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AUGUST 2017

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EXECUTIVE SUMMARY

Discussions of "peak oil demand" tend to focus of passenger vehicles, often from a US and European perspective, and they ignore other markets, such as marine transport, which collectively would also need to show a reduction in demand if oil consumption as a whole were to reach an inflection point. This report explores the outlook for marine bunkers, a niche market that accounts, depending on estimates, for up to 7 percent of the demand barrel. It focuses on the impact of new environmental restrictions that aim to drastically reduce sulfur oxide (SOx) emissions from ships as of January 2020, placing them against the background of past innovations that have been reshaping ships' fuel consumption patterns and assessing their likely impact on future innovation in the sector.

Of the three main compliance options available to ship owners ahead of the new "global sulfur cap," two—installing "scrubbers" to capture SOx emissions from shippers' current fuel of choice, high-sulfur fuel oil (HSFO), and switching from oil-based bunker fuels to liquefied natural gas (LNG)—are more capital intensive and require more advanced planning than the third, switching from HSFO to lower-sulfur products, such as low-sulfur fuel oil (LSFO) or marine gas oil (MGO). Analysts reckon that most shippers will opt to run low-sulfur fuels, but they fear that rising demand for these fuels will bump against refining capacity limits and cause price spikes that might spread to other markets, notably diesel and even crude oil. Some analysts have suggested that delays could help the industry better prepare for the new rules. This report challenges these findings.

Key takeaways include the following:

- New restrictions on marine sulfur emissions are occurring against the background of sweeping changes in the shipping industry, the impact of which is poorly captured in statistics and underappreciated in most assessments of the rules' impact. Whereas forecasters assume steady growth in shipping fuel demand, oil consumption from the sector actually contracted in recent years and looks set to keep doing so—or, at least, grow more slowly than expected. Oil price swings and weak freight margins have served as catalysts of change, reducing the oil intensity of shipping through innovations in vessel design and fleet management and relentless industry consolidation. Digitalization holds the promise of further fuel savings, while LNG is making inroads in the sector.

- Industry participants have taken a cautious approach to capital-intensive measures to comply with the global cap. As the 2020 deadline looms, and given long lead times for scrubbers and LNG engines, low-sulfur bunkers will become the industry's new de facto fuel of choice. This wait-and-see approach is no accident but, rather, a prudent response to the uncertain long-run costs and benefits of the various options. Potential feedback effects have exacerbated the inherent uncertainty of oil and gas markets, while regulatory uncertainty about future nitrate oxide (NOx) and greenhouse gas (GHG) restrictions further clouds the options' economics. Delaying the rules' implementation would not in and of itself change the industry's incentives.

- Performance standards such as the global sulfur cap are normally seen as supportive of innovation, unlike technical standards that "pick a winner" among available technologies. By making low-sulfur fuel the default compliance option of industry, however, the global cap effectively entrenches oil's role in shipping for decades to come. A more integrated approach to marine emissions, one that would have regulated SOx, NOx, and GHG, would have accelerated the switch to LNG, and it would have been a good way to curb all emissions at once.

- Shippers' choice of lower-sulfur fuels as their default compliance option shifts the burden of innovation onto the refining industry, but it will likely prove a lesser challenge for refiners than is commonly understood. Although some analysts have drawn parallels with the 2008 oil rally, when the desulfurization of road diesel helped cause imbalances in distillate markets and propelled oil prices to record highs, that is not an apt analogy. Unlike in the 2000s, diesel demand is far from booming. Furthermore, due in part to viscosity and lubrication requirements, the new bunkers will not be diesel look-alikes but new fuel hybrids, the production of which will entail as much blending as actual refining.

- Noncompliance will further alleviate product market pressures. Given the lack of environmental police on the high seas, enforcement is a daunting challenge for the global cap's implementation. Efforts to beef up enforcement currently focus on tightening paperwork checks at ports, which is a cheaper but less effective approach than actual emission checks by flyover or satellite.

- While the global sulfur cap will be less disruptive than feared, the loss of one of the last remaining market outlets for HSFO might be the death knell for some of the less competitive refineries with high HSFO yields. Falling HSFO prices will also adversely affect producers of high-sulfur crude oil, whose price is often indexed to that of HSFO, such as Mexico.

INTRODUCTION

Discussions of peak oil demand, a trending issue in energy markets and in the energy industry, tend to focus on electric vehicles and personal mobility, and they are often from a US or European perspective. A much talked about report recently predicted that by 2030, "95% of U.S. passenger miles traveled will be served by on-demand autonomous electric vehicles."[1] Such heady forecasts underpin many projections for a sudden plunge in oil use. Yet passenger vehicles only account for about one-fourth of the demand barrel, and it's much less if just US cars are taken into account.[2] If oil use as a whole were to fall, other market segments would also have to undergo declines. The market for marine fuels, which, depending on the estimates, might account for as much as 7 percent of oil use,[3] and which new environmental rules from the International Maritime Organization (IMO) recently brought into focus, is one such segment.

The new IMO regulations, due to take effect in January 2020, drastically lower the sulfur cap for air emissions from ships. It's a challenging move that could theoretically erode oil's dominance in the shipping sector by speeding up the adoption of liquefied natural gas (LNG) as a substitute for high-sulfur fuel oil (HSFO), which is the heavy oil product that accounts for the bulk of shipping demand. While LNG has made some inroads into marine transportation, however, analysts reckon that most shippers will stick to oil. Some shippers are expected to continue to use HSFO in conjunction with emission abatement technology. Most shippers are expected to switch to lower-sulfur fuels, such as marine gas oil (MGO). This is a middle-distillate product somewhat similar to diesel. It is currently used in special emission control areas (ECAs),[4] and analysts fear it might come in short supply as a result.

Expectations of oil demand from the marine sector are thus diametrically opposed to those of road transport demand. In the latter case, talk of a "mobility revolution" and disruptive changes fuels expectations of a collapse in gasoline demand. In the former, analysts warn of a supply crunch and price increases as continued growth in marine demand, coupled with a shift to middle distillates, put refining capacity to the test.[5] Other than the fuel switch, analysts, far from predicting a rethink of shipping, see only business as usual.

Both sets of forecasts—of a collapse in gasoline demand and of a surge in middle distillate requirements—pick up on real issues. Especially in their most radical versions, however, they give in a bit too readily to sensationalism. In the case of the marine sector, the complexity of the challenge raised by the new IMO rules for both the shipping and refining industries can hardly be overstated. Forecasts of a looming fuel crisis ought to be taken with a grain of salt, though. Poor data and lack of market transparency have always been the bane of demand forecasters, and this problem is particularly acute in the case of marine fuels. Partly because of that, much of the recent analysis appears to be based on questionable assumptions of strong bunker demand growth, and it appears to underestimate the impact of innovation on the sector's oil intensity. It also underestimates the strong likelihood of noncompliance on the high seas, especially from smaller vessels.

Some analysts have suggested that delaying the rules' implementation would give the industry more time to prepare.[6] Such calls fail to appreciate how the rules' design has provided shipowners with an incentive to hold back planning for them until the last minute. The industry's wait-and-see approach is, in fact, a prudent, rational response to the uncertain costs and benefits of the various compliance options. Analysts also tend to exaggerate the severity of the challenge raised by the rules for the refining industry. Speculation about a product supply crunch underestimates the industry's flexibility and assumes that shippers will face a binary choice between two main product categories, HSFO and MGO. This ignores how the rules might instead spur a reconfiguration of the demand barrel and the emergence of new types of blended fuel hybrids.

In this note, we highlight the role of innovation in shipping and review some of the economic, technological, and policy-driven factors that have been reshaping marine fuel consumption patterns, including industry restructuring, slow steaming, changes in ship design, digitalization, and fuel switching to LNG and electric batteries. We then proceed to examine how and to what extent the global sulfur cap might further accelerate innovation and transform the sector. We explain how the design of the IMO policy has given shipowners an incentive to stay on the sidelines, in effect shifting most of the compliance burden onto the refining industry. Finally, we consider the likely impact of the IMO's global sulfur cap on crude oil and refined product markets.

However complex and daunting the challenge for the shipping and refining industries might be, we find the global cap to be less disruptive than do many analysts. On the contrary, the rules might paradoxically end up slowing down what might have otherwise been a more rapid transition of the shipping market away from traditional bunker fuels. They will, however, adversely affect simple refineries and producers of heavy, sour crude oil grades, whose prices are sometimes indexed to that of HSFO. We conclude by highlighting a few policy issues that, if properly addressed, would give market participants more clarity and ease their paths to compliance.

SEA CHANGE IN SHIPPING MARKETS

While oil demand in general is poorly measured and understood, oil consumption patterns in the marine sector are especially opaque.[7] Since marine bunkers are, by definition, consumed at sea, countries do not normally include them in their estimates of domestic oil demand. This explains the unusual level of uncertainty attached to global bunker demand data. Even the International Energy Agency (IEA), the global benchmark for energy statistics, shows some inconsistency in this matter. In its medium-term oil market forecast, *Oil 2017*, it estimates the bunker market at 4.2 million barrels per day (bpd), or roughly 4 percent of global oil demand. That includes 3.4 million bpd of HSFO and 0.8 million bpd of lower-sulfur MGO used in ECAs. In its long-term *World Energy Outlook*, however, it pegs total bunker demand at 3.8 million bpd, including 3.2 million bpd and 0.6 million bpd of HSFO and MGO, respectively.[8] The IMO itself goes by a higher estimate of 300 million tons (approximately 5.5 million bpd) for 2012 and a baseline projection of 320 million ton (5.9 million bpd) for 2020.[9] Uncertainty notwithstanding, the IEA's 4.2 million bpd estimate likely provides an acceptable order of magnitude, but its forecast of 1.9 percent average annual growth in total fuel demand for international shipping from 2015 to 2040, including 1.2 percent for oil, looks off the mark. While seemingly low compared to the IEA's projection of 3.6 percent annual growth in shipping activity, it far exceeds the IEA estimate of total oil demand growth (0.5 percent) for the same period.[10] Yet recent evidence suggests that efficiency gains in shipping have far outpaced those in other sectors of the economy, and more gains seem likely in the future.

