Goldman Sachs

The IMO 2020: Global Shipping's Blue Sky Moment

Shipping has a Sulphur problem that the shipping regulator, a UN-body called the IMO, is seeking to solve. While shipping bunker fuel accounts for just 7% of transport oil demand, it generates c.90% of transport sector Sulphur emissions. The IMO has put in place a Sulphur cap that will come into force at the start of 2020 which will limit marine fuel Sulphur emissions to 0.5% from 3.5%. This likely leaves ship owners with a number of options from installing scrubbers to switching to compliant fuels. Beyond Shipping, we expect potential knock-on consequences for the refining, chemicals, mining and industrials sectors. We estimate that if the entire shipping industry follows the rules consumer wallets could be hit by around US$240 bn by 2020.

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MARINE BUNKERS in numbers

How large is the pollution problem in the shipping industry?

c. 7% of **transport demand** is comprised by marine bunkers yet they make up…

15 of the biggest ships emit more SO_2 and NO_X **than all the world's cars combined.**

c. 90%
of transport **sector SO_2 emissions.**

1mn cars
emit as much particulate as **1 cruise ship produces in 1 day**.

Where is it concentrated?

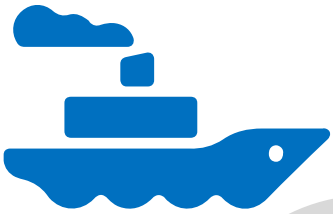
85%
Of global seaborne trade originates or ends at DMs.

28%
Of ships account for **85% of tonnage.**

What is the International Maritime Organization doing to address this?

What are the current restrictions?

3,500x
Higher sulphur limit for marine heavy fuel oil than for diesel used in Europe's cars and trucks.



Only **c.400**
of 90,000 ships have installed scrubbers.

3.5%-0.5%
reduction of sulphur content in bunker fuel effective January 2020.

What are the implications?

50%
Cut in green house gas emissions by 2050 from 2008 levels.

Scrubbers

18%
Penetration of scrubbers in ships by 2025 **creating a revenue pool of c.$15bn.**

LNG

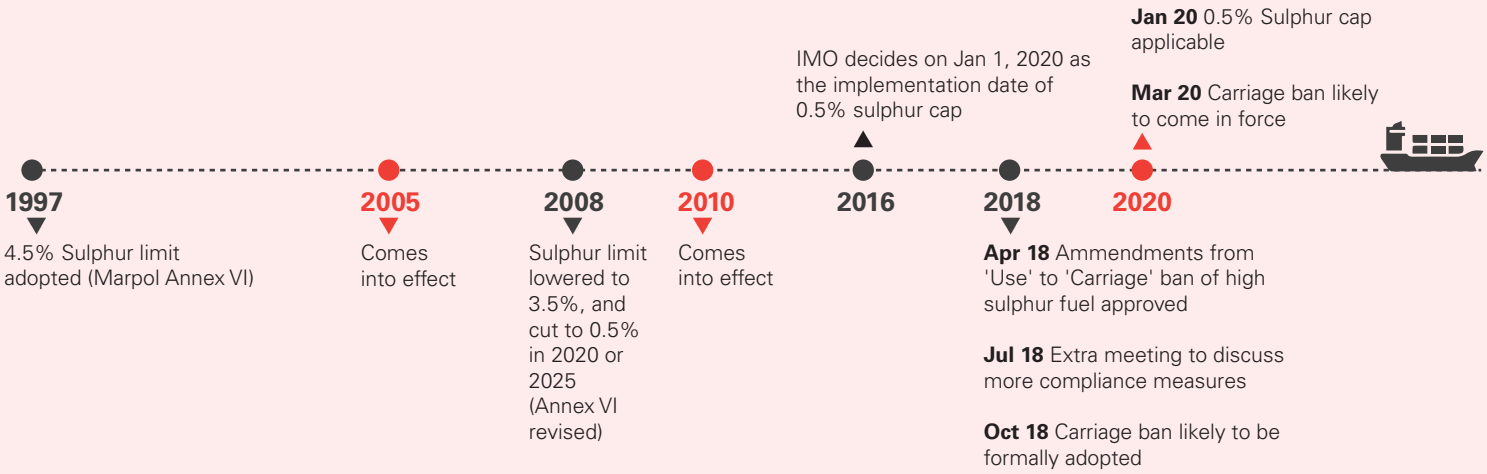
c.5%
Of global shipping fleet to be LNG based ships by 2030.

Refining

3mn bpd
Of high sulphur fuel needs to be destroyed in 2020 in a 100% compliance scenario.

The Ecosystem

IMO timeline of key events



OPPORTUNITIES

	COMPANIES
$240bn higher fuel retail price and freight cost in 2020, from consumers pockets to complex refiners.	Reliance, Formosa Petrochem, Valero Energy Corp., HollyFrontier Corp., Andeavor., Phillips 66
$15bn total revenue pool opportunity for scrubber manufacturers over 2020-25.	Alfa Laval, Wartsilla, yara, Heavy Hyundai Industries, AVIC International Maritime Holdings, Weihai Puyier Environmental & Technology company, Shanghai Bluesoul Environmental Technology
$10-15bn cost reduction for road builders in 2020.	Sadbhav Engineering, Ashoka Buildcon, KNR Construction Ltd.
Hydrogen demand increase driven by higher clean products production from refineries.	Air Products, Praxair, Air Liquide

THREATS

	COMPANIES
$40bn increase in shipping cost, a burden for shipping industry and/or its customers to pass on.	Maersk Line, MSC, CMA-CGM, COSCO, Hapag-Lloyd
$80bn revenue under threat for heavy sour crude oil producers.	Middle East, Latam, and Canada Oil Producers
$6bn increase in Aluminum production costs due to increase in anode coke price.	Aluminum Corp. of China, China Hongqiao, Hindalco Industries, Nalco

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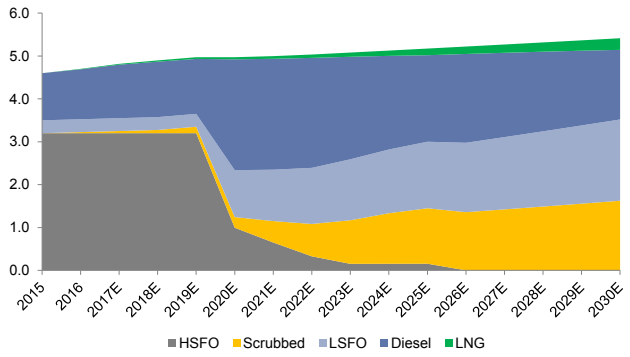
PM Summary: Why should one care about IMO 2020 regulations?

Sulphur emission standards in shipping fuel has lagged requirements on land transportation fuels significantly. **Shipping bunker fuel account for 7% of transport oil demand, but they generate c.90% of transport sector SO2 emissions.** The International Maritime Organization (IMO) decided to lower the sulphur limit from 3.5% to 0.5% effective January 1, 2020. Ship owners have a variety of options to choose in order to comply with IMO 2020 regulation. **The compliance and enforcement to this regulation is still the key uncertainty, and upcoming IMO meetings in July and October could improve the visibility**.Our checks with several refining/shipping industry participants suggest that the shipping companies are initially more likely to opt for a fuel switch from high sulphur fuel oil (HSFO) to low sulphur products vs. capex intensive solutions (eg. scrubbers, LNG based ships). Over the medium term, scrubber uptake could rise with widening clean-dirty spreads as implied by the current forward curve. These changes could have significant implications for land transport fuel prices and shipping freight. **In a full compliance scenario, we estimate the total impact to consumer wallets in 2020 could be around US$240 bn (see exhibit 2), which may largely transfer to the pockets of refiners.** This could potentially also create opportunities for **scrubber manufacturers (new revenue pool of US$15bn)** and hydrogen producers while revenue pool may shrink for heavy crude oil producers.

Full compliance could be a game changer for the refining industry

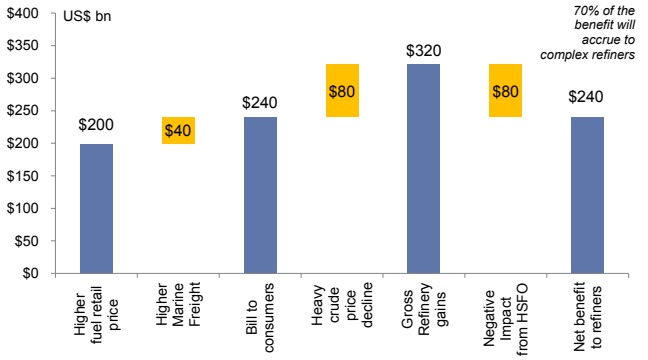
For many decades, refineries have been doing the job of cutting sulphur content from oil products by adding more deep processing (secondary) units to destroy HSFO. While we expect such capacities will continue to come before IMO 2020 kicks in, they are simply not enough to destroy all of this HSFO if IMO 2020 regulations are fully implemented. Refinery projects are quite complex and typically takes 4-5 years from FID (final investment decision) to commercial operations, in a best case scenario. As such, product and crude prices need to move in such a way that refineries are incentivized to take additional steps to cut HSFO production.

Exhibit 1: IMO 2020 sulphur cap regulations could drive a switch from high sulphur towards clean fuels in marine industry
Marine fuel mix Base case (mn bpd)



Source: IEA, Goldman Sachs Global Investment Research

Exhibit 2: In a 100% compliance scenario, IMO sulphur cap would drive a net transfer of US$240 bn from consumers to refiners in 2020
Impact of IMO regulation on consumer/refiners wallet in 2020, US$ bn



Source: Goldman Sachs Global Investment Research

Impact on the various sectors

Refiners: The marine fuel spec changes, if implemented, could tighten the refining supply demand further driving an increase in diesel demand in 2020, which could potentially be met by a combination of (1) higher global refinery runs and (2) an increase in refineries diesel yields. Forward curves are implying diesel cracks to rise the most (by c.$5/bbl in 2020) to incentivize higher diesel yield. In a full compliance scenario, all the surplus HSFO can not be destroyed in the refineries, leading HSFO prices to likely fall substantially towards parity with coal/gas prices to create a new demand source in power plants. As the industry bids against sulphur, our analysis suggests heavy oils discount to light oil could widen by c.$5/bbl in 2020 based on the forward clean-dirty product spreads. Complex refiners will benefit the most due to their high exposure of clean products, low production of HSFO and their ability to cracks cheaper heavier crude, in our view.

Shipping: Shipping companies are most likely to opt for a fuel switch (from high-sulphur fuel to marine diesel oil) vs. capex-intensive solutions (scrubbers, LNG) in order to meet IMO's 2020 regulations. Overall, while a fuel switch would result in relatively high opex inflation (c.6%), we believe that this will be easier to pass-through to customers vs. capex, particularly in the context of improving market fundamentals.

Scrubbers: 5,000 ships could install scrubbers by 2025 which represents a revenue pool of c. $15 bn. We estimate the current payback period of scrubber installation is c.4 years (relative to using compliant fuel in 2020). We expect scrubber installation to pick up from 2020 as payback period may fall to 2 years based on the current forward diesel-HSFO spread, and expect scrubber penetration in ships to be 4%/18% by 2020/25.

Chemicals: Hydrogen demand in refineries have been growing with the increasing need to remove sulphur from refinery products and increasing diesel production. We note in the US the increase in demand has been exclusively met by merchant hydrogen suppliers such as Air Products (APD) and Praxair (PX). Given the need for higher diesel production once IMO sulphur cap regulation kicks in, we expect further boost to hydrogen demand in 2020.

Metals & Mining: As indicated by the current forward curve, we expect IMO 2020 regulations to be inflationary for commodities due to higher freight (iron ore, met coal, thermal coal) and higher input cost for low sulphur anode grade cokes (aluminum). As such the impact will depend on supply demand fundamental which will ultimately drive the ability to pass on to consumers. With balanced aluminum markets we expect higher input cost to be passed on, driving 5% increase in prices. For iron ore we expect CIF price inflation of 6-7% from higher freight with the risk of only partial pass through given our outlook of rising surplus.

