Gas Cleaning Systems (EGCS) which filter sulphur out of the combustion process by spraying alkaline water into a vessel's exhaust to minimise both NOx and SO2 emissions[15]. Although doubts remain as to whether these devices are environmentally friendly, they constitute a much cost-effective solution, especially for shipowners would not need to re-design their fleets nor install ad hoc engines for alternative fuels to comply with IMO regulations.

The installation of scrubbers can cost US$3m to US$ 5m, and reach as high as US$ 10m depending on the size of the vessel. Conversely, the switch to VLSFO involves huge CAPEX (new engine suitable to

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[11] International Chamber of Shipping, “Guidance to Shipping Companies and Crews on Preparing for Compliance with the 2020 ‘Global Sulphur Cap’ for Ships’ Fuel Oil in Accordance with MARPOL Annex VI”, *Marisec Publication*, third ed. (July 2019). Available at https://www.ics-shipping.org/docs/default-source/resources/guidance-for-compliance-with-the-2020-global-sulphur-cap-july-2019.pdf?sfvrsn=24

[12] International Maritime Organisation, “IMO 2020 Consistent Implementation of MARPOL ANNEX VI “, *IMO Publishing* (2019). Available at http://www.imo.org/en/Publications/Documents/Newsletters%20and%20Mailers/Mailers/I666E.pdf

[13] Wood Mackenzie, “IMO 2020, mayhem or opportunity”, *Wood Mackenzie* (1 January 2020). Available at https://www.woodmac.com/nslp/imo-2020-guide/

[14] Lloyd’s List, “Cheaper fuel drives change in shipping routes”, *Lloyd’s List* (28 April 2020). Available at https://lloydslist.maritimeintelligence.informa.com/LL1132115/Cheaper-fuel-drives-change-in-shipping-routes

[15] Costas, “Maritime Emissions Rule Triggers Split in Shipping Costs”, *Wall Streat Journal* (20 December 2019). Available at https://www.wsj.com/articles/maritime-emissions-rule-triggers-split-in-shipping-costs-11576839601#:~:text=%E2%80%9CThe%20scrubbers%20cost%20us%20between,to%2018%20months%2C%E2%80%9D%20Mr.

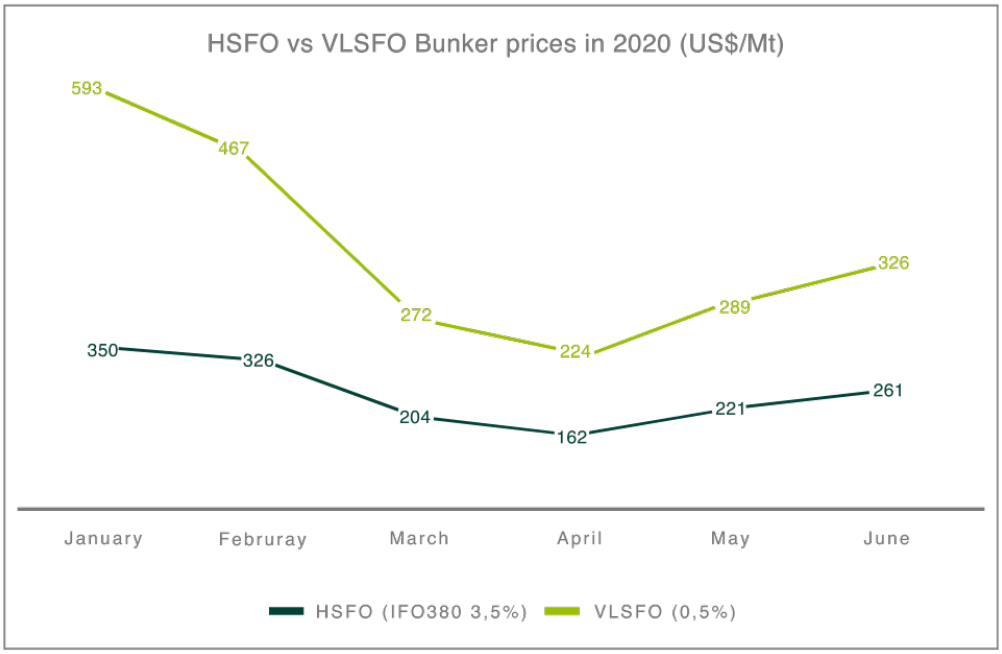
low-sulphur content fuels, tanks and extra design challenges) as well as higher refilling cost than traditional HSFOs[16]. As a reference, before the oil demand slump, VLSFO's price averaged some USD$ 250/Mt higher than HSFO's. For this reason, it does not come as a surprise that as IMO Sulphur 2020 entered into force, scrubbers looked like a preferable option[17].