Bunker Fuel Data Issues

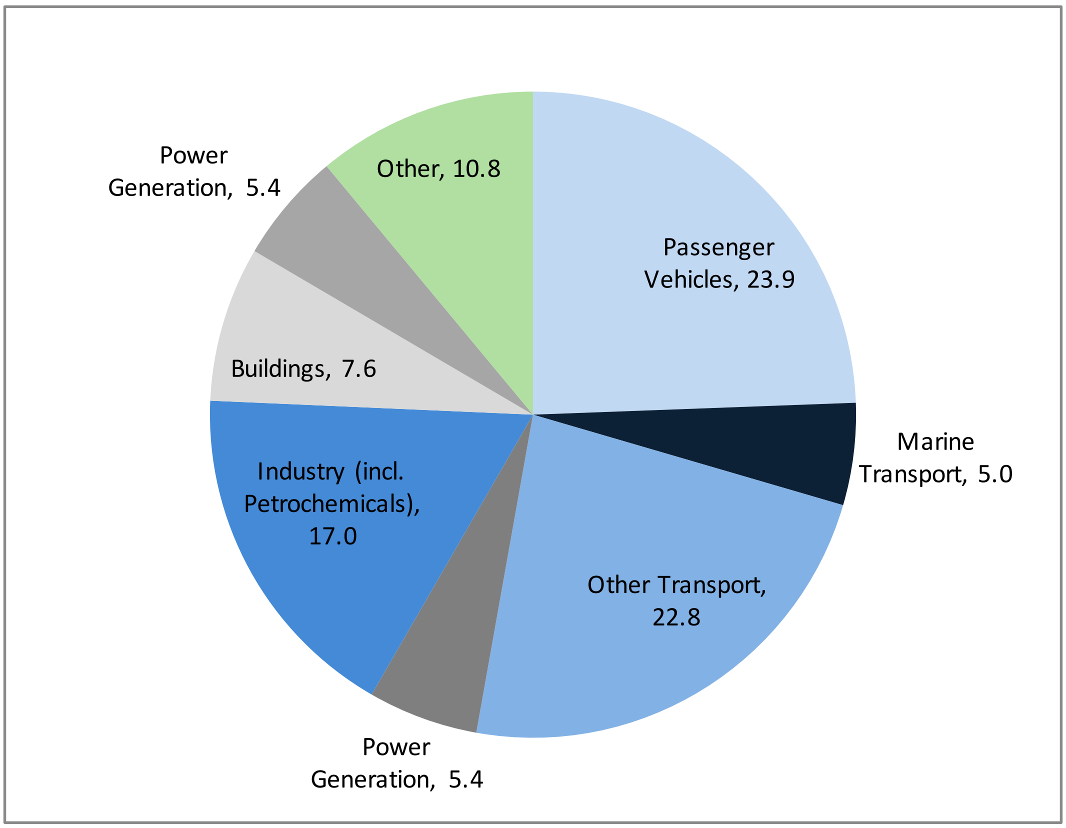
The IEA's data sets and projections offer a glimpse into the challenge of assessing bunker fuel demand trends. In its medium-term oil market report, *Oil 2017*, the IEA forecasts that world bunker fuel demand, including both distillate product, such as marine gas oil (MGO), and residual fuel, such as high-sulfur fuel oil (HSFO), will expand in the coming years, from 3.8 million bpd in 2016 to 4.4 million bpd in 2020 and to 4.6 million bpd in 2022. Its statistical database, *World Energy Statistics*, however, shows that world bunker fuel demand actually contracted by a steep 6.8 percent from 2011 to 2014, the most recent years for which comprehensive reported data on world oil demand are available. Compared to 2007 levels, bunker fuel demand was down by 3% in 2014. Given the scope for reductions in the oil intensity of shipping in the coming years, this recent pattern would seem to cast doubt on the likelihood of a near-term rebound.

On closer examination, however, the year-to-year gyrations in bunker demand indicated by the statistics look suspiciously wide. The recent three-year plunge in demand is front-loaded in 2012, when fuel use is estimated to have crashed by 10 percent year on year - a drop partly reversed un subsequent years, with gains of 1.2 percent and 2.4 percent in 2013 and 2014, respectively. In 2010, bunker use moved in the opposite direction, surging by more than 10%. Steep gains of around 6% were also reported in 2006 and 2007. Such volatility in fuel use seems to re ect data problems more than actual swings in demand.

The IEA data also do show a gain in distillate bunker fuels at the expense of residual fuel oil. This is seemingly consistent with the implementation of a 0.5 percent sulfur cap in emission control areas (ECAs) from January 2015 onward. Here too, however, the recent trend in distillate bunker fuel demand looks exceedingly choppy, with gains of 10 percent in 2010 and 2011 followed by a plunge of about 30 percent in 2012 and a 44 percent jump in 2014.

While all oil-demand data are clouded in uncertainty, estimates of bunker fuel consumption are especially challenging since bunkers are, by definition, an export that no one imports and that no country can report as domestic demand. The fact the shipping industry is notoriously private adds to the data fog. In view of the problems with data integrity, perhaps it is not surprising that the IEA should show some willingness to override its own statistics and forecast steady growth in bunker demand, whereas recent statistical information suggests a contracting trend. Data uncertainty and anecdotal evidence from shipping companies leave room for dissenting views, however. Anecdotal evidence from shipping companies leave room for dissenting views. Based on recent innovations in ship design and fleet management practices as well as on the expected effect of digitalization of fleet optimization and preemptive maintenance, among other things, a narrative of continued decline in the oil intensity of the shipping industry seems highly plausible.

Figure 1: 2015 Oil Demand by Sector: IEA WEO 2016 Estimates (Percent)



Source: IEA World Energy Outlook 2016.

While country-level bunker statistics can be of questionable quality, company-level data do shed some light on consumption trends. Chinese companies and privately owned firms loom large in the sector and are often less than forthcoming about this type of information. Nevertheless, earnings reports and other anecdotal information, when available, suggest that a combination of positive and negative factors, from fuel efficiency gains to slowing world trade growth, has taken a toll on demand. These also suggest the sector's oil consumption might be set for further declines or very slow growth. Like many other oil-intensive industries, marine shipping has been greatly reducing its fuel requirements in a multipronged effort to reduce its exposure to oil-price risk and to shore up profitability. This includes reversible trends, such as slow steaming, a fuel-saving practice first popularized by very large crude carriers (VLCCs) in 1974–1976 and reintroduced during the oil price rally of 2002–2008. It also includes more structural changes that have unlocked substantial gains in fuel efficiency. The impact of those trends has been compounded, at the margin, by the first attempts at fuel diversification away from oil in the marine sector.

Slow Steaming

The shipping industry was hit hard by the 2002–2008 oil rally, which hurt its profit margins despite robust shipping demand. Maersk, the world's largest container carrier company, led the industry in systematizing slow steaming, the practice of deliberately slowing down the speed of a ship as a way to trim costs by lowering fuel consumption. While oil prices eased back in late 2008–2009, and again since mid-2014, the practice of slow steaming survived the oil market downturn, and freight markets remained adversely affected by substantial fleet overcapacity in the wake of new builds and slowing trade growth.

The measure can be especially beneficial and make a big cost difference for container carriers, which account for roughly one-third of the global fleet and have greater speed variability than other kinds of ships. It is also helpful to bulk carrier and tanker operators, albeit to a lesser extent, as those ships have comparatively less speed variability and less scope for slowing down.[11] Industry sources indicate that recent market conditions in certain trade routes have particularly favored extensive lay-ups and slow steaming to mop up excess capacity. Maersk has argued that slow steaming not only saves energy but also reduces carbon emissions and increases marine transport reliability by reducing bottlenecks at terminals.[12]

A 2013 study[13] that sought to estimate the costs and benefits of slow steaming under various volume and fuel-price assumptions found that the practice paid off under then prevalent conditions but that "extra slow steaming" was most beneficial, cutting total costs by 20 percent and carbon dioxide emissions by 43 percent, and it remained optimal for future volumes under a wide range of fuel prices.

Despite signs of institutionalization, past experience suggests slow steaming is likely the most transient of factors yielding to lower fuel consumption, and it remains subject to reversal, depending on market conditions. It was abandoned in the mid-1970s as market conditions stopped supporting it, or were so perceived. As there is no sign of an imminent tightening of shipping markets, though, slow steaming might be expected to continue for the foreseeable future. The state of the global fleet and the shipbuilding order book do not point to any substantial short-term tightening of capacity. Maersk expects ample container fleet capacity for "the foreseeable future."[14] Global container fleet capacity grew 4 percent in 2016, outpacing demand growth of 2 to 3 percent.[15]

Industry Consolidation and Fleet Optimization

The other factors reining in oil demand for marine transport reflect longer-lasting, more structural changes. Consolidation in the shipping industry, notably among container ships, has gained momentum since it began in the mid-1990s, unlocking vast fuel efficiencies. Years of relentless restructuring have achieved substantial economies of scale—and there is more to come. According to a recent ranking by Alphaliner, a trade news service, the top five ocean carriers account for nearly 60 percent of the combined capacity of the top 100 carriers as measured in 20-foot equivalent units (TEUs). The top 10 make up a full 75 percent of the pool.[16] The industry has gone through three successive consolidation waves. The first two waves, in 1996–2000 and 2005–2008, raised the top five companies' market share from an estimated 27 percent to 43 percent. The current wave, started in 2015, looks set to last into the first quarter of 2018, further lifting their share to a projected 57 percent (66 percent for long-haul trades). In the last two years, eight of the top twenty players have been eliminated from the industry roster.[17]

Consolidation has brought with it improvements in fleet management and substantial fuel savings. Maersk credits "network rationalization," one of the main tools in its "cost toolbox," for unlocking "significant cost reductions."[18]

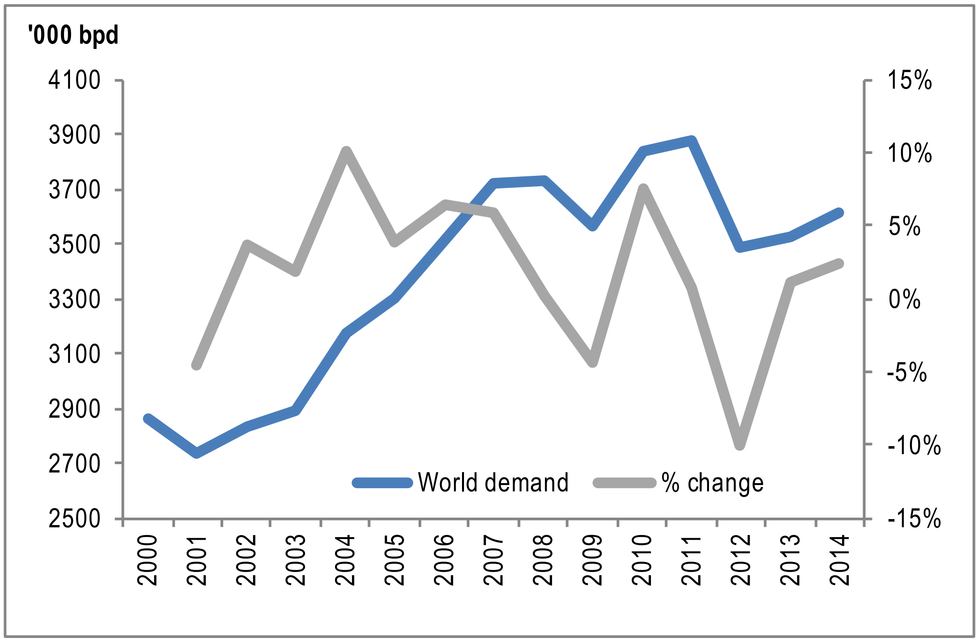
Compounding the impact of mergers, container carriers have also been pooling their fleets into global alliances, akin to those of airliners, to share vessels and to further rationalize their operations. That secondary level of consolidation has allowed them to extend geographic coverage and service range and leverage their assets more effectively. A tertiary form of consolidation is even occurring at the pool level. Earlier this year, the four leading ocean-carrier alliances were cut down to three. The 2M Alliance, Ocean Alliance, and THE Alliance now represent a combined 77 percent of global container capacity and 96 percent of East-West trade container capacity.[19] "Network improvements" and "optimization" allowed Maersk to improve bunker fuel efficiency by 1.8 percent year on year in the first quarter of 2017, the company reported,[20] following up on a 2.2 percent improvement in 2016.[21]

Vessel Design and Economies of Scale

Fuel savings achieved through economies of scale and advances in fleet management have been recently compounded by vast increases in vessel size. Larger and larger carrier ships have unlocked further efficiency gains. The race for size heated up in earnest in 2013. That was when Maersk launched its Triple E class of container ships of more than 18,000 TEUs.[22] China Shipping Container Lines (CSCL, now China COSCO) followed suit with the 19,100-TEU *CSCL Globe*. This was launched in November 2014, along with four sister ships.[23] Then came Mediterranean Shipping Company (MSC) with the 19,224-TEU *MSC Oscar*. This was christened in January 2015, along with its sister ships, *MSC Zoe* and *MSC Oliver*. *MOL Triumph* has since breached the 20,000 TEU mark, and a recent delivery was over 21,000 TEUs. These vessels set records not only for size but also for fuel efficiency. The Triple E name refers to the three principles of economy of scale, energy efficiency, and environmental excellence. CSCL likewise touts the *Globe's* fuel efficiency and cuts in CO_2 emissions and noise.