Why the shipping industry must clean up now

Shipping's worst pollution is its sulphur emission

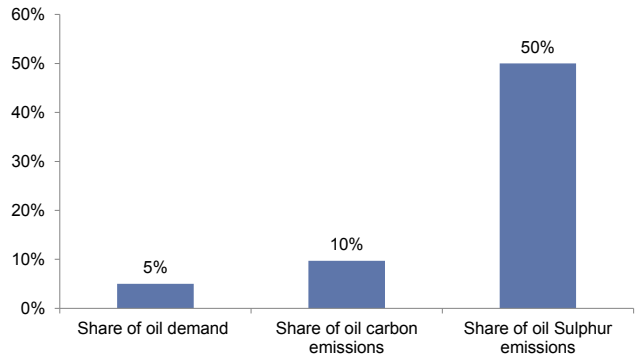
Globalization has driven nearly three fold increase in shipping volumes over the last three decades. **While shipping bunker fuel accounts for just 7% of transport oil demand, they generate c.90% of transport sector sulphur emissions** and 50% of total liquid hydrocarbon linked sulphur dioxide emissions. In a global context, the shipping sector accounts for 12% of global sulphur dioxide emissions, 13% of global nitrogen oxide emissions and 3% of global carbon emissions.

Sulphur emission standards in shipping has lagged requirements on land significantly. **The current 3.5% limit of sulphur content in marine fuel compares with limits of only 10 ppm to 50 ppm for land based diesel fuel**. Industries such as shipping and aviation which are more global in nature have been so far kept out of emission protocols. The process of coming up with global emission standards for shipping has taken much longer due to building up a global consensus as compared to country specific targets on land based transportation fuels.

Impact of SO_2 emission on environment

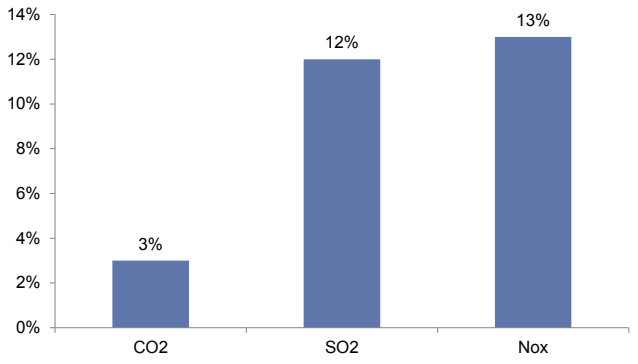
As per EPA, SO_2 (component of the greatest concern in sulphur oxides) emissions harm human respiratory systems which makes breathing difficult. Asthma patients, elderly and children are more sensitive to the effects of SO_2 emissions. SO_2 can also react with air pollutants to form sulphate which form fine particulate matter (PM2.5), which are associated with cardiovascular and respiratory health effects. SO2 along with NOx emissions also lead to acidic disposition which contributes to haze and harms crops and vegetation. As per a science based journal (Nature), ship air pollution is linked to c.400,000 premature deaths from lung cancer and cardiovascular disease alone and around 14 mn childhood asthma cases annually.

Exhibit 3: Shipping fuel pollution share is disproportionately higher than its demand share in Oil
Marine fuel demand and pollution share



Source: IEA , IMO

Exhibit 4: Shipping contribution to SO2 and NOx emissions are quite high
Shipping fuel share of global pollution



Source: IMO, IEA

Overview of IMO regulations to tackle marine fuel pollution

Who is IMO and what is its role in the shipping industry?

The International Maritime Organization (IMO) is a United Nations body responsible for safe, secure and efficient shipping and the prevention of pollution from ships.

What is the limit on Sulphur as per IMO regulations?

The Sulphur limit of marine fuel is set as per Annex VI (Regulation for the Prevention of Air Pollution from Ships) of MARPOL protocol. The current global limit on sulphur content of marine fuel is 3.5%, which was adopted by IMO in 2008. IMO further decided in 2008 to lower this limit to 0.5% effective January 1, 2020, but kept a provision to review the compliant fuel availability before 2020 to decide whether to continue with the 2020 deadline or extend it to 2025. At the end of 2016, IMO confirmed to keep January 1, 2020 as the implementation date to lower the Sulphur cap for marine fuel to 0.5%.

Some regions have even stricter regulations for marine fuel

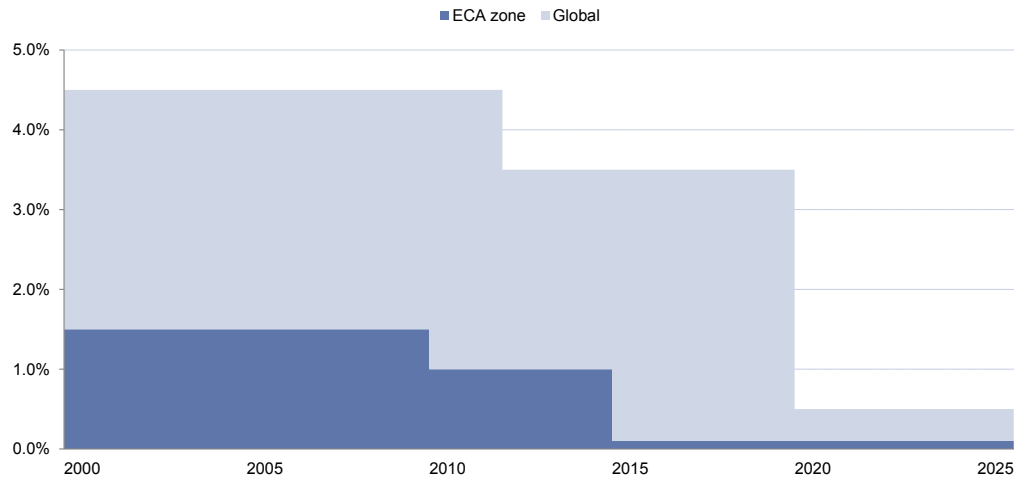
The sulphur limit in ECA (Emission Control Area) is already at 0.1% since 2015 (lowered from 1% prior to that). THE ECA zones include North sea, Baltic Sea, coastal areas in US/Canada, US Caribbean. Apart from the ECA zones, there are few region specific regulations such as those in EU and China. EU has its own directive which requires max of 0.5% sulphur in all EU waters by 2020 and 0.1% max Sulphur in EU ports. Some EU countries also have specific regulation regarding the discharge of scrubber water which makes open loop scrubbers non-compliant. HK already has a 0.5% limit for vessels at berth, and for sea areas outside HK/Guangzhou/Shanghai, China is taking a staged approach towards lower sulphur in marine fuel starting with 0.5%. There is a possibility that a formal application to ECA could be made in 2020.

More regulations are brewing for the shipping industry

Ballast Water Management: This regulation envisages the treatment of a ship's ballast water to reduce the spread of evasive species from source region to the destination. The regulation was confirmed in 2017 and requires ships to install ballast water management systems. The regulation will be implemented over the next few years based on an implementation schedule.

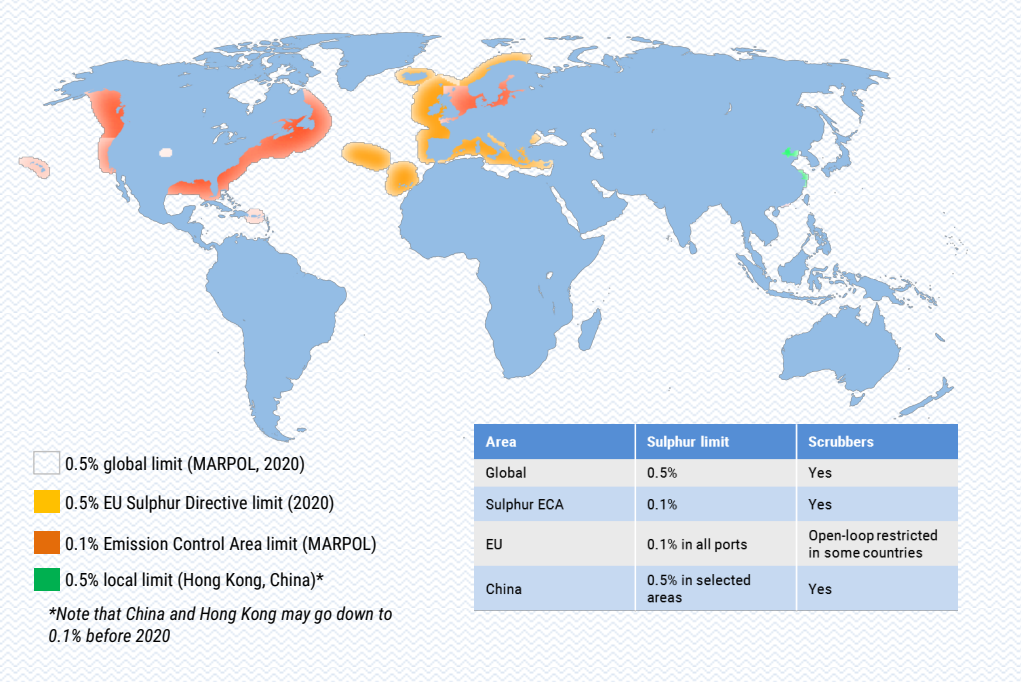
GHG emissions: Last month MEPC 72 of IMO had adopted an initial strategy of cutting ship's GHG emissions by 50% from 2008 levels by 2050. The strategy also includes a reduction of carbon dioxide emission "per transport work, as an average across international shipping" of at least 40% by 2030 and "pursuing efforts towards 70% by 2050". The agreement will be further revised in 2023.

Exhibit 5: Sulphur content of global shipping (bunker) fuel will come down sharply in 2020
Sulphur limits for shipping fuel



Source: IMO

Exhibit 6: Emission Control Areas (ECA) have even stricter sulphur limits on marine Fuel
Sulphur limits on shipping fuel



Area	Sulphur limit	Scrubbers
Global	0.5%	Yes
Sulphur ECA	0.1%	Yes
EU	0.1% in all ports	Open-loop restricted in some countries
China	0.5% in selected areas	Yes

Source: IMO , DVN GL

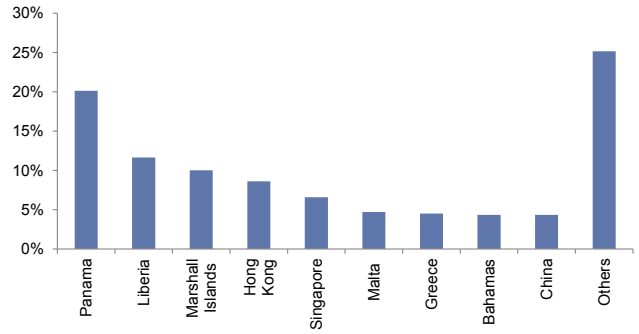
How will IMO 2020 Sulphur Cap be enforced and monitored?

The compliance and enforcement to this regulation is still the key uncertainty, and upcoming IMO meetings in July and October could improve the visibility. IMO does not enforce the sulphur cap regulation, nor does it set any fines for non-compliance, and its Flag/Port/Coastal states who are signatory to IMO are responsible for the compliance of the regulation. As of April 2018, 91 members of IMO have ratified Annex VI and these members account for more than 97% of the global trade.

We note a few smaller countries have the highest ship registration, driving concerns around the likely strength of enforcement. Our checks with several shipping/refining industry participants and companies highlight the following reasons why compliance may be high:

- **Carriage ban of HSFO:** Recently (MEPC 72 in April 2018), IMO made amendments to MARPOL Annex VI to prohibit not just the use, but also the 'carriage' of fuels above 0.5% sulphur (unless ships have a requisite scrubber installed). This may give more authority to port states which could be a crucial way to enforce the compliance as bunkering is concentrated in a few ports and authorities would only have to identify cases where HSFO was onboard the vessel. However, we note this amendment is yet to be formally adopted by IMO with the October 2018 meeting pending (if adopted, enforcement could come at the earliest by March 2020).
- **EM to EM accounts for only 15% of trade flows:** In our conversation with shipping companies and industry participants, we note that the non-compliance risk has been flagged as potentially higher for trade flows between EM (Emerging Markets) where regulatory compliance in general has historically lagged versus DMs. Our 70% compliance assumptions imply high compliance for DM to DM trade, and low compliance for EM to EM trade. We also adjust for 10% unintentional compliance to account for risks around non-availability of fuels.
- **Large ships account for majority of fuel consumption:** We note that big ships operated by large global shipping companies account for the majority of the shipping fuel consumption – as per UNCTAD, around 25,000 ships out of 90,000 globally account for 85% of the total in-service tonnage. As per our discussion with industry participants, larger shipping companies have more at stake in terms of reputational risks and are therefore less likely to breach compliance requirements.
- **Potential loss of insurance coverage:** As per IMO, ships which fail to comply with the global sulfur cap could potentially be declared "unseaworthy" and would thus affect their indemnity in the event of an insurance claim. According to a Platts article (02/02/2018), the IMO 2020 rule falls under MARPOL regulations, and a breach of MARPOL requirements could allow for a vessel's MARPOL certificate to be withdrawn or suspended by a flag state.