From an ecological standpoint, concerns lay on the fact that scrubbers can release high quantities of pernicious waste into waters. Such waste-water needs to be disposed of correctly to avoid a harmful impact on the marine environment. Within the EU, the Landfill Directive (1999) imposes the collection of liquid, leaching, and reactive waste types at seaport facilities until final disposal[18]. When it comes to the costs of waste-water removal, several variables need to be taken into account. For example, depending on the contamination level, expenditure can average between USD$ 30 to 100/m3)[19]. Besides, the quality of services provided by seaports widely varies from one to another. As an example, the Port of Rotterdam ranks quite high in terms of waste-water management, for it relies on the expertise of third firms to handle the issue[20]. There are primarily two types of scrubbers - open-loop or close-loop - although hybrid models are also available. Open-loop scrubbers, in particular, have been recently under scrutiny due to their ability to reduce pollution[21]. Hence, increasing numbers of national, sub-national, and local regions prohibit the use of such devices within their territorial waters. Amongst them, Malaysia, China, Singapore, and the port of Fujairah in the UAE, but also Belgium, Germany, Lithuania, Latvia, Ireland, Norway and parts of the US[22] .

[16] Ibid.
[17] Olufunwa, "IMO 2020: scrubbers - a good investment?", *Holman Fenwick Willan* (2019). Available at https://www.hfw.com/IMO-2020-Scrubbers-A-good-investment
[18] Council Directive 1999/31/EC, Article 2(c)(i)(k)(q), Article 3 and 5
[19] Costas, "Maritime Emissions Rule Triggers Split in Shipping Costs", *Wall Streat Journal* (20 December 2019). Available at https://www.wsj.com/articles/maritime-emissions-rule-triggers-split-in-shipping-costs-11576839601#:~:text=%E2%80%9CThe%20scrubbers%20cost%20us%20between,to%2018%20months%2C%E2%80%9D%20Mr.
[20] Port of Rotterdam, "Scrubber Waste Collection in order in Rotterdam", *Port of Rotterdam* (06 December 2019). Available at https://www.portofrotterdam.com/en/news-and-press-releases/scrubber-waste-collection-in-order-in-rotterdam
[21] Saraogi, "Debunking: the problem of ships using open-loop scrubbers", *Ship Technology* (8 January 2020). Available at https://www.ship-technology.com/features/open-loop-scubbers/
[22] Britannia P&I, "List of Jurisdictions Restricting or Banning Scrubber Wash Water Discharges", *Britannia P&I* (27 January 2020) Available at https://britanniapandi.com/blog/2020/01/27/list-of-jurisdictions-restricting-or-banning-scrubber-wash-water-discharges/