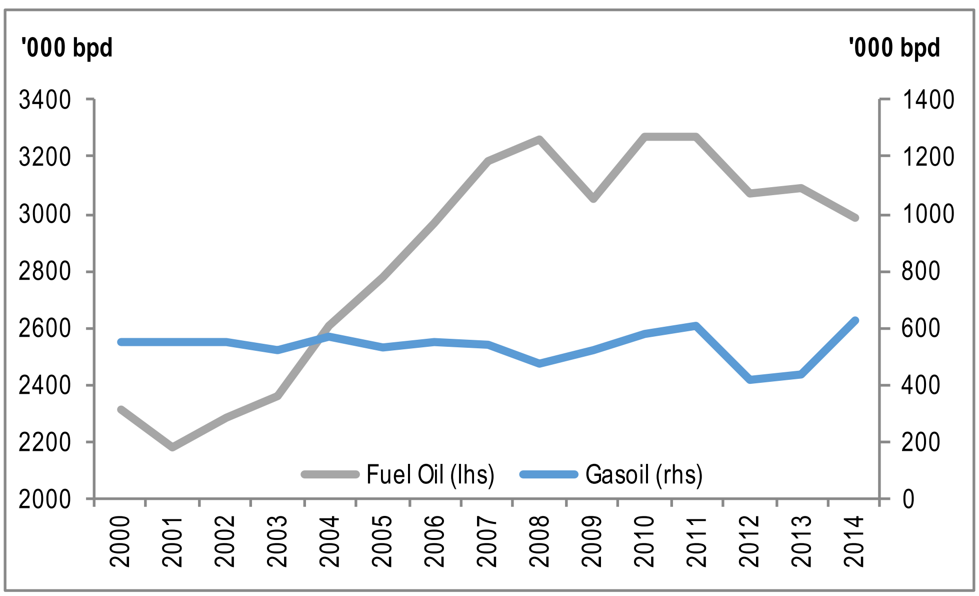
Most shipping companies are less than transparent about their fuel consumption. Some do provide details, however. Hapag-Lloyd boasted about an 8.4 percent year-on-year drop in bunker consumption per TEU for the first quarter of 2017. This brought them to 0.43 metric tons (MT), which was partly credited to the large size of its vessels. Efficiency gains more than counterbalanced an increase in shipping activity, so that total bunker use dropped by 2.2 percent to 803,000 MT, from 821,000 MT a year earlier, despite higher shipping volumes.[24] That followed a string of fuel savings from prior years, including a 6.3 percent plunge in total bunker use in 2016. This was despite a 2.7 percent increase in volume, which was attributed to "the use of larger and more efficient ships as well as the optimization of the deployed fleet and global services network."[25] Hapag-Lloyd's fuel efficiency admittedly might not be fully representative of the entire container shipping industry, but the same market signals that spurred it into action are felt across the board.[26] The bottom line is that the top shipping companies have been using less and less fuel even as they have kept increasing their market share and shipping volumes. Given continued industry consolidation, further reductions in fuel use are likely.

Figure 2: World Bunker Demand



Source: IEA's World Energy Statistics 2016

Figure 3: Bunker Demand: Fuel Oil versus Gas Oil



Source: IEA's World Energy Statistics 2016

Shorter Routes

Changes in the global sea-lane map are also saving shippers fuel. The expansion of the Panama Canal, completed in June 2016, lets it accommodate larger and more numerous vessels. The project doubled the canal's capacity by widening and deepening the lanes and locks and adding a new lane. Whereas the largest ships that could previously make the passage were 5,000-TEU Panamaxes, the expanded canal can now accommodate so-called neo-Panamaxes, or new Panamax ships, of 14,000-TEU capacity.

As global warming melts Arctic sea ice, shipping routes might open up over the North Pole and other previously impassable areas, which could greatly reduce travel times for long-haul shipping. The prevailing view, however, is this remains a relatively distant prospect and is unlikely to occur on a large scale until midcentury.[27]

Digitalization

Looking forward, digitalization is poised to redefine marine transportation just as it is transforming personal mobility. Digitalization promises to take fleet optimization to a new level and unlock new fuel economies. "Digital is changing the way we operate our assets," notes Maersk. After being collected from flowmeters, control and alarm systems, sensors, and time stamps, fleet operation data are run through an analytics engine that lets the company unlock new fuel efficiencies, shorten port stays (a cost center), and improve network design. "Advanced analytics opens up a whole new playground of opportunities," claims Maersk, including "real time network optimization for bunker savings," predictive repairs, cargo mix optimization, and more.[28]

Digitalization thus saves fuel in at least two ways: by optimizing engine performance (through predictive repairs and more) and by optimizing fleet management. Combined with industry consolidation and the pooling of fleets into ever-expanding global alliances, digitalization sets the stage for the "Uberization" of marine transport. In this system, multiple operators pool their fleet capacities and leverage their vessels in the most cost-effective and fuel-efficient way.

Fuel Switching

Besides responding to price signals with efficiency gains, the shipping industry has also been driven to tap into alternative fuels by environmental factors. Liquefied natural gas is making its first inroads into a sector that was long an oil monopoly. This is supported by a newfound abundance of natural gas, advances in liquefaction technology and capacity, and environmental policies aimed at improving air quality. Battery-powered and hybrid ships are still in the future, but their prospects are brightening.

The establishment of relatively stringent sulfur emission standards in certain coastal areas as of January 1, 2015, has led to fuel switching to lower-sulfur oil bunkers in parts of Europe, North America, and Asia, as well as the first forays into LNG bunkers. As the distribution infrastructure required to use LNG as bunker fuel remains in its infancy, LNG penetration has so far remained largely limited to discrete segments of the fleet in ECAs, such as short-haul Scandinavian ferry lines or barges in Chinese waterways. As of 2016, there were just 77 ships reportedly fueled by LNG. That's compared to a total oceangoing fleet estimated at 45,000 vessels. That number is expected to pass the 200 mark by 2020, however. Most LNG-fueled vessels are expected to remain dedicated to specific routes, including several cruise liners and Aframax tankers plying the North Sea–Rotterdam trade.[29]

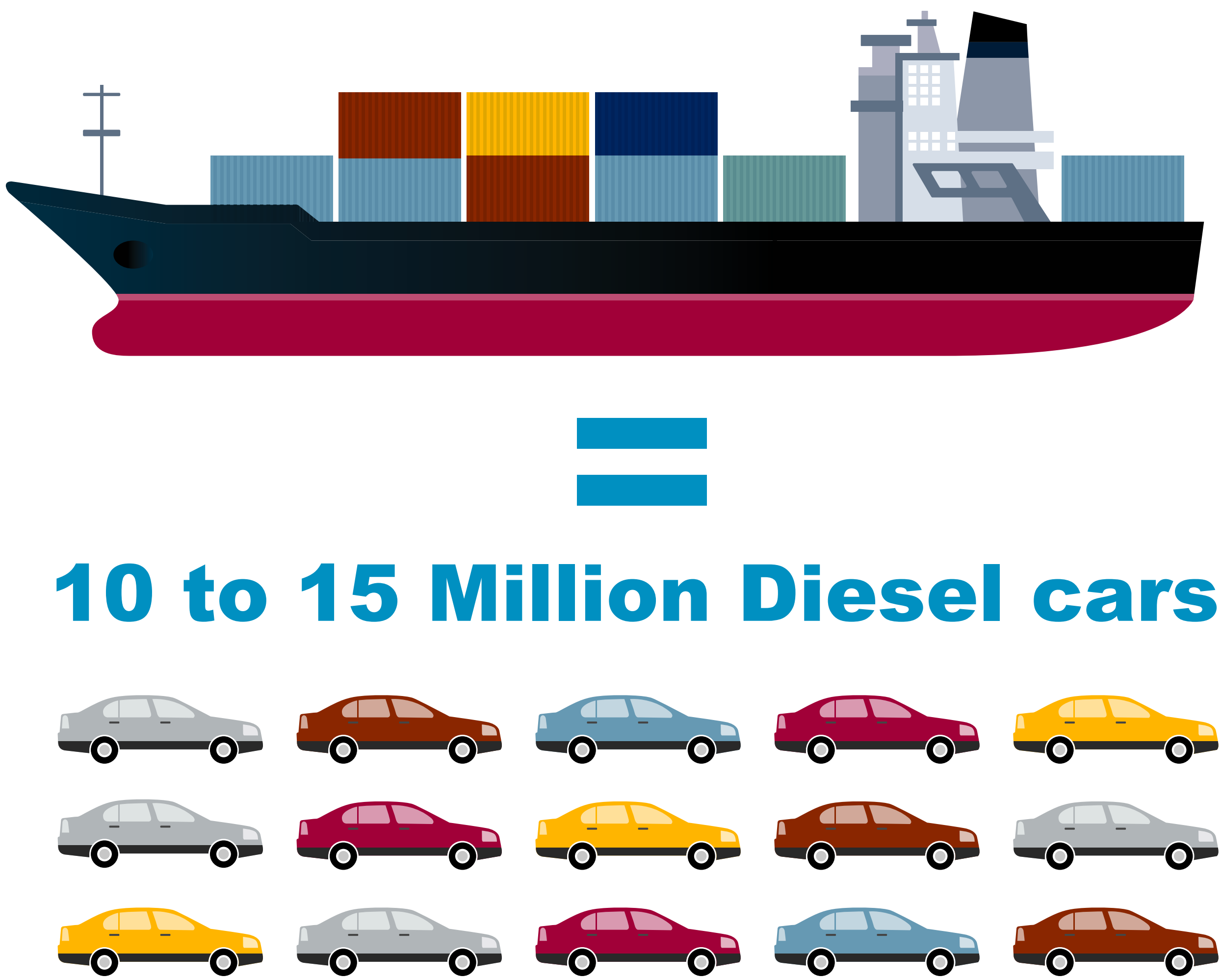
Battery-Powered Ships

Electric ship engines are being developed but are not generally considered a viable option in the near term. They might very well play a role in future, though. Norwegian ferry company Norled AS, shipyard Fjellstrand, and Siemens AS have developed the world's first 100 percent battery-powered passenger and car ferry, the *MF Ampere Ferry*.[30] Hybrid diesel and battery-powered vessels are also under development.[31]

WILL DESULFURIZATION REDUCE OIL USE IN MARINE TRANSPORT?