Exhibit 7: Few smaller countries have the highest ship registration, driving concerns around enforcement
Ship registration by flag state, 2015



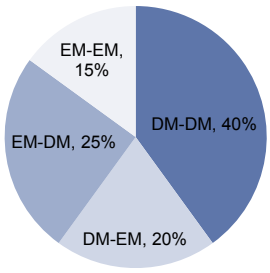
Source: UNCTAD

Exhibit 8: Ban on carriage of HSFO could improve compliance as bunker sales are concentrated in a few ports
Bunker fuel sales by port

	Bunker sales	
	mbpd	%
Singapore	0.9	26%
N Asia	0.4	11%
Fujairah	0.3	9%
Rotterdam	0.3	9%
Other Europe/FSU	0.3	9%
Houston	0.3	9%
Other Americas	0.2	6%
Gibraltar	0.2	6%
Other	0.6	17%
Total	3.5	

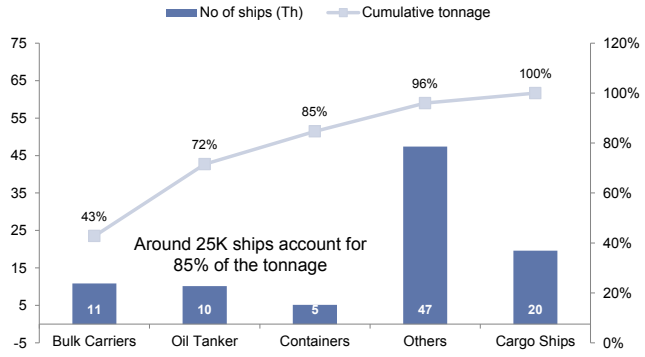
Source: IEA, OPEC, IBIA, MPA Singapore, Port of Rotterdam

Exhibit 9: Almost 85% of the trade originates or ends at DMs
Global trade flow mix



Source: Haver Analytics

Exhibit 10: Big ships operated by global players are most likely to comply given potential reputational risks
Global shipping fleet by type



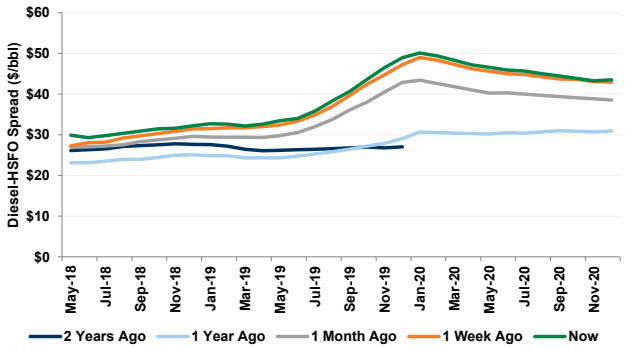
Source: UNCTAD

Exhibit 11: Fines are quite varied even among countries with stricter compliance
Maximum fines by ports

Country	Maximum Penalty	Penalty as % of yearly fuel bill
Belgium	EUR 6 mn	238%
Canada	CAD 50K	1%
Denmark	No Maximum	Varies
Finland	EUR 800K	32%
France	EUR 200K	8%
Germany	EUR 22K	1%
Latvia	EUR 2900	0%
Lithuania	EUR 14,481	1%
Netherlands	EUR 81K+gains	Varies
Norway	No maximum	Varies
Sweden	SEK 10 mn	33%
UK	GBP 3 mn	135%
USA	USD 25K/day	304%

Source: Trident Alliance, Goldman Sachs Global Investment Research

Exhibit 12: Forward curve for diesel-HSFO are already implying partial compliance to IMO 2020 regulations
Diesel-HSFO forward curve

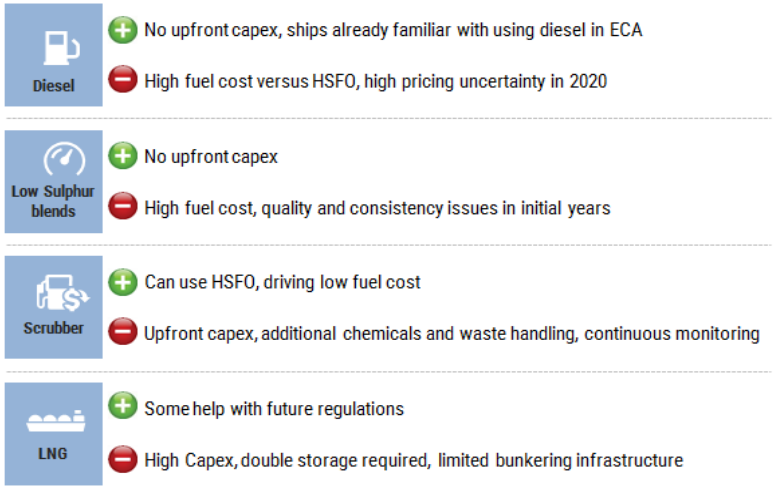


Source: Factset, Goldman Sachs Global Investment Research

What are the options for the shipping industry?

1. **Burn compliant fuel:** Ships can switch to low sulphur fuels such as MGO (marine gasoil i.e. diesel) or LSFO (low Sulphur fuel oil). Blended fuel which adhere to the limit of 0.5% sulphur could also be an option. This option **would not require any upfront capital expenditure** but would result in **higher fuel cost**. In our conversation with ship-owners, MGO was the fuel of choice given ship-owners are already familiar with the fuel. Ship-owners also mentioned that they would be comfortable with using straight run LSFO. However, there was reluctance to use blended fuel as blends of consistent quality could be difficult to get at all ports and can drive unpredictable emission profile.
2. **Install scrubber:** Ship-owners who chose to **invest upfront capital** in scrubbers **can continue to burn HSFO which will be cheaper** versus compliant fuel in 2020. We estimate the current payback period of scrubber installation is 4 years which we believe is not compelling enough. We expect scrubber installation to pick up from 2020 as payback period may fall to 2 years based on the current diesel-HSFO forward curve.
3. **LNG:** LNG based ships are compliant with IMO 2020 regulations. However retrofitting is very expensive with very unattractive payback periods, and in our view new builds are more likely to choose LNG. Given the **lack of LNG bunkering infrastructure and high upfront capital cost,** LNG based ship fuel seems to be a less meaningful driver of bunker fuel mix over the medium term.
4. **Waivers/Non-compliance:** IMO provides a system wherein ships can **seek waivers in a situation where compliant fuel is not available**. In such situation, ships would have to present a record of the actions taken to attempt to achieve compliance. Voluntary non-compliance with the regulation would also be an outcome in the initial few years.

Exhibit 13: Compliance options for IMO 2020 0.5% Sulphur Cap regulations



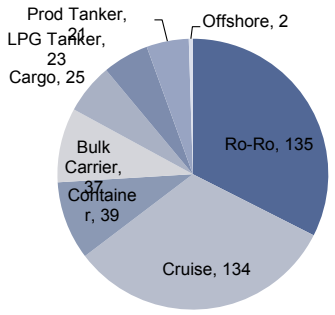
Source: Goldman Sachs Global Investment Research

What role would scrubbers play?

How can scrubbers help in complying with IMO Sulphur regulations? Scrubbers are essentially exhaust gas cleaning technologies that enable the use of high-sulphur fuel and are still compliant with low sulphur regulations. Scrubbers require upfront capex while lowering the fuel operating cost. As such, the feasibility of scrubbers depends mainly on the spread between diesel and HSFO. Our analysis indicates a payback period of 2-6 years based on the range of high sulphur fuel oil and diesel spread seen since 2010 with the current payback at 4 years.

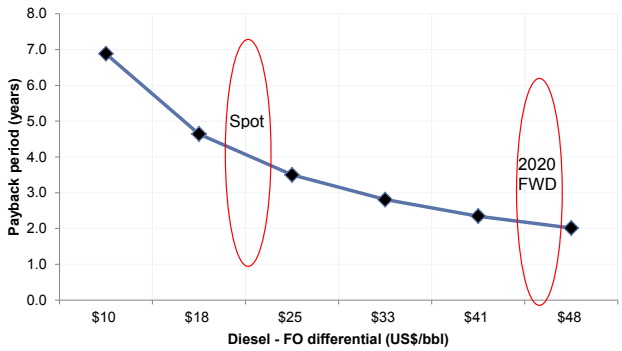
What could be the share of scrubbers in the marine fuel mix? We expect **scrubbers uptake to pick up starting in 2020** as the payback period on forward curve reaches a compelling 2 years threshold with widening diesel versus HSFO spreads. The pace will likely slow down post 2022 as spreads start contracting. **Overall 5000 ships can install scrubbers by 2025, driving 25% of bunker fuel consumption in 2025.**

Exhibit 14: Only c.400 ships (out of 90, 000) have installed scrubbers mostly on cruise and Ro-Ros which account for a small part of bunker fuel consumption
Ships with scrubbers, 2017



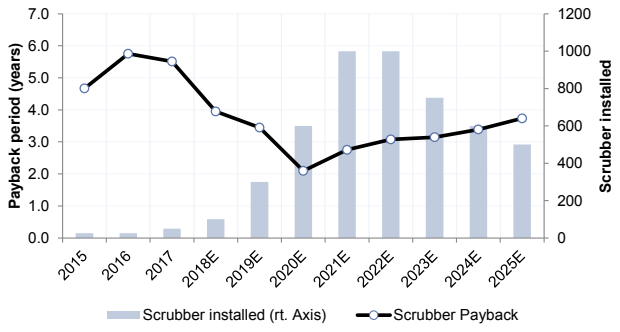
Source: IHS

Exhibit 15: Scrubber economics look compelling at 2020 forward curve
Scrubber breakeven period



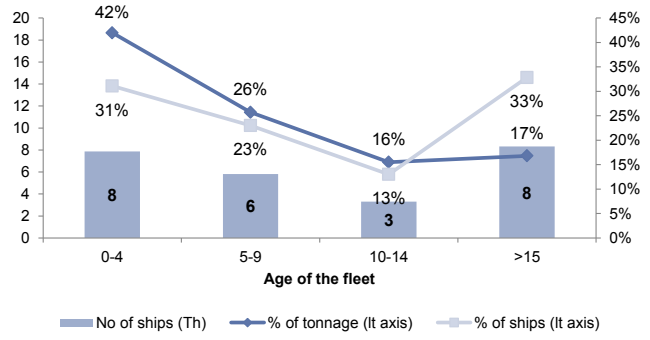
Source: Goldman Sachs Global Investment Research

Exhibit 16: Scrubber installations to likely pick up in 2020 in response to a faster payback period due to the widening of diesel-HSFO spread
Scrubber installations in a year versus payback period



Source: Goldman Sachs Global Investment Research

Exhibit 17: New ships will be the most likely candidates to install scrubbers
Shipping fleet age as of 2015



Source: UNCTAD

Is LNG based ship the solution?

LNG helps meet IMO's 2020 Sulphur cap but is not future proof, in our view: LNG removes sulphur emissions and 95% of the particulate matter making it compliant with 2020 sulphur regulations. However issues such as methane slip in low pressure engines due to LNG leakage can reduce the GHG credentials of LNG.