## The COVID-19 impact on the marine fuel market

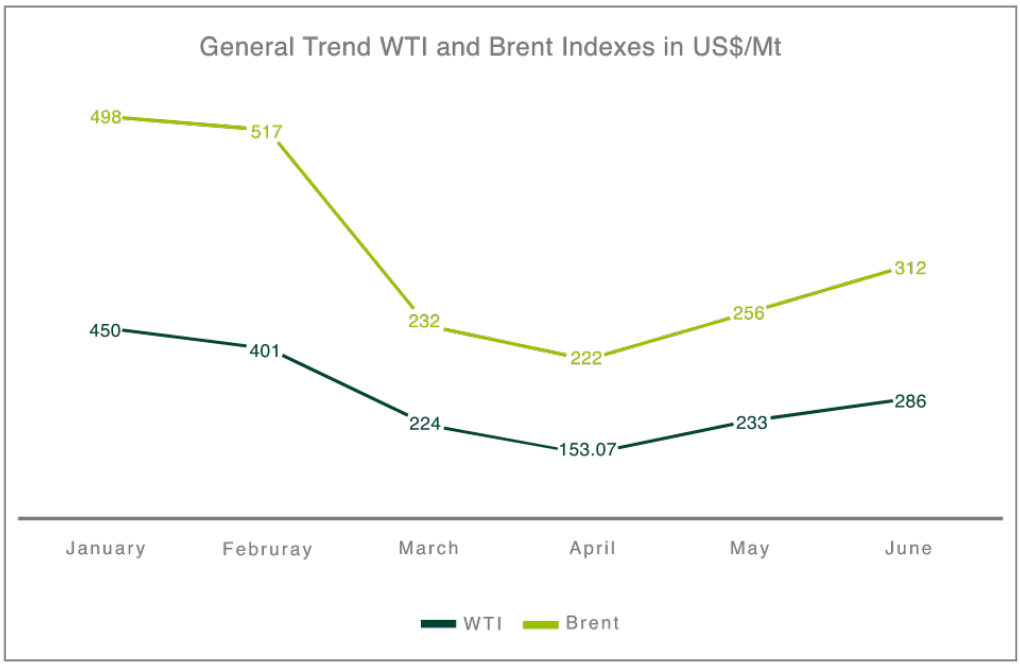
In the oil market, HSFOs are mostly leftover products historically traded for below the price of the crude. As an example, through the last quarter of 2019, as the world was approaching to the IMO Sulphur 2020 regulations, HSFO discount versus crude oil grew more profound since the former had lost value in the eyes of traders. In November last year, HSFO averaged US$ -30/barrel and its premium discount was some US$ 200/barrel[23]. Since its outbreak earlier this year, the COVID-19 has been severely affecting the global economy. Due to movement restrictions, international trade has been suffering significant disruptions with the maritime industry also paying a hefty bill. In the early stages of the pandemic, as petroleum demand shrunk worldwide, prices of marine fuels swiftly traced crude oil down to historic lows. According to Lloyd's List, from January to April, VLSFOs losses outpaced HSFOs', thus marking a drop in the VLSFO-HSFO discount[24]. In April, cuts in the supply of medium/heavy sour crudes following the OPEC++ agreement eventually pulled HSFO further up towards VLSFO rates, thus tightening its availability at European ports.




*Graph 3: Av. 20 biggest ports HSFO (IFO380 3.5%) and VLSFO price fluctuations in 2020 (Ship&Bunker, 2020)*

[23] Sardana, "A much-maligned corner of the oil market is a rare winner during the coronavirus pandemic", *Markets Insider* (15 May 2020). Available at https://markets.businessinsider.com/news/stocks/oil-coronavirus-hsfo-price-jumps-amid-pandemic-supply-cuts-2020-5-1029206084#

[24] Wittels, "Oil's worst product gives refineries a little bit of good news", *Bloomberg News* (14 May 2020). Available at https://www.bloomberg.com/news/articles/2020-05-14/oil-s-worst-product-gives-refineries-a-little-bit-of-good-news




*Graph 4: WTI and Brent Indexes in 2020 (Yahoo Finance, 2020)*

For shipowners who opted for fitting scrubbers, this was just about bad timing. Whereas before the crisis it would have been much more valuable to continue to rely on HSFOs, COVID-19 turned the tables indefinitely. In Rotterdam, the so-called crack spread, a key measure of how much shipowners can save by using emissions cleaning systems, narrowed down from US$ 298/Mt in January to US$ 39.5/Mt on average in June. As a result, incentives to invest in scrubbers dried up and shipowners saw their payback time lengthening quite consistently[25].

[25] Lloyd's List, "Marine fuel market must prepare for a new 'normal'", *Lloyd's List* (26 May 2020). Available at https://lloydslist.maritimeintelligence.informa.com/LL1132452/Marine-fuel-market-must-prepare-for-a-new-normal

## The rise of alternative fuels: The cases of LNG and Ammonia

The current downturn in the world economy and the grim outlook for oil markets suggest the shipping industry has an unprecedented chance to steer towards greener solutions. There is no reason to believe the switch to IMO Sulphur 2020-induced VLSFOs or even ULSFO, would help mitigate shipping environmental externalities. Let alone meet IMO 2050 targets. In light of this, experts predict there will be an increasing number of vessels powered by Liquified Natural Gas in the coming years. Furthermore, the industry could well embark itself in a more profound break away from fossil fuels, thus welcoming the use of carbon-free propellants. Technological developments and falling costs, for example, have made hydrogen a more accessible fuel now than it used to be just a few years ago. In particular, the use of ammonia, a derivate of hydrogen, is highly regarded as the perfect vector to meet the IMO 2050 target of a fully decarbonisation of the maritime industry.