Like aviation, the shipping sector has long been relatively exempt from the more stringent air-quality regulations common to the rest of the oil market. Air emission considerations, such as those that led to the adoption of MGO as fuel in ECAs or even those that supported switching to LNG in some niche market segments, have remained relative exceptions. The sulfur cap for MGO is 0.1 percent in US and European ECAs (since January 2015) and 0.3 percent in China's unilateral ECAs. Elsewhere, HSFO is the fuel of choice. At 3.5 percent, its sulfur content is 2,300 to 3,500 times higher than that of on-road diesel burned by most cars and trucks, which is capped at 15 parts per million (ppm), or 0.0015 percent in the United States. It's even less (typically 10 ppm) in the European Union and China.[32] A single container carrier, therefore, emits as much SOx as millions of diesel cars.[33] That makes the shipping industry one of the world's top sources of SOx by far, as well as a major source of NOx and GHG emissions.[34] As winds carry marine emissions inland, ships have been an important cause of premature human deaths and respiratory symptoms in coastal regions outside of ECAs.[35]

Figure 4: Comparison of emissions



Source: Adapted from IGU, Enabling Clean Marine Transport, with CGEP calculations.

The new IMO standards coming into effect in 2020 go a long way toward bridging the gap between air emission standards on land and at sea. The SOx content of air emissions from ships outside ECAs will drop to a level corresponding to a bunker sulfur cap of 0.5 percent. That's still higher than diesel but dramatically lower than previous levels. It's an overdue but potentially very impactful plunge.

Given the scope of the change in SOx emission standards, one would expect the new IMO rules to significantly accelerate the shift in bunker fuel consumption patterns, which are already driven by economic and technical factors. In particular, the new regulations could promote the use of relatively sulfur-free LNG as marine transportation fuel. In practice, there is a lot of daylight between the scope of adjustment called for by the new regulations and the changes that are actually occurring. Nearly 10 years after the regulations were introduced, LNG adoption rates remain low in the marine sector, and the impact of the new rules has remained limited. Despite some growth in the order book of LNG ship engines, and despite the fact major ports and bunker providers have taken early steps to offer LNG bunkering services, natural gas will not be the first choice for shippers to meet the new emission standards, at least initially.

Broadly speaking, few industry participants have so far provided evidence that they have taken concrete steps to comply with the rules, prompting analysts to worry that time is running out to achieve the regulations' objective. In view of the complexity of the challenge and the way in which the IMO policy was designed, however, delays are not surprising. Far from a sign of neglect or the effect of insufficient advance notice, the industry's seeming apathy can be seen as a prudent, rational reaction to a difficult challenge—or as a perverse consequence of the rules themselves.

An Embarrassment of Options

In its bid to foster cleaner bunkers, the IMO has picked performance standards ("obligations of result") over technical ones ("obligations of conduct"). It is not the first time the regulator has opted to remain agnostic as to the path chosen by shippers to achieve the target. It is easy to see why. Technical standards "pick a winner" and run the risk of discouraging innovation by mandating the use of a preferred technology. In contrast, performance standards leave it up to market participants to chart their paths to a desired outcome. Performance standards are widely seen as promoting market innovation and minimizing lock-in risks. Market participants are effectively incentivized to innovate and come up with new technological options in their bids to comply at the lowest possible cost. On the flip side, performance standards have a recognized downside: they are, by nature, notoriously difficult to enforce.[36] The IMO sulfur cap meets the definition of a performance standard in that it specifies an intended outcome, or *result*—the amount of sulfur oxide that ships are allowed to release into the air—but leaves the *conduct*—how shippers meet that goal—up to them.

On current technology, shippers have three main options to meet the new low-sulfur requirements. They can run on LNG; they can continue to use HSFO and process air emissions through an exhaust gas cleaning system (EGCS), more commonly called "scrubber," which must be fitted on board the ship, along with dedicated tanks to hold and treat resulting wastewater from the process; or they can switch from HSFO to a lower-sulfur fuel, such as MGO or a new type of residual fuel known as low-sulfur fuel oil (LSFO).[37] Each option has its costs and benefits. Those, however, depend on market conditions that are inherently difficult to foretell. Market unpredictability is further exacerbated by regulatory uncertainty and, as we shall see, potential feedback effects from the new standards themselves. Although IMO policy is, on paper, technology neutral, all this accumulated uncertainty effectively favors the option that requires the least planning and up-front expenditure from shippers: lower-sulfur bunkers.

Waiting Game

Although the IMO first announced the cleaner-burning bunker rules as far back as 2008, many industry participants have yet to decide which of the three paths to compliance to adopt. This has led some industry stakeholders to recommend postponing the rules' implementation.[38]

Why the delay? It did not help that the IMO initially kept open the option of postponing the rules by up to five years, pending the results of a fuel-availability study commissioned from a consortium of third-party consultancies. A final decision on the time frame of implementation had been planned by the end of 2018. As such a late decision would not have left much time for unprepared shipowners to comply by 2020, many shippers and market analysts wrongly assumed that the IMO would delay implementation. They were surprised when the IMO, in a bid to give clarity to the market, moved up its final decision and, in October 2016, confirmed January 1, 2020, as the date when the rules would take effect.

Only then did the prospect of the new rules send tremors through the industry. Corporations set up ad hoc planning committees. Scrubber manufacturers reported a sudden, steep increase in inquiries. While some shipping firms have taken steps to meet the standards and have invested in scrubbers or LNG engines, however, most have not. Despite fielding more inquiries, scrubber manufacturers have yet to report an actual pickup in orders.[39]

"What we're expecting is a wait-and-see approach from ship owners," said Mark VandeVoorde, managing director at GCC Bunkers. "While what will happen is by no means clear, what is becoming increasing [*sic*] clear is that relatively few people will take a proactive approach to 2020."[40]

Three sets of factors can be identified that discourage a prompt response to the new policies: the financial burden of premature compliance; financial risks stemming from market uncertainty, which is exacerbated by the IMO policy itself; and regulatory uncertainty.

The Cost of Compliance

Premature compliance can be punishing. Both MGO and low-sulfur residual fuel oil (LSFO), a new product developed by refiners to comply with ECA sulfur requirements, trade at a significant premium to HSFO. Shippers, therefore, have no incentive to use these higher-cost fuels, or even slightly higher-sulfur blends, until required. Meanwhile, the LNG and scrubber options both entail multimillion-dollar up-front capital expenditures, including the capital cost of new processing units and storage tanks (for LNG or wastewater), the one-off loss of revenue from laying up ships in dry dock for weeks to be retrofitted, and the permanent opportunity cost of losing deck space and loading capacity to the new equipment.[41] By rushing to respond to the new standards, shippers run the risk of taking on an unnecessary financial burden, and they put themselves at a disadvantage to more circumspect competitors.

Market Uncertainty

The unpredictable ups and downs of oil and gas markets make it difficult to forecast the relative costs and benefits of the various options. This is another reason for market participants to remain sidelined. Roughly speaking, investing in an LNG engine makes sense for shippers as long as natural gas prices stay low enough (compared to oil prices) to offset the engine's up-front cost over the vessel's remaining life-span.[42] The LNG option could prove a losing proposition, however, in the event of a natural gas rally. Likewise, installing a scrubber on a ship requires that the HSFO discount (relative to low-sulfur fuel) be wide enough to offset capital costs. Switching to low-sulfur fuel will have the advantage of sparing shippers the up-front cost of a scrubber or LNG engine, but it would be a money loser if the low-sulfur-fuel premium exceeded that cost. Forecasting those interfuel price spreads is risky. Given the inherent uncertainty of oil and gas prices, delaying a decision, in the hope of gaining more visibility on market direction as time goes by, seems to make sense.

The IMO's preference for performance standards only adds to the uncertainty. The global SOx cap could itself cause hard-to-predict feedback effects. The industry's rate of adoption of the various options might impact, at least at the margin, their competitiveness. Large-scale adoption of LNG bunkering would boost demand for the fuel and, thus, tend to support its prices. This, in turn, could undermine the business case for this option. Scrubber costs could change depending on the technology's rate of penetration. HSFO prices might plummet in the case of large-scale fuel switching to LSFO or LNG, but then again, they could prove surprisingly resilient if scrubber sales exceeded expectations and maintained a baseline of demand for this fuel. The first shippers to commit to any given option will necessarily suffer from a deficit of information and, therefore, put themselves at a disadvantage—leaving it to late respondents to reap the rewards of their patience. This gives shippers an incentive to take their time before staking positions. Similarly, late adopters of LNG engines or scrubbers might enjoy lower capital and operating costs if rising adoption rates foster standardization, economies of scale in manufacturing, efficiency gains, and technology improvements, which would also encourage delays.

Regulatory Uncertainty

Finally, regulatory uncertainty gives shippers further reasons to hold back. The global cap only covers SOx emissions but fails to address NOx or GHG, even though those are also due to come under tighter regulations. This further clouds the relative economics of the various compliance options. The business case for scrubbers might not work so well if the global cap is extended to NOx or GHG instead of being limited to SOx because scrubbers do not filter out NOx and are relatively carbon intensive. LNG used as a bunker fuel has the advantage of being relatively low in both SOx and NOx emissions. There are, however, some concerns that methane leakage—if not properly contained—could make it a source of relatively high GHG emissions. This is a somewhat controversial issue that calls for further investigation. Burning LSFO or MGO also comes at a cost in GHG if the full life cycle of the fuels is taken into account, given the carbon intensity of refinery upgrading and desulfurization. Bunker blending to meet the new targets could also call for increased long-haul shipments of blending material. This, in turn, would raise life-cycle emissions from nominally compliant fuels. Uncertainty as to the scope and timing of future NOx and GHG regulations warrants further caution on the part of shipping operators.

Default Option

With all these reasons not to rush to a decision, the shipping industry's seeming indecisiveness should not come as a surprise. Less than three years before the new standards are to take effect, scrubber penetration remains marginal. By one count, less than 1 percent of the world's estimated 45,000 vessels have been equipped with scrubbers.[43] New orders, according to manufacturers, remain few and far between.[44] LNG orders are rising but from an extremely low base. An absence of response is itself a kind of response. Given how long it takes to retrofit a ship or to order and to take delivery of new scrubber-equipped or LNG-fueled vessels, and given the limited capacity of both scrubber and LNG-engine manufacturers, shippers' cautious approach means that, at the end of the day, most of them will go for low-sulfur fuels.