Key challenges with LNG as shipping fuel

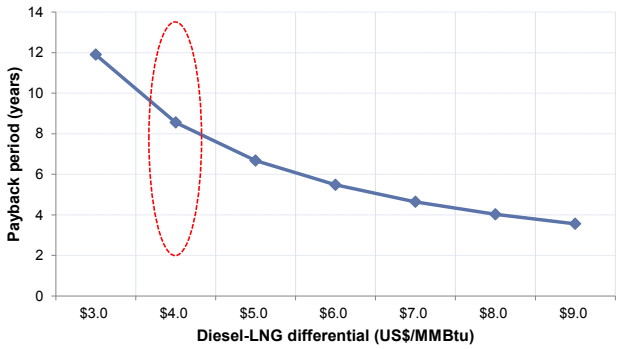
1. Economics: LNG as shipping fuel requires high upfront capital expenditure due to the need of cryogenic LNG storage tank which could make up more than half of the capex. Further the capex requirement increases with ship size as the size of the required tank system increases as well. As per DNV GL, the capex could range from US$ 3 mn to 30 mn. Further LNG tanks on ships also take up space which reduces the cargo carrying capacity. On current differentials we estimate a payback period of 8 years for LNG retrofitting before adjusting for bunkering costs.

2. Bunkering infrastructure: While the bunkering infrastructure for LNG is improving, it is not fully developed yet and would require investment in cryogenic bunker barges and transfer devices. In the meantime the delivered cost of LNG could be higher due to the high bunkering cost before LNG bunkering reaches a certain scale.

Newbuilds to favor LNG overtime; we expect 5% marine fuel share by 2030

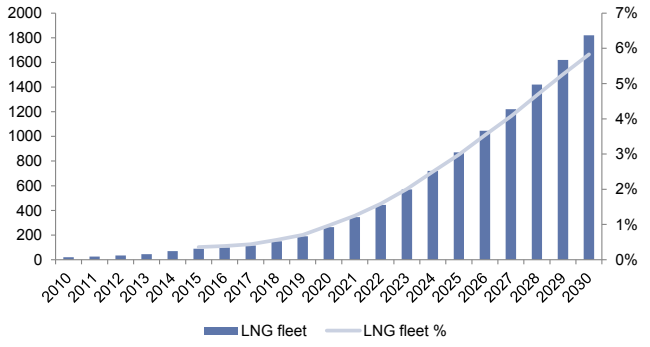
We expect LNG to be more favored by new ships with fixed and medium range routes. Owners of new ships have to think about the next 30 years and can also opt for better design optimization. Fixed route can ensure LNG availability is not an issue and medium range routes will ensure fuel storage tanks are not too prohibitive economically. LNG is currently a negligible part of marine fuel mix with just over 100 vessels consuming LNG. **LNG will more likely be a longer term solution with minimal impact in the medium term, in our view.** We estimate LNG will comprise of 3%/5% of the marine fuel mix in 2025/2030, respectively.

Exhibit 18: LNG retrofitting economics does not look compelling at current spreads
LNG retrofitting economics



Source: Goldman Sachs Global Investment Research

Exhibit 19: We expect LNG ships will comprise 6% of shipping fleet and will account for 5% of the marine fuel mix by 2030
LNG fleet assumptions



Source: Company data, Goldman Sachs Global Investment Research

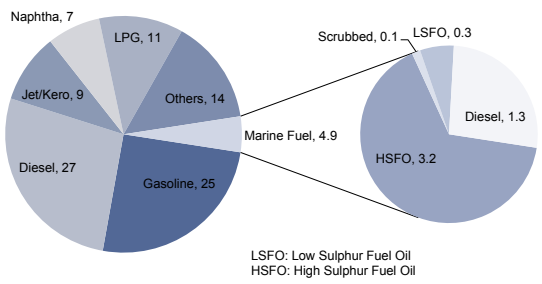
How will the bunker fuel demand mix likely change?

Current mix: Bunker fuel consumption (fuel used in ships) is around 5 mn bpd, which accounts for 5% of the global liquids consumptions. High Sulphur Fuel oil (HSFO) at 3.2 mn bpd accounts for 65% of the bunker fuel consumption while diesel (MGO) accounts for 25%. Low Sulphur Fuel Oil (LSFO) is small in the marine fuel mix currently.

High compliance can change marine fuel mix: In 2020 demand for HSFO will likely decline as ships turn to diesel due to the new sulphur limits. LSFO demand will rise as it will be used to create blends which meet the 2020 regulations. Post 2020, HSFO demand will slowly grow from the 2020 levels as ships install scrubbers.

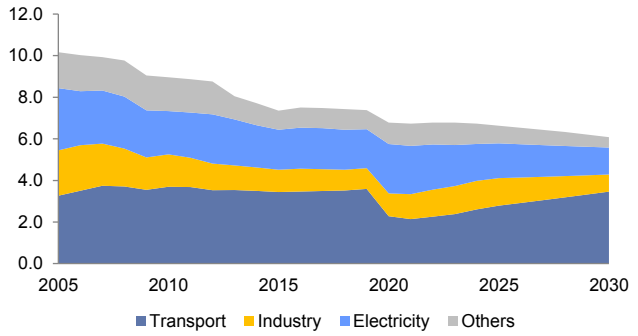
Apart from marine, HSFO is also used in power and industries. HSFO demand in these sectors will likely increase in 2020 as we believe around 0.8 mn bpd of HSFO will remain undestroyed by refineries and need to be absorbed. This should reverse over 2021-23 as new HSFO destroying capacities come online.

Exhibit 20: Shipping sector accounts for 5% of the global oil demand
Marine fuel demand in overall demand mix, 2018E



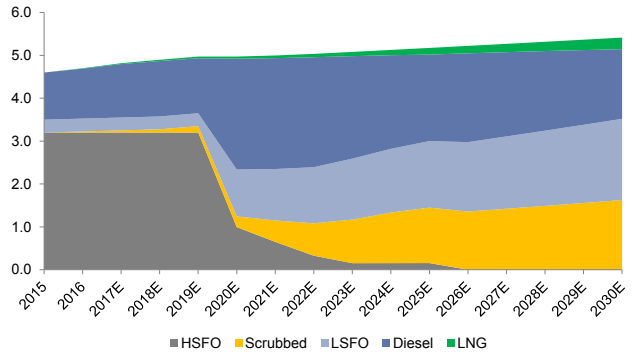
Source: Goldman Sachs Global Investment Research

Exhibit 21: HSFO demand has been steadily declining
Fuel oil demand by segment, mbpd



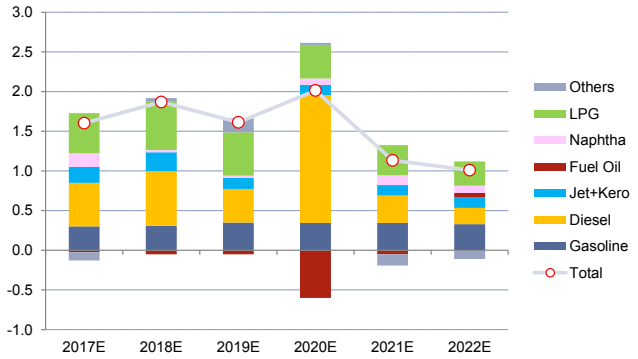
Source: IEA, Goldman Sachs Global Investment Research

Exhibit 22: Assuming partial compliance, we expect diesel replacing HSFO in the near term while share of scrubbers will gradually rise
Marine fuel mix Base case (mbpd)



Source: IEA, OPEC, Goldman Sachs Global Investment Research

Exhibit 23: We expect a potential boost to oil demand in 2020 due to additional HSFO demand in the power sector
GS oil demand forecast by products



Source: Goldman Sachs Global Investment Research

How much would IMO 2020 cost, who will pay the bills, and who will benefit?

In a scenario of high compliance of IMO 2020 regulations, it will likely have significant implications for transport fuel prices and shipping freight considering window is too short to upgrade the refinery capacities before 2020. We estimate the total consumer impact to be US$240 bn in 2020, assuming a 100% compliance scenario. This will potentially also create opportunities for scrubber manufacturers and hydrogen (industrial gases) producers while revenue pool may shrink for heavy crude producers.

Transfer from consumers to refiners: In a 100% compliance scenario, IMO regulation would be inflationary potentially driving a net transfer of US$240 bn from consumers to global refiners, as per our calculations. The transfer would likely be in the form of (1) higher retail prices for all clean products (diesel jet and gasoline) as a sharp switch to diesel in 2020 would tighten refining markets and (2) a higher freight rate for the marine industry which we expect would be passed on to the end consumers. These transfers are before tax and do not account for likely higher (but not significant) operating cost.

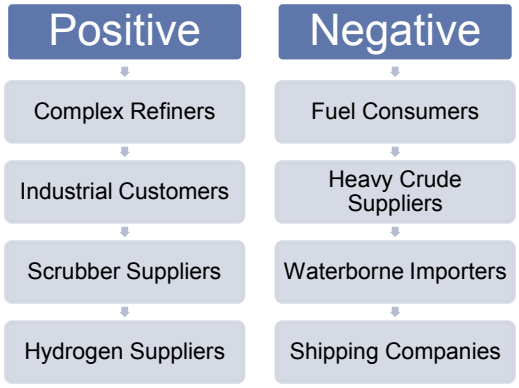
Heavy crude will see lower realizations, hydrogen/scrubber suppliers may benefit: With the increasing need to remove sulphur, we expect heavy oils discount to light oil to further widen as heavy oils typically have high sulphur concentration. We also believe demand for hydrogen, which is used in refineries to remove sulphur as well as produce diesel, will likely see a positive boost. Suppliers for scrubbers to the marine industry could benefit, creating a US$15 bn revenue pool opportunity in our base case.

Industrial customers of HSFO, bitumen and petcoke may benefit: Bottom of barrel products such HSFO, bitumen and petcoke are also consumed in industries such as power, cement, road building. These industries either already have scrubbers or use these products for non energy use. We believe such industrial users will likely see prices of these materials fall.

Exhibit 24: IMO sulphur cap would drive a net transfer of US$240 bn from consumers to refiners in 2020 under 100% compliance
Impact of IMO regulation on consumer/refiners wallet in 2020, US$ bn

Source: Goldman Sachs Global Investment Research

Exhibit 25: Potential impact from IMO regulations in 2020



Source: Goldman Sachs Global Investment Research

Implications across key sectors

Refining: High compliance to marine fuel regulation a "game changer"

High compliance to the marine fuel spec changes could reshape the refining industry. Diesel prices will likely rise, high sulphur fuel prices will fall towards parity with coal/gas prices and spreads between light/sweet and heavy/sour crude likely widening – a positive for the profitability of complex refiners.

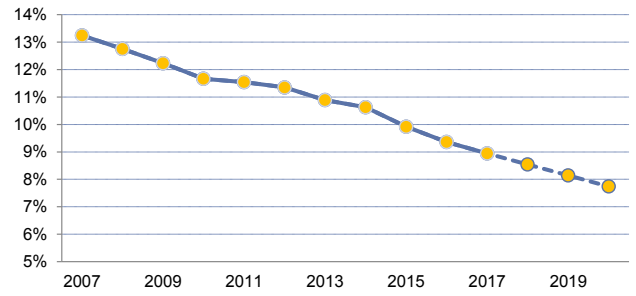
Are refineries prepared to meet the changing product mix? Refineries have been removing sulphur from oil products by adding more secondary units. They can supply most of the complaint fuel under our base case, providing that prices for crude/products move to incentivize that. However, some HSFO may still need to be destroyed in the power sector. The following drivers will help refiners produce compliant fuel:

Rising deep processing capacities: The refinery system is getting more complex by adding more deep processing capacities at a faster rate than base distillation capacity additions. This is driving lower yields of high sulphur products.

Higher flexibility: With rising complexity, refiners have shown flexibility to switch between diesel and gasoline depending on the relative demand and product margins.