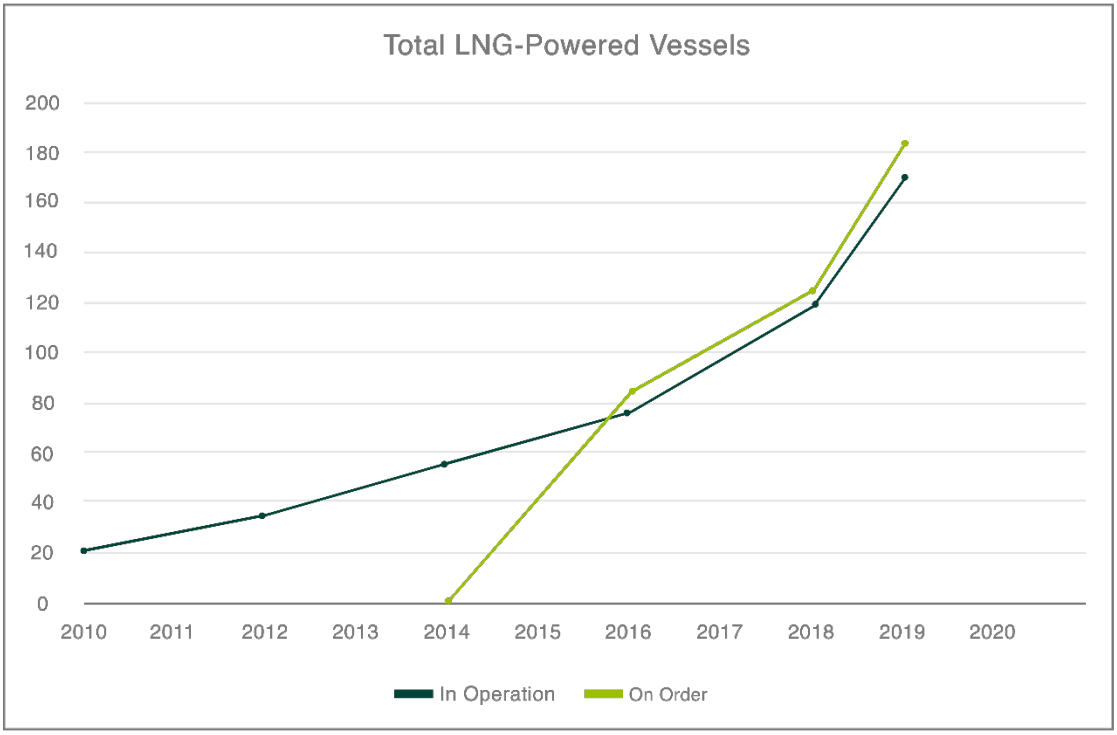
### LNG: A well-known bridge fuel

The experts have long deemed liquified Natural Gas (LNG) as the bridge fuel of choice. Concerning maritime shipping, it owns a high potential for replacing fuel oils as a low-sulphur content bunker fuel, especially in the short-to-medium term. On the one hand, its combustion emits just a negligible quantity of sulphur dioxide as well as up to 25 per cent less CO2 and some 90 per cent less nitrogen oxide (NOx) emissions, which makes it perfectly adherent to the IMO Sulphur 2020 regulation. On the other, as the price of natural gas decreases and both the technological and infrastructural costs continue to fall, the prospect to substitute HSFOs and MDOs with LNG is becoming increasingly feasible in the shipping industry. Since the first LNG-fuelled ship built in 2001, the cumulative number of vessels has grown significantly. DNV GL estimates there were a total of 170 operational vessels in the LNG fleet by the end of 2019, whereas 184 more units were on order. However, data on LNG is not always accurate due to discrepancies in data classification. For instance, including LNG carriers in the total number, the latter increases to about 750 ships in service or on order[26][27]. Nonetheless, the figure is projected to grow substantially in the future as more than 10 per cent of the world's shipping fleet is expected to be powered by LNG by 2030[28].