Even if scrubber orders were to suddenly pick up ahead of the new rules, assembly line constraints and manufacturing lead times would cap the uptake.[45] LNG adoption, though up from very low initial levels, remains marginal when seen against the full scale of the bunker market. Both scrubbers and LNG will have supporting roles in complying with the new regulations, but they will not take center stage. With the 2020 deadline looming, the scope for substantially scaling up these measures is limited. The industry's wait-and-see approach means that low-sulfur bunkers, the option that requires the least planning and up-front investment from shippers, though not necessarily the most cost effective in the long run, will, by default, be the most widely adopted.

A CRISIS IN THE MAKING?

While for shippers, lower-sulfur fuels may be the low-cost, "easy" way to meet the coming IMO sulfur standards, the prospect of a sudden migration of shipping demand to lower-sulfur fuels appears, for the refining industry, as a daunting challenge. Shippers, by relying on the "default" option, effectively shift the burden of compliance onto fuel suppliers.

For the latter, the problem is twofold: a potential collapse in demand for HSFO, a byproduct of refining for which there are few other uses, and a surge in demand for lower-sulfur fuels, of which there is limited supply. Most analysts reckon that the new shipping fuel of choice will be some kind of MGO, a middle distillate akin to diesel (albeit with a higher sulfur content). The concern is then that with diesel demand from other sectors also widely expected to boom, refiners might not be up to the task without substantial investment in processing capacity.

A diesel shortfall, if it were to occur, could be disruptive. Diesel, or more generically middle distillate, is the most versatile of oil products, used in many applications, from trucking and railroads to passenger vehicles, power generation, agriculture, space heating, and various industrial uses, as well as shipping. A diesel rally could quickly spread across geographies and spheres of economic activity. Surging diesel demand was widely associated with the 2008 oil rally, when the price of front-month light, sweet crude futures reached a record $147/barrel at the NYMEX.[46] As the theory goes, an imbalance in diesel supply and demand put a price premium on light, sweet crude benchmarks such as West Texas Intermediate (WTI) and North Sea Brent, which both have a high yield of diesel and other light products.[47]

Yet just as shippers show few signs of having taken concrete steps to prepare for the IMO rules, the same may be said of the refining industry. With a few notable exceptions, most refiners, unsure of the shipping industry's response, seem to have taken a wait-and-see approach to the new standards. This has led many analysts to draw analogies with the 2008 rally and recall that another, albeit far more dragged out, desulfurization campaign, that of road diesel, had helped tighten diesel markets and send oil prices through the roof a decade ago.

While the challenge for the refining industry is undeniable, such fears overlook three key factors. First, forecasts of diesel demand are highly uncertain. The desulfurization of road diesel in the 2000s occurred against a backdrop of surging diesel demand from China and other emerging economies, the effects of which were compounded by the dieselization of the European car fleet. In contrast, current expectations of robust growth for trucking and other uses may well be way overstated—so shippers may not have to compete as hard for finite distillate supply. Second, expectations of surging MGO demand from the marine sector assume that shippers that do not switch to LNG will be largely limited to a choice between two established refined products, HSFO and MGO. While today those may be the main fuels on the menu, that might not be the case in the future. Given the high viscosity requirements of large ship engines, most future bunker fuels are more likely to be new LSFO hybrids. Producing these new fuels will not put as much stress on the distillate pool as analysts fear, but will likely require large volumes of vacuum gasoil (VGO), an intermediate feedstock that is an important building block of European gasoline production. Gasoline, rather than diesel, could thus be the product that comes short. Finally, forecasts of a tight diesel market give short shift to shippers' option of last resort: noncompliance. Unattractive as it might seem, noncompliance may play an important role in the shipping industry's response to the new rules—especially in view of the IMO's absence of enforcement capability on the high seas.

A Replay of 2008?

Although bunkers only account for an estimated 4 to 7 percent of global oil demand, their importance for refiners as the world's largest sink for the "bottom of the barrel," the low-value, high-sulfur byproducts of the refining process, far exceeds their share of the overall market. Changes in bunker fuel markets could thus have far-reaching impacts on the "downstream" sector as a whole, precipitating the demise of some of the less competitive European refineries and accelerating the restructuring of the global refining industry. Among other effects, this could make Europe more dependent on refined-product imports and further enhance the role of trading companies in global product supply, with potential implications for energy security and oil price volatility.[48]

Argus Media, a specialized energy communications and analysis firm, reckons that marine bunkers alone account for nearly half (47percent) of the world's end-user demand for that increasingly unwanted product, with power generation a distant second (32 percent), followed by other industrial uses (20 percent).[49] Stationary demand for residual fuel oil has been dwindling as power stations increasingly turn to natural gas, renewable sources, or even coal instead of HSFO, supplemented in many emerging markets by the widespread use of diesel-fired backup generators. This has only served to increase the importance of bunker fuels as the last remaining sink for heavy products. Now that sink too is at risk.

Many analysts reckon that the new IMO rules will drastically cut residual fuel oil use from the marine sector, with HSFO consumption seen down by more than 75 percent to perhaps just 500,000 bpd to be burned on scrubber-fitted vessels, leaving up to 2.5 million bpd of demand to migrate to lower-sulfur fuel markets. Of that amount, analysts expect 500,000 bpd to 600,000 bpd at most to be LSFO, and the rest MGO. Such a large-scale shift away from HSFO would leave much of the refining industry scrambling to find alternate outlets for high-sulfur fuels. Notional HSFO refining margins are usually negative, giving refiners an incentive to invest in conversion capacity to cut their HSFO yields. Significant erosion of the HSFO market would widen that negative spread. Not all refineries can muster the capital to upgrade, however. Some of the more challenged, smaller, less competitive refineries with high HSFO yields might not survive the test.

Conversely, analysts fear that surging low-sulfur fuel demand will put distillate production capacity to the test, in a replay of the 2008 oil rally. LSFO supply is seen as constrained by the limited availability of low-sulfur crude oil, which refiners can run to produce LSFO without sulfur removal.[50] That would leave MGO, which is produced from higher-sulfur crude but must usually go through a desulfurization unit, as the main option to meet the bunker specs. Just as LSFO supply will bump against feedstock constraints, hardware limits, notably in cracking and upgrading capacity, could cap MGO availability.

The IEA, the global benchmark for oil analysis, reckons that low-sulfur crude availability will cap production of compliant LSFO at about 500,000 to 600,000 bpd by 2020. Based on its bullish take on shipping requirements, it projects growth in MGO demand of up to 2.9 million bpd by 2020, adding to incremental diesel consumption forecasted at 1.9 million bpd. While middle distillate demand is thus projected to expand by a total of nearly 5 million bpd, refinery upgrades and expansions are seen boosting refinery throughputs by close 4 million bpd—leaving the market short of diesel by roughly 1 million bpd. Expanding distillate production capacity beyond projects that are already underway would come at a steep cost and take too long anyway to be completed in time.[51]

A consensus of sorts appears to have coalesced around the forecast of an imbalance of this order of magnitude by 2020. That projected 1 million bpd distillate gap is fueling concerns about a diesel rally, which analysts fear could spread to low-sulfur crude oil grades like UK Brent or US benchmarks West Texas Intermediate (WTI, the base of the NYMEX/ICE crude future contract) and Light Louisiana Sweet (LLS). With ships seen competing head-on for finite distillate supplies with trucks, railroads, European motorists, farmers (agricultural pumps, tractors) and backup generators (ubiquitous in emerging markets), all these sectors could feel the pinch. Given that 80 percent of internationally traded goods are moved by ship, higher shipping costs could also spread to the broader economy at the margin via pass-through to manufacturers and consumers. The ripple effects could be disruptive.[52]

Analysts have ominously compared the challenge of the IMO rules to the desulfurization of road transport fuels in the 2000s, which many have identified as a major driver behind the surge in oil prices of 2008. In the words of the IEA, "Lowering [the sulfur cap for marine bunkers] from 3.5% to 0.5% is easily the most dramatic change in fuel specifications in any oil product market on such a large scale."[53]

On paper, a disruptive run-up in diesel prices as demand bumps against capacity constraints could ultimately speed up a move away from oil in marine transport and incentivize investments in alternative fuel sources such as LNG bunkers. Expectations of such a disruptive market response rest on several questionable assumptions, however.

Uncertain Diesel Demand

While the oil market has a long record of supply/demand imbalances and price spikes, the history of forecasting errors and unexpected twists in oil demand patterns is even longer. Distillate markets may well tighten by 2020, but a full-blown supply crunch would be a worst-case scenario. As discussed above, projections of robust bunker fuel demand growth give short shrift to the efficiency gains already achieved by shippers and to the high potential for further improvements on the back of digitalization and industry consolidation. Forecasts of robust diesel demand growth from other sectors seem equally overstated.

Strong growth in diesel demand was a salient feature of the oil market of the 2000s, driven in part by the takeoff in the Chinese economy and the dieselization of the European automobile fleet. Gasoline markets were a mixed bag, with strong growth in emerging markets, led by China, but contraction in advanced economies, with signs of "peak demand" in the United States and fuel switching in Europe. Forecasters extrapolated from these trends to project robust growth in diesel consumption over the medium term, leading refiners to pile up investments in upgrading capacity to boost their diesel yields.

These trends appear to have stalled. Diesel demand from India and China in the first half of 2017 came in below expectations. Diesel has fallen out of style in Europe for automobile combustion engines in the wake of a 2012 World Health Organization study connecting particulate emissions from diesel exhaust to cancer. More recently, evidence of misreporting by diesel engine manufacturers about meeting emission standards—the so-called Volkswagen emission scandal—helped undermined policy support for the fuel. The scandal, also known as "emissionsgate" or "dieselgate," started in September 2015 when the US Environmental Protection Agency (EPA) found that German automaker Volkswagen Group had programmed some of its diesel engines to hide NOx emissions up to 40 times US limits, and charged it with violating the US Clean Air Act. Several European cities now plan to ban diesel for transportation.

Following many years of steady growth, diesel consumption in major European economies, from France to the Netherlands, has already switched into reverse, while gasoline use is on the rebound. Diesel use in distributed power generation (backup generators, or gen-sets) in emerging countries is also facing headwinds, as alternatives, including natural gas and renewable energy, are being harnessed for electricity generation. Should forecasts of rapid electrification of the vehicle fleet in the United States and Europe come true, that too would undermine distillate markets. Meanwhile, the potential for efficiency improvement in the trucking sector, a leading center of diesel fuel use, is considerable.

Birth of a Fuel

From the supply side of the equation, expectations of a distillate crunch also appear overstated. Such worries overplay the linkage between bunkers and distillate fuels and imply a "business as usual" segmentation of marine fuel markets into HSFO and MGO: forecasts assume shippers will simply shift from one to the other, changing the products' respective market shares but leaving their assays and the delineation between product categories essentially unchanged. In fact, refiners have more flexibility to maximize their yields of one type of fuel or another than they are given credit for. More importantly, the new IMO rules will likely move the boundaries that currently separate product categories and incentivize the emergence of new blended products. Shippers' and refiners' reluctance to invest in capital-intensive compliance options will put the onus of innovation on the blending side of the market—and in so doing may help entrench the role of oil in marine transport.