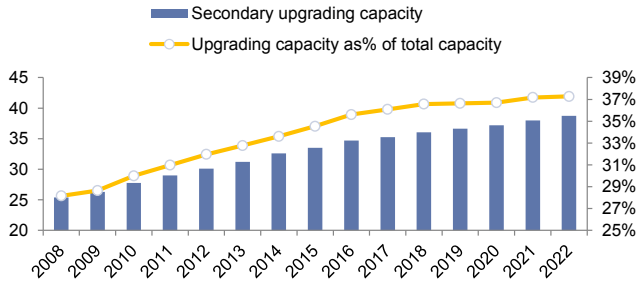
More capacities coming: We expect the refining capacity addition momentum to be stronger in 2019-22 driven by a more constructive refining macro in the last few years.

Exhibit 26: We expect FO yields decline to continue
World FO yield



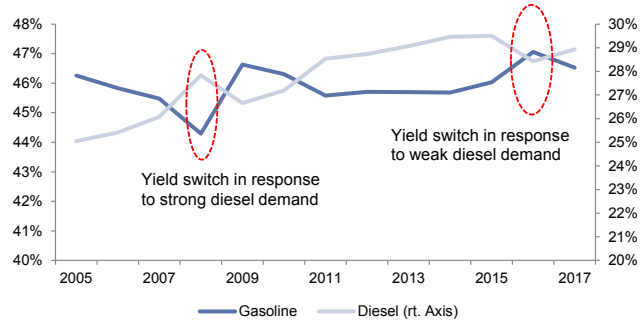
Source: JODI, EIA, PPAC, PAJ, Goldman Sachs Global Investment Research

Exhibit 27: Refineries are becoming more complex globally
Upgrading capacity as % of total base (CDU) capacity



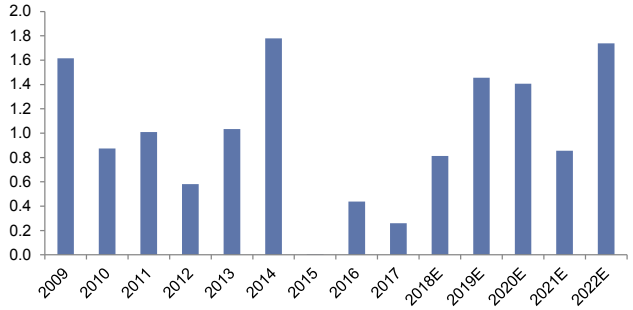
Source: OPEC, Platts, Goldman Sachs Global Investment Research

Exhibit 28: US refiners have shown flexibility to change yields
US refinery gasoline and diesel yield



Source: EIA

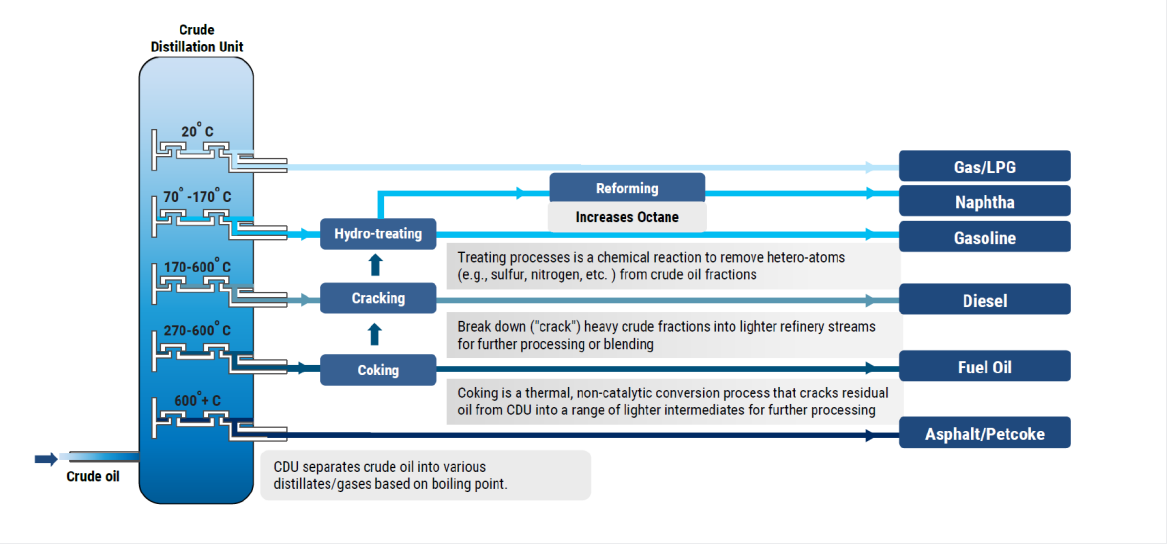
Exhibit 29: Global refining capacity additions to pick up in 2019
Refining capacity additions, mbpd



Source: BP, Goldman Sachs Global Investment Research

Refining 101

Exhibit 30: Basic operating units of a refinery



Source: Goldman Sachs Global Investment Research

Refineries add secondary units for three key reasons: (1) Improve the yield of high value products such as diesel/gasoline, (2) destroy low value products such as fuel oil, and (3) remove sulphur from products to meet regulatory requirements. Typically the capex intensity of secondary units is higher than primary units such as crude distillation. Complex refiners typically include all or most of the secondary units.

Exhibit 31: Key processes in refineries and its characteristics

Main Process	Methods to achieve	Key characteristic	
Crude Distillation	Atmospheric Distillation	The atmospheric distillation uses heat to exploit boiling points of various components of crude oil to separate them from each other.	Separates components of crude
	Vacuum Distillation	Some heavy hydrocarbons which cannot be separated using Atmospheric distillation are sent to Vacuum Distillation, which operates at very low pressure.	
Cracking	Fluid Catalytic cracking (FCC)	Operates at high temperature, low pressure with a catalyst to convert very heavy distillates to lighter product.	Improves product yields and hence better margins
	Hydrocracking	Performs the same function as FCC but has extensive operating flexibility and yield between gasoline, kerosene and diesel can be marginally altered.	
Treating	Hydrotreating	Hydro-treating helps to reduce sulfur content from sour crude, which trades at discount to sweet crude	Helps process sour crude
	Gasoline/Diesel Desulphurification	Desulphurification of products to reduce sulphur content. The process is employed before FCC for Ultra light sulphur diesel (ULSD)	Largely to meet product standards
Coking	Coking	Coking is a thermal, non-catalytic conversion process that cracks residual oil, into a range of lighter intermediates for further processing	Helps to process heavy crude and reduce fuel oil yield
Reforming	Catalytic Reforming	Largely used for Gasoline and Naphtha for increasing the octane and to produce some aromatic petchem feedstock	Product Premiumization and hence better refining margins
Upgradation	Alkylation, Isomerization, Etherification	Various process like Alkylation, Isomerization, Etherification are used to produce premium blend stocks	

Source: Goldman Sachs Global Investment Research

How will the refining industry tackle the compliant fuel challenge?

We believe refineries will need to perform a number of inter-related steps to address the compliant fuel demand in 2020: (1) Yield shift towards diesel/low sulphur fuel oil, (2) higher refining runs and, (3) raise secondary unit utilization to destroy HSFO. Further, steps such as shifting undestroyed HSFO to the power sector will be required to fully solve the IMO 2020 problem.

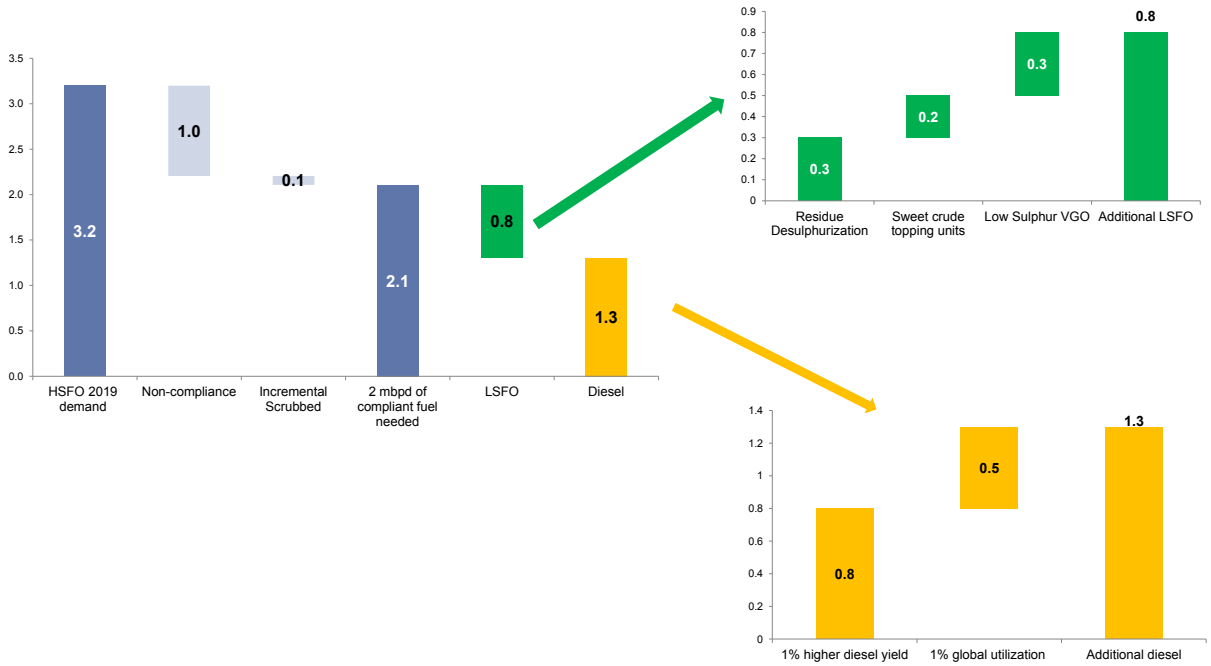
What exactly is the compliant fuel challenge for refineries in 2020?

Between now and 2020, refiners need to do the following:

1. Be able to destroy 2.1 mn bpd of HSFO in 2020
2. Supply 1.3 mn bpd of diesel and 0.8 mn bpd of LSFO for the marine sector while also supplying...
3. ...Land fuel demand growth of 1.5 mn bpd for diesel and 1 mn bpd for gasoline between now and 2020

Typically refineries have invested in "sulphur removing units" called desulphurization units for higher value adding products such as gasoline and diesel. Theoretically refineries can invest in "residue desulphurization" units to convert HSFO to LSFO. However these units are highly capex intensive and would take 3 to 4 years to come online. Hence we believe the likelihood of new capex related solutions between now and 2020 is low and refiners would likely have to improve the systems which will be online by 2020.

Exhibit 32: We expect refiners would need to increase production of both diesel and LSFO to improve the compliant fuel mix in 2020
Solving for compliant fuel (mn bpd)



Source: Goldman Sachs Global Investment Research

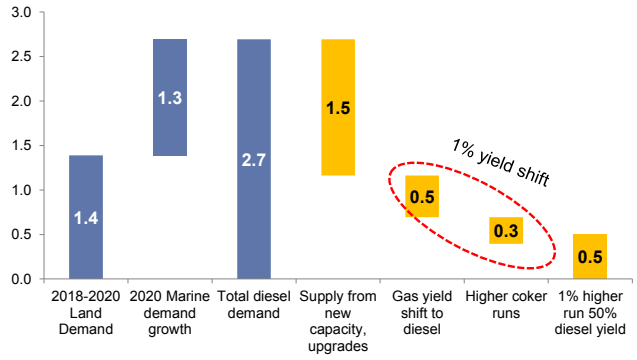
Diesel production needs to rise through yield switch and higher runs

Refineries need to create 1.3 mn bpd of additional diesel versus normal operations in an ex IMO 2020 world. This can be possibly achieved by (a) a 1% yield switch towards diesel from gasoline/fuel oil and (b) 1% higher global refining runs. Further, refineries will also need to create 0.8 mn bpd of LSFO in 2020 through a combination of (1) planned residue desulphurization units, (2) topping units for sweet crude, and (3) diverting the low sulphur VGO from secondary units to the bunker pool.