[26] Pavlenk et al., "The Climate Implications of Using LNG as a marine fuel", *The International Council on Clean Transportation* (January 2020). Available at https://www.stand.earth/sites/stand/files/20200128-ICCT-StandEarth-Climate-Implications-LNG-As-Marine-Fuel.pdf

[27] Gas Infrastructure Europe, "Small Scale LNG Map", *Gas Infrastructure Europe* (15 June 2020), https://www.gie.eu/maps_data/downloads/2020/GIE_SSLNG_2020_A0_FULL_1009.pdf

[28] Le Fevre C.N., "A review of demand prospects for LNG as a marine transport fuel", *The Oxford Institute for Energy Studies*, OIES Paper: NG133 (June 2018)




*Graph 5: Total number of LNG-fuelled vessels (DNV GL, 2019)*

However, the use of LNG as a bunker fuel entails as well as some challenges. For instance, although it contains less carbon per unit of energy than conventional marine fuels, its adoption might not help to reduce well-to-wake GHG emissions. This concern lays on the fact that LNG mainly consists of methane which is a rather harmful GHG. According to a study by the International Council on Clean Transportation (ICCT), "methane slip", or unburned methane discharged in the atmosphere, may offset the benefits of reduced CO2 emissions[29]. By looking at the upstream generation, it highlights how the relatively energy-intensive production of LNG from shale gas (i.e. natural gas trapped within shale formations) often leads to "increased gas venting following high-volume hydraulic fracturing". However, methane slips are mainly the product of inadequate engines, for only a relatively small portion of the cumulative number of LNG-fuelled ships in service or on order use high-pressure injection dual fuel (HPDF) engines. Currently, the only type of engine ensuring a sufficient degree of efficiency[30].

Furthermore, the switch to LNG-fuelled vessels poses extra design challenges for shipbuilders and stakeholders, thus implying high CAPEX. As an example, given LNG low energy density (0.0142

[29] Ibid.
[30] Ibid.

MWh/kg), LNG-fuelled ships need gigantic cryogenic storage tanks to be fitted along with high-tech refrigerated refuelling pipes[31]. Significant investments are also required to adopt the infrastructural network to provide ships with secure and smooth "bunkering" procedures. In recent years, the Port of Rotterdam (Europe's largest bunker port) has made necessary steps forward to assert its position as an international LNG hub for import, export, storage, and bunkering[32]. As of today, no less than 93 ports are capable of delivering LNG bunkering procedures, and 54 more are expected to follow up in the coming years[33]. However, the shift from oil fuels to LNG can look transitional to the stakeholders as opposed to carbon-free alternatives. Moreover, considering the achievements of zero-emission shipping, LNG would likely remain a bridge solution towards decarbonisation. Unless developments to reduce the impact of methane slip are accompanied by improvements in engines' efficiency and so-called carbon capture and storage (CCS) technologies.

### Hydrogen-based ammonia as a pure carbon-free fuel

A study by the Energy Transition Commission and the University Marine Advisory Services (UMAS) for the Getting to Zero Coalition predicts that in 2050 the split between carbon-free and non-carbon containing fuels will be 50-50. Moreover, it identifies ammonia as the fuel of choice to power zero-emission vessels (ZEVs)[34]. Ammonia (NH3) is a compound with nitrogen and hydrogen whose application as fertiliser dates back to the early 20th century. In its purest and most stable form, ammonia is a colourless gas, but it can be easily converted into liquid form at temperatures higher than those required for LNG[35]. For this reason, in recent years, it has begun to gain traction as an alternative to conventional fossil fuels, notably, in the maritime sector.

Nowadays, hydrogen is a widely acknowledged solution for sustainable transport as fuel cells offer an efficient way of generating power carbon-free. However, the use of hydrogen as opposed to conventional bunker fuels comprises a series of engineering challenges - increased storage volume, fuel cells technology and infrastructural overhaul - which raise doubts on whether it would be economically feasible for longer journeys in the near future. For this reason, there are relatively few hydrogen-powered ships in operation today, and for just short distances[36]. In contrast, hydrogen can

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[31] Bureau Veritas “LNG as a Fuel” excerpt from ”2020 Fuels and Beyond: compliance now and the road to 2050”, *Bureau Veritas*, Technology report #04 (2019).
[32] Port of Rotterdam, “Record Breaking LNG bunkering for Sleipnir in Rotterdam”, *Port of Rotterdam* (27 March 2020), https://www.portofrotterdam.com/en/news-and-press-releases/record-breaking-lng-bunkering-for-sleipnir-in-rotterdam
[33] Hellenic Shipping News, “LNG-fuelled ships on order to rise by 50% in 12 Months Says SEA\LNG”, *Hellenic Shipping News*, (13 February 2020). Available at https://www.hellenicshippingnews.com/lng-fuelled-ships-on-order-rise-by-50-in-12-months-says-sealng/
[34] Krantz et al., “The scale of investment needed to decarbonise international shipping”, *Energy Transition Commission & UMAS* (2019)
[35] McKinlay et al., “A comparison of Hydrogen and Ammonia for Future Lon Distance Shipping Fuels”, *The Royal Institution of Naval Architects* (29 January 2020)
[36] Ibid.

be converted into ammonia via the Haber-Bosch chemical process. The production of ammonia accounts for 53 per cent of hydrogen utilisation[37].