For several reasons, shippers are unlikely to be limited to a binary choice between HSFO and MGO. Already the global sulfur cap is spurring the emergence of new hybrid products combining the viscosity and lubricating properties of HSFO (required by most ship engines) and the low sulfur of MGO. Blending will likely play as large a role in producing those fuels as refining: some of the new LSFO products will be mixes of multiple components whose supply may not be constrained by upgrading or desulfurizing capacity.

The preference for new LSFO blends reflects in part the challenge of using MGO in large vessels whose engines call for fuels with higher viscosity than MGO can provide. MGO's lubricating properties, which are substantially different from those of HSFO, also require a corresponding adjustment in lubricating oils. This can be tricky. The switch to MGO has reportedly already contributed to collisions and other minor accidents due to engine failures or a lack of immediate engine response.[54]

Suppliers in some of the larger bunkering centers have already started offering new LSFO hybrids. Anecdotal evidence shows that shipping companies have been increasingly adopting this new bunker fuel grade.[55] Hapag-Lloyd's fuel usage here too is a case in point. In addition to its fuel consumption, its earnings reports have long provided details about its fuel mix, including the split between what it labels "marine fuel oil" (MFO) and "marine diesel oil" (MDO), a product akin to MGO. Recently it has started breaking down MFO use into low- and high-sulfur categories. Consumption of both high-sulfur MFO (HSFO) and MDO edged down in 2016, in line with a steep decline in overall bunker use, but that of low-sulfur MFO, or LSFO, bucked the trend, up by a steep 130 percent, lifting its share of the overall fuel mix by four percentage points year-on-year to 7 percent.[56]

It seems unlikely that LSFO production capacity will be as limited by refining constraints or crude oil availability as some projections suggest. Supply will come in part from blending vacuum gas oil (VGO), widely used in European refineries as intermediate feedstock for gasoline production.[57] A key source of VGO supply to Europe has historically been Russian refineries. Recent refinery upgrades have already reduced the availability of Russian VGO for export. VGO blending into the bunker pool by Russian refiners, which collectively have also been the world's leading bunker suppliers, will further constrain VGO shipments to Europe.

Thus, shifts in bunker fuel quality as a result of the IMO's new specs may affect gasoline supply more directly than they affect diesel supply. The shift will come, however, at a time when electric vehicles, compounding the effect of efficiency gains, are increasingly expected to take a toll on gasoline demand growth. Many analysts expect that the growing popularity of ride sharing and self-driven vehicles will speed up EV penetration, denting gasoline demand. Meanwhile, on the supply side, US gasoline production capacity is on the rise, thanks to high upgrading of US Gulf Coast refineries and rising supply of gasoline-rich shale oil.

In summary, expectations that the IMO sulfur standards will restrict bunker fuel availability and cause product markets to rally are likely overblown. Product suppliers often surprise the market with their flexibility and propensity for innovation. Nevertheless, simple refineries in Europe may be doubly challenged by declines in HSFO demand and reduced VGO availability. Heavy, sour crude oil grades, some of which are sold at formula prices partly based on those of HSFO, will also likely face headwinds. Heavy oil producers such as Canada, Mexico, and Venezuela may be particularly challenged. At the same time, the availability of hybrid bunker fuels will likely ease somewhat the pressure on shippers to move away from oil in favor of non-oil alternatives such as LNG bunkers.

Noncompliance

Last but not least, there is another factor that may at the margin reduce the risk of a surge in diesel demand when the IMO rules come into effect: the IMO's limited ability to enforce them.

No single entity has the authority, let alone the technical capacity, to carry out inspections on the high seas. The IMO lacks jurisdiction over the high seas and does not maintain a force capable of carrying out inspections. That leaves enforcement of the new rules in the hands of port states, which can check the records of the ships and bunker suppliers, as well as flag states—of which the top three are Panama, Liberia, and the Marshall Islands[58]—that have neither the capacity nor perhaps the will to carry out inspections.

While ships are required to keep records of bunker purchases, quality, and use, and port authorities can verify the bunker logs of incoming ships and require verification of bunker quality from bunker suppliers in the port, written records are generally not considered as reliable evidence of actual fuel consumption at sea. The most effective means of checking fuel use are flyovers and remote sensing of vessel emissions. These are costly enough to carry out in ECAs, let alone on the high seas.

Performance standards like the global sulfur cap are inherently challenging to enforce, compared to technical standards.[59] In the case of the sulfur cap, the challenge is particularly overwhelming, given the technical difficulty of tracking air emissions from a ship at sea and the complete lack of any credible enforcement authority on the high seas. Interestingly, the IMO in one earlier occasion had pointedly opted—with great success—for a technical standard rather than a performance standard, when it required that oil tankers be double-hulled in support of its oil-spill prevention policy.[60] Despite ongoing efforts to address it, the problem of verifying compliance with the global SOx cap remains fundamentally unresolved.

Most ocean carriers, dry bulk shipping firms, and tanker companies will undoubtedly consider it in their interest to comply with the new rules. Larger companies will be particularly wary of the reputational risks of noncompliance and, thanks to their economies of scale, will be in a better position to shoulder the cost of compliance than smaller operators. But the lack of a credible deterrent—and the fact that inspections and fines for noncompliance in ECAs, where enforcement is a far lesser challenge, have remained exceedingly rare and inconsequential—may nevertheless result in some level of noncompliance, notably from smaller operators.

At the very least, noncompliance is likely to act like a de facto safety valve in the event of a run-up in low-sulfur fuel costs. Noncompliance would likely be exacerbated by any upward pressure in the cost of complying with the new standards, such as a run-up in low-sulfur bunker fuel costs, and thus act as stabilizing feedback. Furthermore, the IMO recognizes that in some cases, compliant fuel may on occasion be unavailable in some ports, in which case vessels in need of bunkers will be granted waivers.

CONCLUSION AND POLICY CONSIDERATIONS

Intense competition in the shipping industry, against the background of overcapacity, slow global trade growth, and, until 2014, high oil prices, has been a catalyst for innovation.

Like most sectors of the oil market, marine transport is in flux. Industry consolidation, changes in ship design and size, improvements in fleet management, digitalization, and advances in data science are reshaping it, as will environmental and climate policy. Fuel efficiency is improving, and the switch to LNG—and perhaps soon to electric batteries or electric hybrids—is slowly gaining traction. New IMO regulations setting much more stringent sulfur standards for ships will require considerable adjustments from both the shipping industry and the fuel suppliers—refiners and trading companies—that service it. But the transition may not prove as disruptive as some analysts seem to fear nor warrant the concerns that have been expressed about a looming distillate supply crunch. A more comprehensive and integrated approach to environmental standards, simultaneously covering SOx, NOx, and GHG, could have accelerated a switch to LNG bunkering. Instead, heightened market and regulatory uncertainty have created the conditions of a waiting game where both ship owners and refiners are incentivized to stay on the sidelines and refrain from capital-intensive decisions. While often seen as disruptive, the new IMO rules are arguably more supportive of the status quo.

In opting to set a performance standard rather than a technical one, the IMO has ostensibly chosen technical neutrality. Performance standards are normally more supportive of innovation than technical ones, which by definition "lock in" a given technology. By effectively disincentivizing capital-intensive solutions and making low-sulfur fuel the default compliance option, however, the global sulfur cap entrenches, as it were, the role of oil in shipping more than it threatens to displace it with "cleaner" options.

It takes longer to turn over the global vessel fleet than the global car fleet: whereas motorists keep their cars for 15 years, most modern vessels have a lifespan of 25 to 30 years. Oil-fueled ships ordered today are designed to run on oil bunkers for their entire useful life. While the order book of LNG-fueled ships is growing, relatively few oil-fueled ships are being retrofitted with either scrubbers or LNG engines. Due to market and regulatory uncertainty and to the long lead times and capital requirements of LNG retrofits and scrubbers, shippers have by default adopted the compliance option that requires the least planning and upfront capital spending for existing ships, though not necessarily the most cost-effective one in the long run: conversion to lower-sulfur residual fuel oil. The global sulfur cap may thus inadvertently ensure oil's future in shipping and suggests that oil bunkers, unlike perhaps gasoline for cars, will be phased out with a whimper, not a bang.

But while the global sulfur cap does little to accelerate a transformation of the shipping industry, it does also, as a consequence, open considerable space for innovation in refined product design. The new rules set the stage for a substantial reconfiguration of the product markets. The emergence of a new breed of hybrid LSFO fuels will reduce the availability of VGO for gasoline production in Europe, but it seems unlikely to lead to the strong pressures on diesel markets that have been predicted. Considerable uncertainty remains as to the market's response to the new standards, however, and the risk of noncompliance is significant.

More focused policy measures by IMO states could have reduced market and regulatory uncertainty and may still do so. First, provisions could have been made to offset the burden of premature compliance for early scrubber or LNG adopters. As discussed, a key impediment to planning for the new measures is the financial burden of meeting the standards earlier than required. Providing shippers with incentives, fiscal or otherwise, to compensate for the cost of early compliance could have helped phase in scrubber and LNG retrofits until the cap comes into effect.

LNG bunkering suffers from a classic chicken-and-egg problem: ships need a sufficiently dense bunkering infrastructure to be deployed on a large scale, but in order to commit multibillion-dollar investments to LNG bunkering infrastructure, a sufficiently large fleet of LNG ships is needed. Although investment in slowly being allocated to LNG port infrastructure, LNG bunkering is unlikely to reach a meaningful scale until well after January 2020. As attractive as LNG might appear as a compliance path, the new IMO standards are insufficient to give LNG bunkers a strong push. More coordinated measures among ports would help overcome structural hurdles in the adoption of LNG bunkers and speed their development.

More clarity of future NOx and GHG restrictions would also reduce regulatory uncertainty and help market participants chart their path to compliance. The IMO Marine Environment Protection Committee (MEPC) shed some light on its GHG strategy at its weeklong 71st session, which concluded on July 7, 2017. It also set up new NOx Tier III ECAs and issued new rules on bunker delivery notes and new guidelines for the IMO's Fuel Oil Data Collection System. Stronger integration of the IMO's GHG, NOx, and SOx policies via a comprehensive global cap covering all types of emissions, far from increasing the burden for shippers, would greatly reduce the risk of separate policies working at cross purposes. A simultaneous SOx, NOx, and GHG cap would have been much more favorable for LNG, as neither scrubbers nor a switch to low-sulfur marine fuels can reduce CO2 and NOx emissions as effectively as LNG.

Finally, a more robust regime to enforce SOx regulations would go a long way toward making the IMO sulfur cap more credible. While the IMO may not be in a position to provide policy guidance in this area, others could step in to fill the gap. Cost sharing among major ports could help undertake spot inspections by overfly or monitor ship emissions via satellite. Explicit interport and international coordination among port states could give individual enforcement measures more impact and credibility. So would appropriately scaled fines and penalties. Developing a new international architecture for environmental inspections and regulatory enforcement would go a long way toward assuring broader compliance with emission standards.