Even gasoline/Jet market could tighten

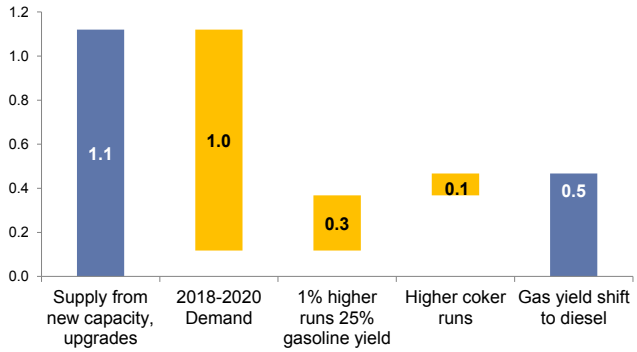
Given the co-product nature of the refining industry, we believe gasoline and Jet markets could tighten as well. While higher runs will likely yield more gasoline, it will be more than offset by yield switch against gasoline and FCCU feed being diverted to the bunker pool. Jet and Diesel are part of the middle distillates yield for refineries and generally trade in line with each other.

Exhibit 33: Higher diesel production will require (1) switching against gasoline, (2) higher coker runs, and (3) higher refining utilization rates
Diesel SD bridge, mn bpd



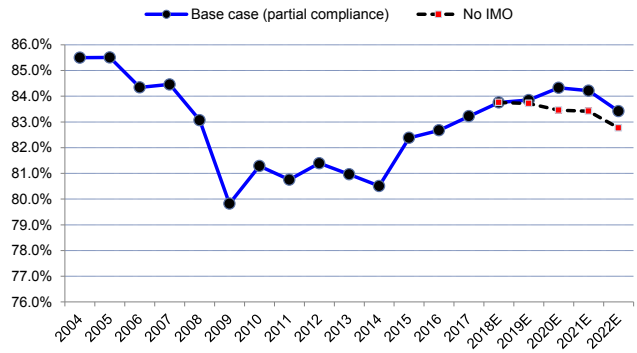
Source: Goldman Sachs Global Investment Research

Exhibit 34: Higher global runs will create some buffer to accommodate gasoline switch towards diesel
Gasoline SD bridge, mbpd



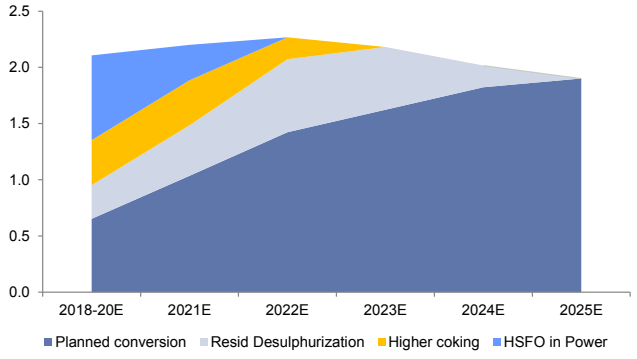
Source: Goldman Sachs Global Investment Research

Exhibit 35: Global utilization likely to rise in 2020 to increase diesel production
Global refining utilization rates



Source: BP, Goldman Sachs Global Investment Research

Exhibit 36: The effects of IMO regulation will likely fade by 2022/23 as refineries in normal operations will be able to destroy enough HSFO
HSFO destruction



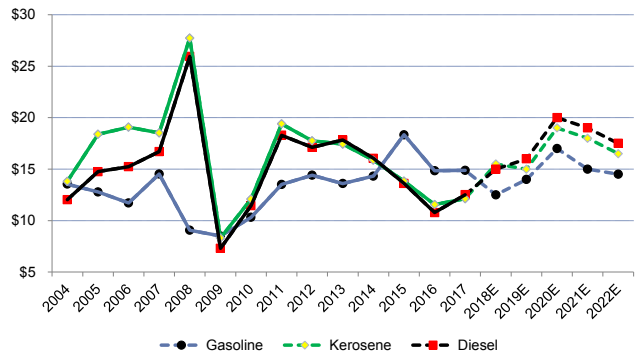
Source: Goldman Sachs Global Investment Research

What are the implications for refined product cracks?

In a high compliance scenario, crack for clean products such as diesel/gasoline and jet to go up while cracks of HSFO will come down sharply. Crack for LSFO will likely be in line with diesel in 2020/2021 before settling at a market determined discount to diesel over the medium term. Cracks may start reacting from 2H19 itself, as implied by the current forward curves. Below we highlight our expectations on the mechanism by which cracks for various products will be determined by 2020:

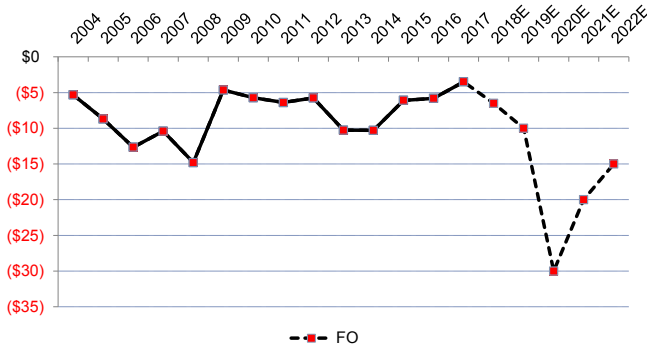
1. HSFO prices will start to react negatively first in order to incentivize higher coker runs driving HSFO cracks lower
2. Diesel cracks will go up by US$5/bbl to incentivize yield switching
3. As refiners will not be able to fully destroy HSFO in 2020, HSFO prices will fall further to create new demand source.
4. Given the need to drive higher refining runs, cracks for other products such as gasoline and Jet will need to rise as well.

Exhibit 37: In a partial compliance scenario, diesel cracks will need to rise over gasoline to drive switching away from gasoline
Light and middle distillate cracks



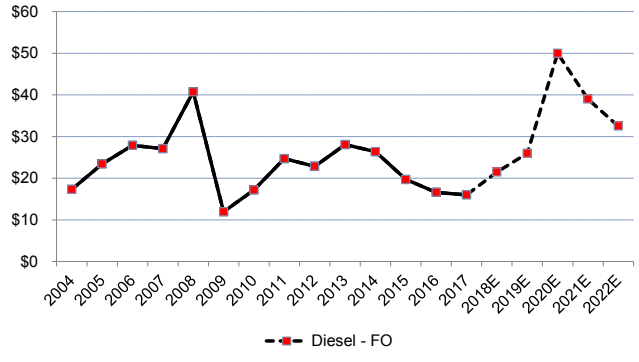
Source: Platts, Goldman Sachs Global Investment Research

Exhibit 38: FO margins will fall with power parity price dictating the floor, all else equal
HSFO cracks



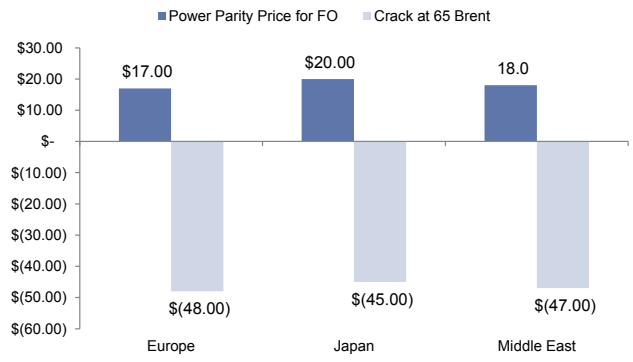
Source: Platts, Goldman Sachs Global Investment Research

Exhibit 39: Diesel-FO will widen to historic highs to drive higher coking runs
Diesel-FO differential



Source: Platts, Goldman Sachs Global Investment Research

Exhibit 40: Lower bound of FO cracks will be dictated by power price parity
Fuel oil parity with coal price



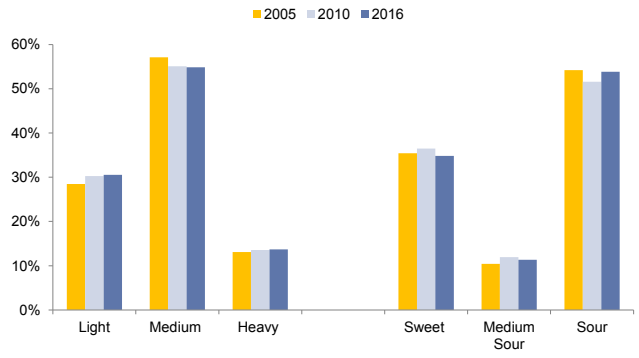
Source: Goldman Sachs Global Investment Research

What are the implications for crude differentials?

Global crude slate has been getting lighter due to the increase in light sweet production from the US. However changes have been modest at best and clearly not enough to reduce the sulphur content of HSFO on a global basis.

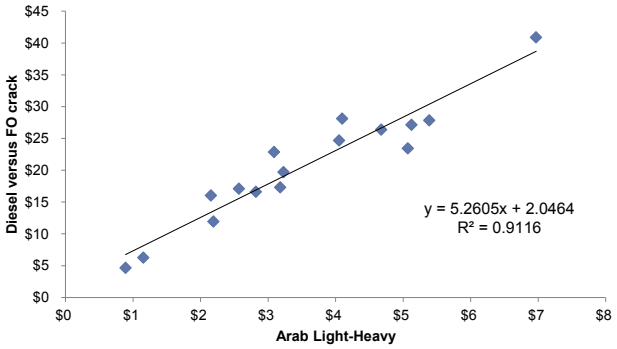
Heavy crudes generally have high concentration of Sulphur and yield higher proportion of HSFO. As such heavy oils trade at a discount to light oil. As the industry bids against sulphur, we expect heavy oils discount to light oil to widen.

Exhibit 41: Crude grades are relatively lighter and sweeter versus history but changes have not been significant
API and Sulphur content of crude



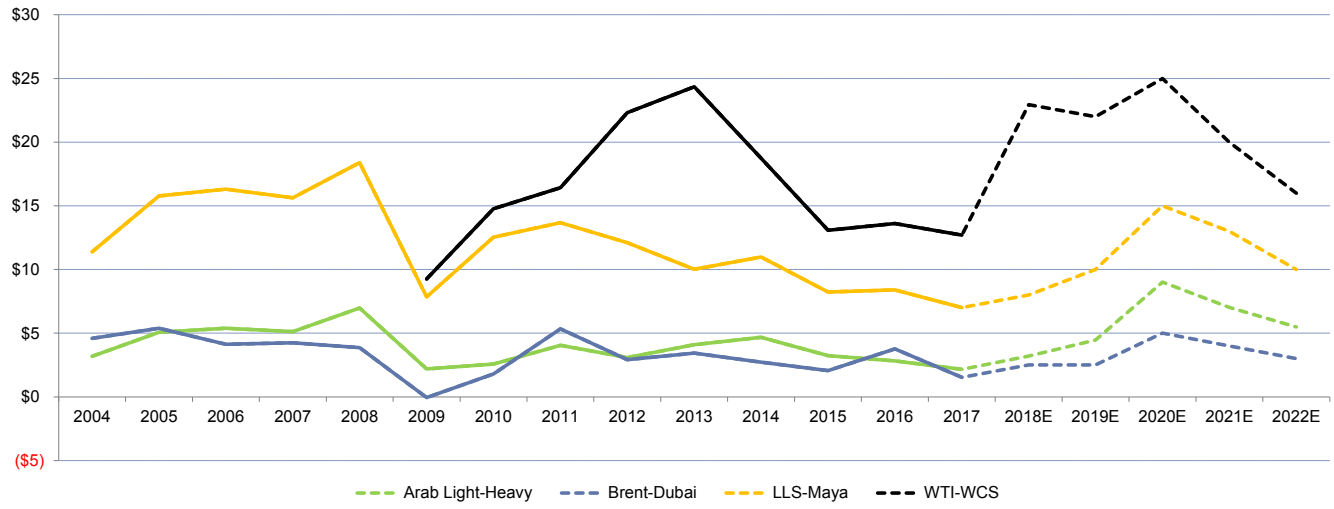
Source: ENI

Exhibit 42: Diesel-FO is highly correlated with Light-Heavy in Asia
Regression Analysis of Diesel-FO crack with light-heavy differential



Source: Platts, Bloomberg, Goldman Sachs Global Investment Research

Exhibit 43: We expect heavy/medium grades to trade at a discount to light/sweet crude
Crude differentials (US$/bbl)



Source: Platts, Bloomberg, Goldman Sachs Global Investment Research

Who will benefit the most amongst the oil value chain?