## Benefits and concerns of using ammonia

The reason why ammonia has gained so much attention as a bunker fuel in recent times is essentially twofold. On the one hand, it is mildly cryogenic, meaning that it is relatively easier to store in liquid form as it does not require the same amount of cooling hydrogen needs. This is a considerable advantage as it removes part of the construction-wise constraints[38]. On the other, even though ammonia is nowhere near conventional fuel oils in terms of efficiency, its energy density is almost two times higher than hydrogen. A higher energy density also brings about several benefits. For example, by taking a traditional fuel tank (HSFO) as a reference, an ammonia fuel tank would require 2.7 times the same volume to deliver the same amount of power, while liquid hydrogen needing it 4.1 times bigger[39]. Hence, ammonia seems to offer a more feasible solution, particularly for long-hauls, ocean-going freights when compared to fuel cells hydrogen-powered ships. Another feature of ammonia is that it has rather limited flammability, meaning that it requires a pilot fuel — usually fossil fuel feedstock such as MDO or LNG — for ignition. This comes as both a condemnation and a blessing, particularly for no significant incidents involving uncontrolled explosions have occurred throughout its history[40].

However, ammonia is not a silver bullet. Concerns regarding the potential impact of ammonia in the decarbonisation process of the maritime industry lay on the fact that. In contrast, both its production and combustion are totally and unquestionably carbon-free, the same cannot be said for its core element. Indeed, hydrogen's supply chain can be quite carbon-intense at times, depending on which method is used to produce it. With demand on the rise, many worries that emissions may just shift upstream, for hydrogen can be yielded from the reformation of steam methane whose combustion — as explained in the previous paragraph on LNG — produces substantial GHG emissions. In this case, the outcome is referred to as "blue hydrogen"[41]. Yet, there is a cleaner way to generate hydrogen through electrolysis, a process which uses electricity to separate its molecules from water. When

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[37] Ibid.

[38] Balcombe et al.,"How to decarbonise international shipping: Options for fuels, technologies and policies", *Elsevier*, Energy Conversion and Management 182 (2019) 72–88.

[39] McKinlay et al., "A comparison of Hydrogen and Ammonia for Future Lon Distance Shipping Fuels", *The Royal Institution of Naval Architects* (29 January 2020)

[40] Cord, "Successful tests pave the way for ammonia as a future marine fuel", *Wärtsilä* (2 July 2020). Available at https://www.wartsila.com/twentyfour7/innovation/successful-tests-pave-the-way-for-ammonia-as-a-future-marine-fuel?utm_campaign=247&utm_medium=organic-social&utm_source=twitter&utm_content=ammoniafuel&utm_term=marine

[41] Boerner," Industrial ammonia production emits more CO2 than any other chemical-making reaction. Chemists want to change that", *C&EN*, Volume 97 Issue 24. (15 June 2019)

electricity is sourced from renewables, and thus CO2 emissions are struck out of the equation, electrolysis would produce so-called "green hydrogen"[42]. Even though production costs remain considerably high as opposed to conventional fuels, the gap is deemed to drop as renewables become cheaper and cheaper, and the efficiency of electrolysers continues to scale up. Particularly, when strong public incentives and stricter green policies would enter the process[43]. Current hydrogen production costs from electrolysis in the Netherlands hub market average EUR 2.5-3/Kg, whereas it is estimated these could go as down as EUR 1.92/Kg in the future[44][45].