Postponing the rules, as some have recommended, would not necessarily give industry more time to prepare, as the rules in their current form provide industry with an incentive to delay preparing for them for as long as possible. The IMO was therefore right to reaffirm the January 2020 deadline at its MEPC71 meeting. Phasing them in—for example, by giving out prizes for early compliance or by setting gradual targets—might have helped.

On current trends, however, the marine sector seems unlikely to experience the type of upheaval that many predict in the personal transportation sector. Although it is not sitting still, its course is more likely to be that of relatively slow and gradual reform than revolution. As the oil sector as a whole seems to sit on the cusp on radical change, the marine sector may paradoxically provide the oil industry with a lasting outlet for its changing products—and an island of relative stability.

NOTES

1 James Arbib and Tony Seba, "Rethinking Transportation 2020–2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries," *RethinkX*, May 2017, https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/591a2e4be6f2e1c13df930c5/1494888038959/RethinkX+Report_051517.pdf?pdf=RethinkingTransportation .

2 International Energy Agency (IEA), "World Oil Demand by Sector in the New Policies Scenario," World *Energy Outlook* 2016, November 2016.

3 As discussed below, estimates vary widely. Since marine bunkers are, by definition, consumed at sea, countries do not normally include them in their estimates of domestic oil demand. There is, therefore, great uncertainty clouding global demand assessments and, as discussed below, a wide range of estimates.

4 Emission control areas (ECAs) are 200-nautical-mile bands located in parts of northern Europe, North America, and the Caribbean, as well as in sections of coastal China, where relatively stringent air emission standards already apply. Sulfur limits within ECAs in the Americas and Europe have been set at 0.1 percent sulfur (S) since January 1, 2015. In Chinese ECAs, the sulfur cap is 0.3 percent. See http://www.imo.org/en/mediacentre/hottopics/ghg/documents/sulphur percent.

5 Examples of this type of analysis include the following: International Energy Agency (IEA), "Developments in Marine Bunkers," Oil 2017: *Analysis and Forecasts to 2022*, March 2017; IEA, "Marine Gas Oil to Seize Bunker Fuel Market Share," *Medium-Term Oil Market Report 2016*, February 2016; Housley Carr, "Under the Blade—The Far-Reaching Impacts of Low-Sulfur Bunker Fuels on Demand, Price and Refining," *RBN Energy LLC*, March 1, 2017; Philip Shaw, "Changing Regulations for Fuel Oil Sulphur Caps" (online PowerPoint presentation, Argus, January 2017); and Ned Molloy, "The IMO's 202 Global Sulfur Cap: What a 2020 Sulfur-Constrained World Means for Shipping Liners, Refineries and Bunker Supplies," *Platts*, October 2016. See also Antoine Halff, "IMO Roundtable: The Future of Marine Transportation," *Columbia University Center on Global Energy Policy (CGEP)*, July 2017. This is a summary of a discussion cohosted by CGEP, Axelrod Energy Projects (AEP), and the Royal United Services Institute (RUSI) in London on February 20, 2017. See also Antoine Halff, "Sulfur Regulations on the High Seas: Global Energy Dialogue Report," *CGEP*, April 2016.

6 International Energy Agency, Oil 2017, 109-110; Halff, IMO *Roundtable*.

7 Bunker fuels are exports that do not get imported into any country and, thus, tend to fall into the cracks of official statistics.

8 International Energy Agency, Oil 2017, 105; International Energy Agency, *World Energy Outlook* 2016, 117–118. The two reports seem to use different reference years. Oil 2017 uses 2016, while the *World Energy Outlook* uses 2015. A one-year difference, however, does not explain the gap between the estimates.

9 Edmund Hughes, "0.50 Percent Sulphur Limit for Fuel Oil Used by Ships" (presentation, CGEP-AEP-RUSI Roundtable, London, February 20, 2017).

10 International Energy Agency, *World Energy Outlook* 2016, pp. 118–119.

11 According to industry estimates, tankers and bulk carriers together account for more than 100 million tons per year of HSFO demand, or roughly two-thirds of the market. That's compared to roughly 55 million tons per year consumed by a global fleet of about 5,500 container carriers.

12 "Slow Steaming Here to Stay," A.P. Moller -Maersk, September 1, 2010, http://www.maersk.com/en/the-maersk-group/press-room/press-release-archive/2010/9/slow-steaming-here-to-stay. See also "Maersk Line: Moving Away from Slow-Steaming

Would Require a Fundamental Change to the Network," *Ship and Bunkers*, January 22, 2015, https://shipandbunker.com/news/world/223738-maersk-line-moving-away-from-slow-steaming-would-require-a-fundamental-change-to-the-network.

13 Michael Maloni, Jomon Aliyas Paul, and David M. Gligor, "Slow Steaming Impacts on Ocean Carriers and Shippers," *Maritime Economics & Logistics* 15, no. 2, June 2013, 151–171.

14 "Maersk—The New Direction" *A.P. Moller – Maersk*, online PowerPoint presentation, Capital Markets Day, December 13, 2016, http://files.shareholder.com/downloads/ABEA-3GG91Y/3465870944x0x920931/5F45D673-AD7D-43FC-A6C0-7548D2069ADC/Transport_and_Logistics_CMD_2016.pdf).

15 *Annual Report* 2016 (Copenhagen: A.P. Moller – Maersk, 2017), 14–15.

16 "Alphaliner TOP 100," *Alphaliner*, accessed July 3, 2017, https://alphaliner.axsmarine.com/PublicTop100/.

17 "Maersk—The New Direction" *A.P. Moller – Maersk*, 13. Mergers and acquisitions proceeded at a brisk pace in 2016. This included the announcement or completion of several large deals, such as the merger of China Ocean Shipping Co. and China Shipping Group, now China COSCO, China's biggest shipping company and fourth on the Alphaliner list; Hapag-Lloyd AG and United Arab Shipping Co.; CMA CGM and Neptune Orient Lines (NOL) Singapore; and Maersk and Hamburg Sued. *Q4 – FY 2016 Investor Report*, (Hapag-Lloyd AG, March 24, 2017), 7, accessed July 3, 2017, https://www.hapag-lloyd.com/content/dam/website/downloads/pdf/HLAG_Investor_Report_FY_2016.pdf. In July 2017, Cosco also agreed to acquire smaller rival Orient Overseas (International Ltd.). See the *Wall Street Journal* from July 10, 2017.

18 "Maersk—The New Direction," 34.

19 N. Poskus, "What the New Ocean Carrier Alliances Mean for Your Freight," *Flexport.com*, accessed July 3, 2017, https://www.flexport.com/blog/what-are-ocean-alliances/ .

20 "Maersk Q1 2017 report – 11 May 2017 conference call," (*Maersk*, online PowerPoint presentation, p. 9, accessed July 3, 2017, http://files.shareholder.com/downloads/ABEA-3GG91Y/4890832430x0x942439/74BCF21F-9B4B-4FAC-82E6-7F1B08AC02D1/Maersk_Q1_2017_Presentation.pdf).

21 *Annual Report* 2016 (Copenhagen: A.P. Moller – Maersk, 2017), 13.

22 "The World's Largest Ship," *Maersk.com*, accessed July 3, 2017, http://www.maersk.com/en/hardware/triple-e.

23 N. Cabrera, "The Largest Container Ships in the World: *CSCL Globe, MSC Oscar*," S*hip Lilly*, December 26, 2014, http://www.shiplilly.com/blog/largest-ships-world-cscl-globe-msc-oscar/.

24 Q1 2017 *Investor Report* (Hapag-Lloyd AG, May 12, 2017), 7 and 12, downloaded July 3, 2017, https://www.hapag-lloyd.com/en/ir.html .

25 Id., 11–12.

26 Although the company's investment reports focus on vessel size as a driver of efficiency gains, slow steaming might have played an important role.

27 Jugal K. Patel and Henry Fountain, "As Arctic Ice Vanishes, New Shipping Routes Open," *New York Times*, May 3, 2017. Ørts Hansen, Grønsedt, Lindstrøm Graversen, and Hendriksen, "Arctic Shipping—Commercial Opportunities and Challenges" (presentation, CBS Maritime, Copenhagen Business School, Frederiksburg, Denmark, 2016), accessed July 3, 2017, https://services-webdav.cbs.dk/doc/CBS.dk/Arctic%20Shipping%20-%20Commercial%20Opportunities%20and%20Challenges.pdf.

28 "Maersk—The New Direction" *A.P. Moller – Maersk*, 38 and 56–61.

29 Anna Shiryaevskaya and Rakteem Katakey, "Oil Tankers to Cruise Ships Fueled by LNG Offer Hope on Gas Glut," *Bloomberg News*, April 25, 2017, https://www.bloomberg.com/news/articles/2017-04-25/oil-tankers-to-cruise-ships-fueled-by-lng-offer-hope-on-gas-glut. New LNG vessels on order reportedly include seven cruise lines from Carnival and four Aframax tankers from Russia's largest tanker operator, Sovcomflot. See also Mike Corkhill, "The World's LNG-Fuelled Ships on Order, 2017," *LNG World Shipping*, April 24, 2017, http://www.lngworldshipping.com/news/view,the-worlds-lngfuelled-ships-on-order-2017_47089.htm.

30 See "Ampere Ferry: World's First All-Electric Car Ferry," *Corvus Energy*, http://corvusenergy.com/marine-project/mf-ampere-ferry/.

31 "The Marine Hybrid Battery Is Here," *Corvus* Energy, July 1, 2014, http://corvusenergy.com/the-marine-hybrid-battery-is-here/. See also Hai Lan, Su Li Wen, Ying-Yi Hong, David C. Yu, and Lijun Zhang, "Optimal Sizing of Hybrid PV/Diesel/Battery in Ship Power System," *Applied Energy* 158, (November 15, 2015): 26–34.

32 Sulfur content is more commonly expressed in parts per million (ppm) in the case of low-sulfur fuels. Expressed in this unit, 0.0015 percent equals 15 ppm, and 0.001 percent is equivalent to 10 ppm.

33 According to the International Gas Union, one large container ship at sea using 3 percent S bunker fuel emits as much SOx as 50 million diesel-burning cars. See International Gas Union, *Enabling Clean Marine Transport*, March 2017, 4 (IGU.org, accessed July 3 2017, http://www.igu.org/sites/default/files/node-document-field_file/IGU_A4_CleanMarineTransport_Final%20March%202017_3.pdf). References provided for this estimate include Monitoring Atmospheric Composition and Climate (MACC) II, *Report on the Evaluation of Ship Emissions and Harmonized Dataset*, July 2014 (accessed July 2, 2017, http://www.gmes-atmosphere.eu/documents/maccii/deliverables/emi/MACCII_EMI_DEL_D_22.2.final.pdf) and Olaf Merk, *Shipping Emissions in Ports*, International Transport Forum Discussion Paper, Paris, OECD, December 1, 2014 (accessed July 3, 2017, http://dx.doi.org/10.1787/5jrw1ktc83r1-en). A back-of-the-envelope effort to replicate this calculation yielded significantly lower—albeit still staggering—results. An average size (8,000 TEU) container ship running on 3.5 percent S HSFO (higher sulfur than in the IGU case) releases as much sulfur oxide (SOx) as 9.9 million small passenger cars running on 15 ppm sulfur diesel or 14.9 million cars using 10 ppm sulfur diesel. This assumes that the ship consumes about 225 tons of fuel per day at a speed of 24 knots, with a conversion rate of 1,009 liters per ton, and it assumes the car consumes 5 liters per 100 kilometers.