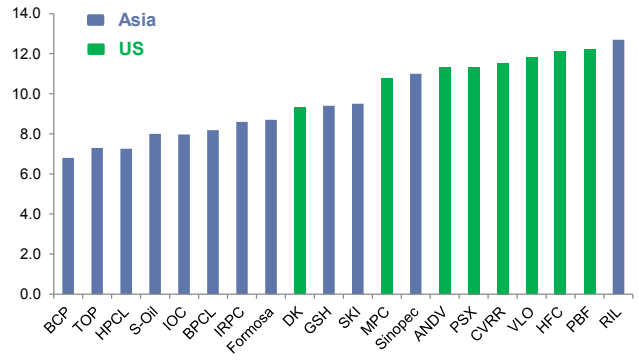
Complex refiners (deep conversion capacities) benefit from cheaper heavier crude. They also have very low exposure to HSFO and high exposure to clean products which should drive their margins higher as well.

Explaining Refining Complexity: Higher refining complexity enables refiners to process heavier crude oils and yet produce products of international specification. This is captured by using the Nelson Complexity Index (NCI), which measures the secondary conversion capacity of a refinery relative to its primary distillation capacity. The higher the NCI, the greater the ability of the refinery to produce more light and middle distillates even from challenged crude oil feedstock.

Refinery capex on the rise, even without IMO impact; full upgradation could require c.$120bn capex

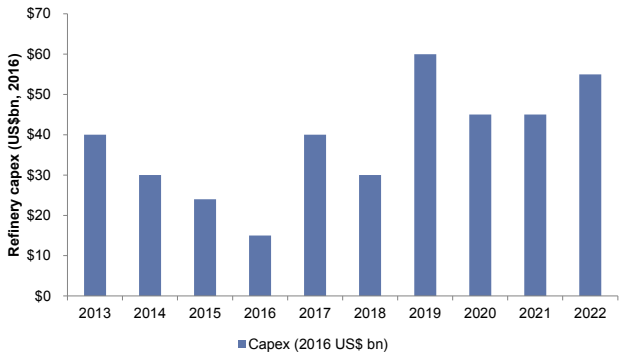
Refinery projects are quite complex and typically take 4-5 years from FID (final investment decision) to commercial operations, in a best case scenario. We expect a pick up in the pace of new capacity additions over 2019-22, which implies a pick up in refinery capex as well. However, these capacities were added in response to the higher refining cash flows since 2015 on the back of strong oil demand led upcycle. As IMO 2020 kicks in, we expect a widening of clean-dirty spreads in 2020, which may theoretically incentivize further refinery upgradation. However, there are currently uncertainties about scrubber penetration uptake in the ships, and until that clears out, we believe there may not be a significant pick up in "new" refinery upgradation projects. Theoretically, if all the refineries were to be upgraded to reduce marine related HSFO production(3.2 mn bpd) to zero, we estimate c.$120 bn capex will be required. As per IEA 150 kbpd of upgrading unit costs around US$5.3 bn.

Exhibit 44: US refiners are mostly complex, RIL in India has the highest complexity
Complexity (Nelson Index) , 2016



Source: Company data, Oil & Gas Journal, data compiled by Goldman Sachs Global Investment Research

Exhibit 45: Refining capex is expected to pick up
Global refining capex, (US$ bn, 2016)



Source: OPEC

Shipping: Inflationary but likely a pass-through

Authored by Venetia Baden-Powell, European Transport Analyst

We believe shipping companies are most likely to switch fuel (from high-sulphur fuel to marine diesel oil) vs. opting for capex-intensive solutions (scrubbers, LNG) in order to meet IMO's 2020 regulations. Overall, while a fuel switch would result in relatively high opex inflation (c.6%), we believe this will be easier to pass-through to customers vs. capex, particularly in the context of improving market fundamentals.

The new regulations are a growing concern for an industry where bunker costs are equal to 15-30% of total opex, depending on the shipping segment (container, tanker, dry bulk etc.). This is especially pertinent given that the industry has only recently begun to emerge from a decade-long depression triggered by weak trade growth and a large capacity overhang following the global financial crisis. In this section, we lay out the options available to shipping companies and analyse the implications throughout the supply chain.

What are the options?

In order to meet the IMO 2020 regulations, carriers have three options, which vary in terms of margin impact and capex requirements.

1. **Fuel switch:** The simplest solution requiring no capex, however it would increase fuel costs by c.40% based on the current spread between HSFO and MDO and opex by ~6%.
2. **Scrubbers:** Allow shippers to burn cheaper HSFO, but upfront capex is required ($5-10mn/ship). Further negatives are increased opex for monitoring and waste disposal, and the lack of clarity on whether this is a sustainable environmental solution (waste discharged in ocean, no reduction in other GHG emissions).
3. **LNG:** European LNG is c.40% cheaper vs. MDO (similar to HSFO), however the price discount varies widely globally. LNG engine retrofits are also relatively more capex intensive ($20-25mn/ship), would raise shipper unit costs (large engine size reduces cargo space on board), and are only useful in so far as there is sufficient bunkering infrastructure. Today, only 7 of the top 20 global ports either have or have plans for LNG bunkering stations.

Fuel switch most likely, easier cost pass-through to consumer

As shipping capacity is a commoditized product and globally mobile, **pricing power has historically been a simple outcome of the supply-demand balance in a given shipping segment**. Indeed, as shown in Exhibit 48, yoy changes in supply-demand drive the yoy change in fuel-adjusted container rates. Fuel tends to have a temporary impact on profitability; if supply-demand is tight, fuel inflation is passed through. **The current context of a consolidating container market and slowing supply growth, driven by a wave of M&A and market exits, should therefore enable pass-through, in our view.**

We believe that the low ocean transportation cost as a proportion of cargo's overall value (typically <10%, Exhibit 46) facilitates this. Extrapolating from this and based on a) the current HSFO/MDO spread (+c.40%) and b) bunker accounting for c.15% of shipping companies' total opex, a pure fuel switch would thus result in c.6% opex inflation. In order to maintain EBITDA margins of 12-13% (GS 2020 forecasts for Maersk/Hapag), our model suggests liners would need to raise prices by c.5%, in turn implying c.0.5% inflation for the end consumer.

Looking into capex-intensive solutions, a back-of-the-envelope calculation suggests that the capex required to retrofit the global container fleet with scrubbers would be ~$42bn (assuming $8mn cost/container ship as per company comments). Applying e.g. a required return of 8.5% (Maersk target return) would imply ~$4bn in additional revenues, equal to c.3% price inflation in the $120bn container market. While this is lower than the scenario of a pure fuel switch, **opex inflation is easier to pass through, in our view, making it more likely that shippers will opt for MDO vs. capex-intensive solutions**. For LNG, the capex requirement is likely larger: Companies either have to retrofit vessels with an LNG engine (~$20-25 mn/container ship and only possible for those with sufficient space for fuel storage) or invest in LNG-capable newbuilds.

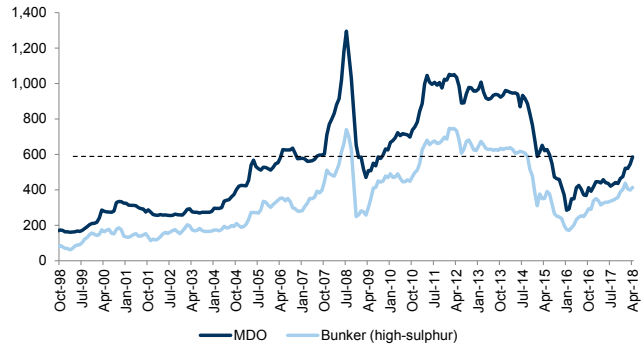
A natural response to higher fuel prices would be further implementation of slow steaming. This would also help absorb surplus capacity and hence increase pricing power. Since 2008 however, vessel speeds have already come down ~25%. Given the exponential relationship between fuel consumption and vessel speed, an incremental slowdown would thus imply fewer fuel savings vs. the first wave of slow-steaming. Moreover, voyage times would become too long. For instance, by reducing a container ship's average speed by a further 10% from ~12 knots today, the sailing time between Shanghai and Rotterdam would increase from ~36 to 41 days. **Thus, while some additional slow steam is feasible in order to ease inflationary pressures and improve capacity, we believe a full offset is unlikely.**

Exhibit 46: Ocean transportation costs account for a low proportion of total cargo value
Ocean transportation cost, % of cargo value

USD	Units/TEU	Price/unit	Value	Freight rate (excl. fuel), % value	Fuel, % value	Total ocean trans. cost, % value
Flat screen TVs	400	400	160,000	0%	0%	**1%**
Cars	2	40,800	81,600	1%	1%	**1%**
Mattresses	200	300	60,000	1%	1%	**2%**
Refrigerators	55	400	22,000	3%	2%	**5%**
Bananas	48,000	0.3	14,400	4%	3%	**7%**

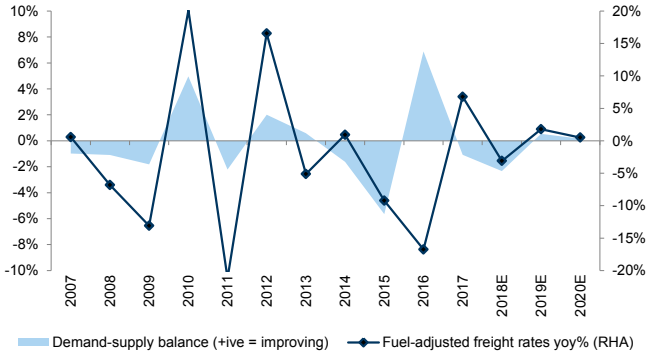
Source: Goldman Sachs Global Investment Research

Exhibit 47: MDO price in line with historical HSFO prices
Marine diesel vs. High-sulphur fuel oil, US$/tonne



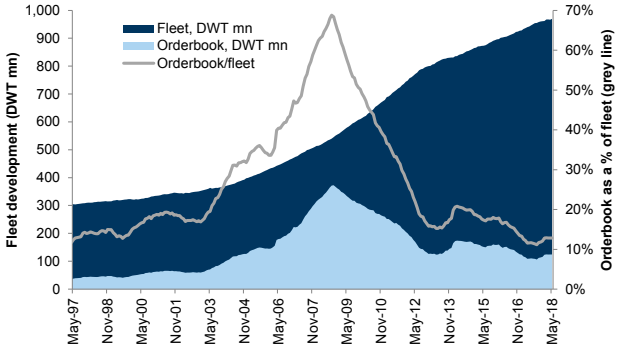
Source: Clarksons

Exhibit 48: Prices at constant fuel have historically varied with supply-demand; fuel tends to be a pass-through
Yoy% chg in supply-demand vs. fuel-adjusted rates



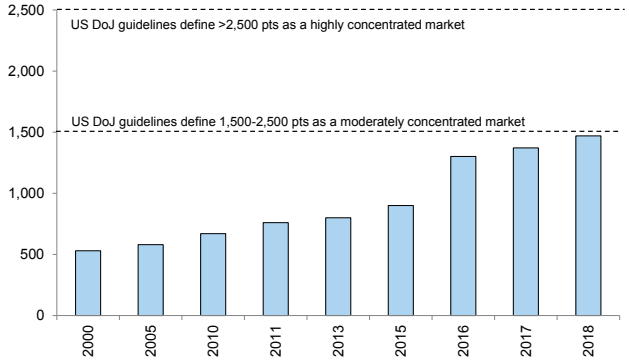
Source: Goldman Sachs Global Investment Research

Exhibit 49: Medium-term supply outlook is positive across the industry
Global shipping fleet and orderbook in DWT mn & as % of fleet



Source: Clarksons

Exhibit 50: In container, this is supported by an increasingly consolidated market
Global container shipping HHI



Source: Goldman Sachs Global Investment Research, Alphaliner

What the ship owners are saying

Maersk Line - containership carrier

"**The 2020 0.5% sulphur cap will be a game-changer for maritime transport**. It will add substantial cost either in the form of higher fuel cost or in the form of capex needed to make technical changes to the vessels." *(Capital Markets Day on February 20, 2018)*

"For the moment...**we don't prefer the scrubber solution...we are looking into LNG [and] into different mixes of fuel**." *(Capital Markets Day on February 20, 2018)*