Hydrogen Netherlands PEM electrolysis (inc. CAPEX) MA EUR/Kg) in 2020

| | 04 May | 11 May | 18 May | 25 May |
|---|---|---|---|---|
| Eur/Kg | 2.5899 | 2.5805 | 2.577 | 2.4327 |
| | **02 June** | **09 June** | **16 Jun** | **22 June** |
| Eur/Kg | 2.75838 | 2.8375 | 2.8905 | 3.0101 |

*Table 1: The cost of "green hydrogen" in the Netherlands (May-June 2020) (S&P Global Platts, 2020)*

Further concerns relate to the fact that ammonia is highly corrosive and toxic as well as that, due to its high nitrogen content, its combustion releases high levels of NOx, thus raising doubts on compliance with IMO's regulations. According to Bureau Veritas, for engine manufacturers and shipbuilders to comply with MARPOL Annex VI, the burning of ammonia would require devices such as Select Catalytic Reductions (SCRs) and Exhaust Gas Recirculation (EGR) to decompose the harmful compound to nitrogen and water[46]. The installation of such components is likely to induce higher CAPEX and thus constitute a barrier to global commercialisation. However, another way to avoid NOx emissions could be to use ammonia as a hydrogen carrier rather than as a bunker fuel. Once stored,

[42] Dincer, "Green methods for hydrogen production." *International journal of hydrogen energy* 37, no. 2 (2012): 1954-1971.
[43] Dolci et al. "Incentives and legal barriers for power-to-hydrogen pathways: An international snapshot", *International Journal of Hydrogen Energy,* Volume 44, Issue 23, (2019)

[44] Mulder, et al., "Outlook for a Dutch hydrogen market: economic conditions and scenarios", *Centre for Energy Economics Research*, CEER Policy Papers 5 – University of Groningen, The Netherlands (March 2019)
[45] S&P Global Platts, "Platts Hydrogen Assessment", *S&P Global Platts* (2020)
[46] Bureau Veritas, "Ammonia: an answer to decarbonising shipping", *Bureau Veritas* (26 March 2020). Available at https://marine-offshore.bureauveritas.com/magazine/ammonia-answer-decarbonizing-shipping

ammonia would be then converted back to hydrogen and used for ship propulsion[47]. Furthermore, one of the advantages of ammonia having a century-long pre-existing supply chain is that there are already some safety protocols in place. Within the EU, a list of Directives and Regulations comprises the policy framework around the use of ammonia.[48]

## Conclusion

When adequately evaluated for the value of the goods transported, the maritime industry still represents the most cost-effective means of transportation, also concerning its environmental impact. However, for the size of its scope and the absence of obligations, emissions have continued to rise almost unchecked throughout the last decades. In a recent report, the NGO Transport & Environment has found CO2 emissions produced by the European maritime fleet between 2015 and 2019 accounted for more than the volume produced by automobile transport[49]. Whereas some first steps have been taken to deal with the issue, particularly by the IMO and the European Union, much remains to be done. Both the international community and stakeholders now face a twofold conundrum, that is responding to the most profound drop in trade the world has ever seen since the Second World War while investing in decarbonised shipping.

In a previous publication, we tried to shed some light on how some ports have already adopted policies to try curb emissions and lay the basis for more sustainable operations. However, to reach the decarbonisation goals set by the International Maritime Organisation, shipowners will likely have to commit themselves to much-needed changes. As the prices of greener technologies continue to decrease, and alternative fuels become ever more profitable, governments have, although with guilty delay, started to allocate time and attention to tackle emissions. In this regard, there is no doubt effective cooperation between private and public sectors will play a significant role in the process towards the decarbonisation of the maritime industry to Notably, by accelerating the utilisation of carbon-free alternatives that can pull it away from a paradigm which has long relied on fossil fuels.

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[47] McKinlay et al., "A comparison of Hydrogen and Ammonia for Future Lon Distance Shipping Fuels", *The Royal Institution of Naval Architects* (29 January 2020)

[48] List of EU Regulations and Guidance Documents over the use of ammonia include: ATEX 94/9/EC the "Equipment Directive"; ATEX 99/92/EC the "Workplace Directive"; EN 378 a four-volume standard on safety and environment requirements for refrigeration systems and heat pumps; EN 60079 promoting electrical installations inspection and maintenance; IEC 60335-2-40 comprising safety guidance for household and similar electrical appliances; and PED 97/23/EC the "Pressure Equipment Directive".

[49] European Federation for Transport and Environment, "EU Shipping's Climate Record: Maritime CO2 Emissions and Real-World Ship Efficiency Performance". *European Federation for Transport and Environment* AISBL: Transport and Environment (December 2019). https://www.transportenvironment.org/sites/te/files/publications/Study-EU_shippings_climate_record_20191209_final.pdf

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