34 According to the International Energy Agency international shipping activity in 2015 emitted 8.2 million tons of sulfur dioxide (SO2), or 10 percent of global energy-related SO2 emissions. The IEA noted that the relative share of shipping is much higher in coastal areas, and Hong Kong reached 44 percent of SO2 emissions before the adoption of corrective measures (International Energy Agency, *World Energy Outlook 2016*, 120). Other estimates are higher. For example, the Organization for Economic Cooperation and Development (OECD) estimates that ships generate "approximately 5–10% of all SO2 anthropogenic emissions"—not just energy-related SO2 emissions—at a global level. The OECD also notes that these shipping emissions "can represent a large share of total emissions in port-cities and have important health impacts." See *Reducing Sulfur Emissions from Ships: The Impact of International Regulations*, OECD Corporate Partnership Board Report, International Transport Forum, May 9, 2016, 10 (accessed July 3, 2017, https://www.itf-oecd.org/sites/default/files/docs/sulphur-emissions-shipping.pdf). According to the IMO, during 2007–2012, shipping on average accounted for about 3.1 percent of annual global CO2 and 2.8 percent of annual GHG emissions on a CO2-equivbalient basis, and international shipping accounted for about 2.6 percent and 2.4 percent of CO2 and GHG emissions, respectively. "Third IMO GHG Study 2014," IMO, http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenhouse-Gas-Studies-2014.aspx). IEA estimates that the shipping sector accounts for around 2 percent of global energy-related CO2 emissions. That's equivalent to the emissions of Indonesia and Malaysia combined (International Energy Agency, *World Energy Outlook 2016*, 118).

35 US Environmental Protection Agency, *National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports, Office of Transportation Air Quality*, 2016, (EPA-420-R-16-011).

36 See Daniel Bodansky, *The Art and Craft of International Environmental Law* (Cambridge, Massachussetts and London: Harvard University Press, 2010), 76–79, and Scott Barrett, *Why Cooperate? The Incentive to Supply Global Public Goods* (Oxford: Oxford University Press, 2007), 161–162.

37 LSFO is most often understood to have a sulfur content of 1 percent and, therefore, does not meet the coming 0.5 percent S IMO limit, let alone the current and more stringent 0.1 percent S ECA limit. In response to changing bunker specs, however, several refiners have been offering or developing fuel oil products with a lower sulfur content, and shipping companies have started adopting them. For example, Shell offers a 0.1 percent S ECA-compliant, ultralow-sulfur oil grade (ULSFO). In this article, LSFO is generally assumed to meet the 0.5 percent S cap and includes the narrower ULSFO subcategory. See M. Desmarescaux and I. Grigorjeva, "NWE LSFO Premium to HSFO Widens on Weak HSFO Barges, Despite Low LSFO Demand," *Platts*, January 7, 2015, https://www.platts.com/latest-news/oil/london/nwe-lsfo-premium-to-hsfo-widens-on-weak-hsfo-26976395; "Low Sulfur Fuel Oil," *Shell.com*, accessed July 3, 2017, http://www.shell.com/business-customers/marine/fuel/ulsfo.html; and "Shell Trading & Supply: Marine Fuels," *Shell.com*, accessed July 3, 2017, http://www.shell.com/business-customers/marine/fuel/ulsfo/_jcr_content/par/textimage.stream/1473174550832/3b2ee2813d9f9ceb756bd7b5ade60c1ea828f0abe6b8d3f7c1e0364fa6c2aea9/typical-properties-shell-ulsfo.PDF. For an example of a company that has adopted LSFO, see Q1 2017 *Investor Report* (Hapag-Lloyd AG, May 12, 2017) and Q4 – FY 2016 *Investor Report*, (Hapag-Lloyd AG, March 24, 2017), downloaded July 3, 2017 from https://www.hapag-lloyd.com/en/ir/publications/investor-reports.html#tabnav.

38 IEA (Oil 2017) issued a thinly veiled call for delays or for a more gradual implementation, noting that in the EU diesel sulfur limits, however disruptive they might have been, were progressively introduced. "In the EU, it took over a decade of gradual changes to lower road sulphur limits…Countries in Southern Europe were allowed to delay the implementation of the directive…Each of the options discussed above has its limitations when it comes to wide-scale use as early as 2020…With our forecast…we do not see availability of low-sulfur bunkers in the required volumes…Given the size of the modern global fleet though, this will be an issue well beyond the medium term." (109-110)

39 As noted above, given limited scrubber-manufacturing capacity, there could be a restriction in meeting the timeline in the event of late orders. This is because each installation is a bespoke arrangement. Halff, "IMO Roundtable," July 2017, 7-8.

40 "This is Why Maersk Will Not be Using Scrubbers When the 0.50% Global Sulfur Cap on Bunkers Comes Into Force in 2020," *Ship & Bunker*, May 18, 2017, https://shipandbunker.com/news/world/224210-this-is-why-maersk-will-not-be-using-scrubbers-when-the-050-global-sulfur-cap-on-bunkers-comes-into-force-in-2020.

41 Halff, "IMO Roundtable," 2017, 6-10.

42 This includes the time out of service for modifications (and lead time for design, supply of tank, and equipment), loss of cargo volume, and deadweight.

43 According to Argus Media, citing consultancy Ensys, only 346 vessels have invested in scrubbing through 2016. Of those, 70 percent are in ECAs. The global fleet is estimated at around 45,000 vessels. Argus Media, "Changing Regulations for Fuel Oil Sulphur Caps" (online PowerPoint presentation, January 2017). At the time of writing, several leading shippers, including two of the largest container liners, Maersk and Hapag Lloyd, let it be known they would not adopt scrubbers as a way to comply with the IMO rules. On the other hand, Carnival Corp., a leading cruise ship operator, was reported to have completed scrubber installations on 60 of its vessels. ("This Is Why Maersk Will Not Be Using Scrubbers When the 0.50% Global Sulfur Cap on Bunkers Comes into Force in 2020," Ship & Bunker, May 18, 2017, https://shipandbunker.com/news/world/224210-this-is-why-maersk-will-not-be-using-scrubbers-when-the-050-global-sulfur-cap-on-bunkers-comes-into-force-in-2020.)

44 Halff, "IMO Roundtable," July 2017, 7-8. Most scrubber orders are for new builds. Demand for retrofits of existing ships is limited by the need to amortize the investment over the remaining life of the ship.

45 Scrubbers are customized and made to order. It's a process that takes several months, and the assembly line to make them has limited capacity. In addition, there is limited dry-dock capacity to fit them on ships. This alone is a process that can take up to a month.

46 Philip K. Verleger, in his weekly *Notes at the Margin* and other publications, was one of the first analysts to posit a connection between diesel desulfurization in the 2000s and the 2008 oil rally. Lawrence Eagles, then head of oil analysis for J. P. Morgan, and others followed suit. Salvatore Carollo picked up the argument in *Understanding Oil Prices: A Guide to What Drives the Price of Oil in Today's Markets*, Chichester, United Kingdom: Wiley, 2011.

47 Low-sulfur, or "sweet," crude oil grades are expected to come under upward price pressure in the event of a run-up in demand for low-sulfur products because of their comparatively high yield of the latter. The sulfur content of residual fuel oil depends on that of the crude oil used as feedstock to produce it. Middle distillate coming out of a cracking unit will have a relatively low sulfur content and may be further desulfurized through a hydrotreating unit; however, sweet crude grades also have a higher yield of low-sulfur distillates.

48 On the globalization of the refining industry and its effects on price volatility and energy security, see Halff, "The Impact of Refining Sector Changes on Patterns of Oil Product Trading," Oxford Energy Forum, Issue 92, May 2013, pp. 4–5.

49 Argus. It is important to note, however, that residual fuel oil is widely used as feedstock for refinery conversion units. If fuel oil traded as feedstock were taken into account, bunker's share of the fuel oil market would be considerably lower.

50 As noted above, LSFO is here understood to have a sulfur content of 0.5 percent or less.

51 HSFO cannot simply be run through a hydrotreater for desulfurization, as it will cake up the catalyst. Increasing MGO supply requires upgrading capacity (in the form of hydrocracking or fluid catalytic cracking units) to raise gasoil yields. If needed, the gasoil can them be hydrotreated to reduce its sulfur content, though coming out of a hydrocracker, the sulfur content will be relatively low. Capacity upgrade projects typically have a lead time of up to six years, including two years to design and bid the units and another three to four to build them. Costs run up in the billions of dollars.

52 Economic literature has highlighted the importance of transport costs in trade, access to markets, and per capita income. Fifteen years ago, World Bank economists found that "for most Latin American countries, transport costs are a greater barrier to U.S. markets than import tariffs." Ximena Clark, David Dollar, and Alejandro Micco (February 2002): "Maritime Transport Costs and Port Efficiency," World Bank Policy Working Paper 2781.

53 IEA (*Oil 2017*), p. 109. See also "New Shipping Fuel Regulation Set to Hit Commodities," *Financial Times* (May 30, 2017): "A change in international fuel regulation little discussed outside the shipping industry is set to wreak havoc on the world of commodities."

54 Communication from industry source.

55 Shell is, as noted, a case in point.

56 In percentage terms, the share of MDO in the company's overall fuel mix actually fell faster than that of HSFO. The former plunged from 12 to 9 percent, whereas the latter slid by a single percentage point, from 85 to 84 percent. In absolute terms, however, use of HSFO, given its much larger baseline share of the mix, fell faster, by 193,000 MT, compared to MDO, use of which contracted by 143,000 MT. *Q4 – FY 2016 Investor Report* (Hapag-Lloyd AG, March 24, 2017), 12, accessed July 3, 2017, https://www.hapag-lloyd.com/content/dam/website/downloads/pdf/HLAG_Investor_Report_FY_2016.pdf .

57 The IMO's own commissioned study of fuel oil availability differs markedly from the prevalent view of industry analysts in predicting that LSFO, rather than MGO, will make up the bulk of IMO-compliant fuels. This may in part, but not entirely, reflect

definitional differences. According to the IMO study, which is based on the expectation of relatively strong bunker demand growth overall, the refining industry will be able to supply enough LSFO to meet shipping demand under any of its different scenarios, although this will require significant shifts in bunker trade flows. See Halff, "IMO Roundtable," 2017, 3.

58 "Flag State 2015: Top 10 Ship Registers," *Lloyd's List*, accessed July 3, 2017, https://www.lloydslist.com/ll/static/classified/article506818.ece/binary/Flag-worldfleet-final2.pdf.

59 Bodansky, 76–79, and Barrett, 161–162.

60 Barrett, 161–162. On the other hand, results-driven requirements have applied to oily-water separators and more recently ballast water treatment systems. In each case this has resulted in problems in meeting the results outcome required.

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