Hapag-Lloyd - containership carrier

"We are studying the best way to do it: LNG? More expensive fuel? Right now, **we're not leaning towards scrubbers**. But **we may come up with a mixture of measures in the end**." *(Excerpt from analyst earnings call on March 28, 2018)*

"**We do think that the cost will go up, but we should be able to pass it onto the customer**." *(Excerpt from analyst earnings call on August 29, 2017)*

"Most ships today are technically performing at their best at the existing speeds...**going much slower would not yield a material saving in bunker and would require more capacity.** So I don't personally think [further slow-steaming] is likely." *(Excerpt from analyst earnings call on May 14, 2018)*

Euronav - crude oil tanker

"**The stats that I love: 1% of the world fleet has scrubbers on board, and the total scrubber capacity in production is 1% of the world fleet. So by 2020 there is never going to be more than 3% of the world fleet with scrubbers on board**… You also have to make sure that you have suitable availability of HSFO i.e. so that you can actually buy the oil that's going to give you a value discount." *(Excerpt from analyst earnings call on January 25, 2018)*

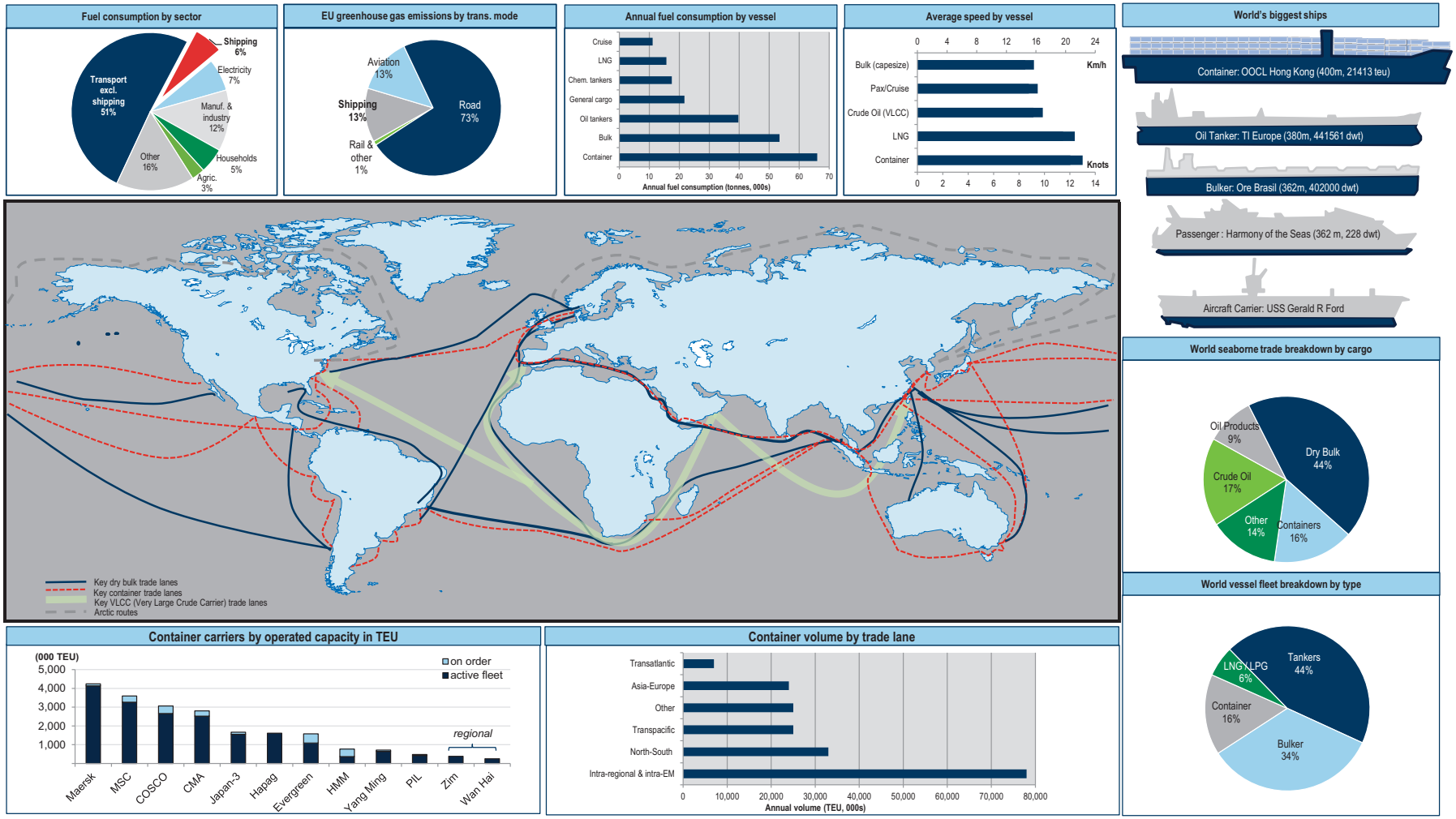
GasLog - LNG carrier

"A lot of the [newbuild] demand looks to be driven by people taking a view on the new emissions targets in 2020. **There is a lot of interest on newbuilds that are LNG capable** - being bunked by an LNG or driven by LNG...newbuildings for car carriers, containerships and even tankers and bulkers are looking to be LNG suitable." *(Excerpt from analyst earnings call on May 4, 2018)*

Golden Ocean - dry bulk carrier

"We are still considering our options and haven't decided which strategy to take." *(Excerpt from analyst earnings call on February 20, 2018)*

Exhibit 51: Shipping at a glance: Overview of the key trades, segments & fuel consumption



Source: Goldman Sachs Global Investment Research, Clarksons, UNSD, IMO, Bloomberg, EEA

Scrubbers: A US$15 bn revenue pool opportunity

Authored by Jonathan Hanks, European Capital Goods Analyst

We expect c.5000 ships to install scrubbers by 2025 which represents a market size of US$15 bn. We estimate scrubber uptake to pick up in 2020 based on wider clean-dirty spreads as per forward curve. However with rising scrubber uptake, payback period will likely start rising again as clean-dirty spreads normalize.

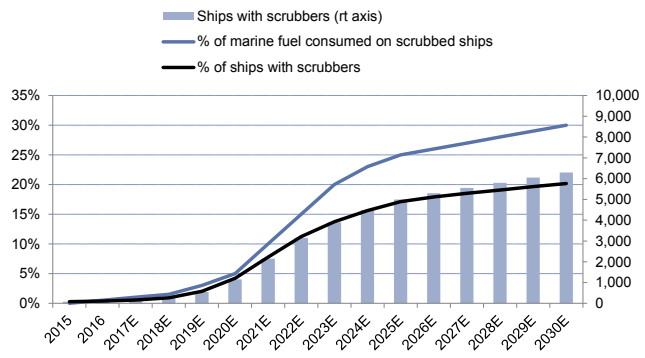
Scrubbers: We expect c.5k ships to install scrubbers by 2025

Scrubbers are essentially exhaust gas cleaning technologies that make possible use of high-sulphur fuel and are still compliant with low sulphur regulations. Scrubber installation can take 4 to 6 months depending on the complexity and size of the ship. Scrubbers are installed during dry docking periods.

The largest and youngest vessels are the most likely to install the systems.Our conversation with industry participants imply that the likely capacity of scrubber installation based on the drydocking schedule of ships likely to install scrubbers is around 1000. We expect scrubber installation to peak at 1000 in 2021/22 and falling thereafter with total scrubber installation of c.5000 by 2025. We see upside risks to this estimate primarily come from the smaller vessels outside of Bulk Carriers/Oil Tankers/Containers. Many of these smaller vessels already operate very close to coastal regions and hence are probably already in compliant with low sulphur emissions requirements, though the exact proportion is unclear.

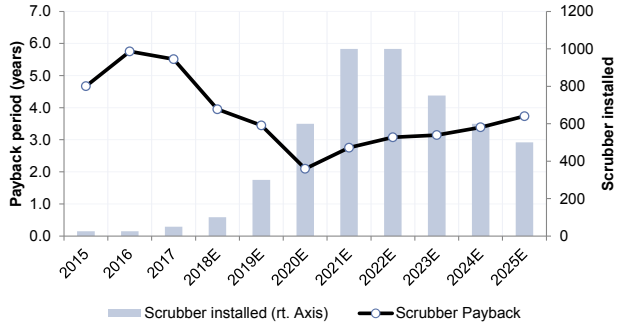
Recent commentaries from companies have suggested very strong order momentum in 1Q18. Firstly, Wartsila received orders for 74 scrubbers in the quarter (34 newbuild, 40 retrofit) vs 77 in the whole of 2017 (all new build). Secondly, Alfa Laval's CEO also said that they are more positive on the market outlook for scrubbers today vs. when they made their original 2016 forecasts despite toning down expectation in 2017.

Exhibit 52: We expect 5000 ships to install scrubbers by 2025 accounting for 25% of bunker fuel consumption
GS scrubber uptake assumptions



Source: Goldman Sachs Global Investment Research

Exhibit 53: We expect scrubber installations to pick up in 2020 in line with a faster payback
Scrubber installations in a year versus payback period



Source: Goldman Sachs Global Investment Research

Scramble for installations could boost pricing; we expect a €13bn (or US $15 bn) revenue pool opportunity

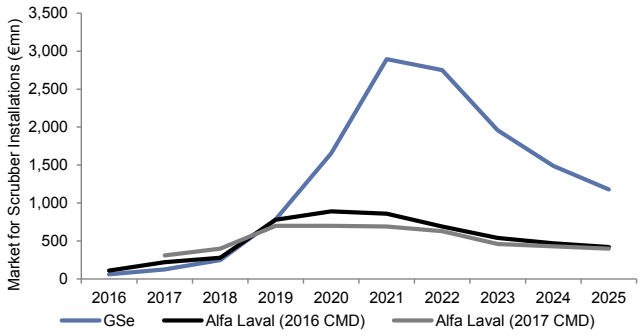
The current cost per scrubber system is around €2.5mn per vessel (source: Wartsila), although it can vary between €1mn and €6mn depending on the vessel size; for example cruise vessels typically tend to be towards the top end of the range as they typically have two systems installed. We expect this system value to grow as strong demand combined with a fairly consolidated set of suppliers supports at least low to mid single digit pricing over the next three years (followed by low to mid single digit decline as volumes fall). This implies a total revenue pool opportunity of around €13bn.

- **Alfa Laval forecasts a market size of €5bn for 5000 vessels, implying a system price of around €1mn a vessel.** We believe they are assuming significant deflation as the technology matures (they note this is typical as any technology matures) and the suppliers achieve economies of scale.
- **However, we believe that the demand acceleration is likely to be so steep and the supplier base so concentrated (see Ex. 54) that price deflation is unlikely.** We forecast scrubber installations growing from 50 in 2017 to 600 in 2020. We also estimate that the Herfindahl-Hirschman index for the market is c.2500, at the threshold that the Department of Justice considers a market to be 'highly concentrated'. Whilst these tend to be capital light assembly businesses, which might suggest low barriers to entry, there is significant engineering capability required. For example, Alfa Laval had to add engineering capacity in Finland to cope with the number of 'request for proposals' they were expecting. Further, marine customers tend to be quite conservative and hence typically would try and stick with established suppliers.
- **Alternatives cap potential price inflation but low to mid single digit pricing doesn't materially alter payback periods:** Given ships have multiple choices to comply (I.e. using low Sulphur fuel), scrubber prices are inherently capped by the fact that the more expensive they are the less attractive they become to ship owners. That said, in our Scrubber payback model a price increase of 5% per year to 2020 only increases the payback period by 2-3 months and still suggests the payback period troughs at 1.9 years.
- **There is precedent for price inflation; recent commentary appears supportive:** In the late 2000's the 'Clean Air Interstate Rule' drove significant inflation in the price of scrubber systems for power plants (see case study below). Recent commentary on expanding lead times (Alfa/Wartsila/Yara) as well as rising nickel prices (up 50% yoy) are also supportive of this view.

Note that our revenue pool opportunity estimate refers to the system cost; it does not include the cost of installation. This can typically be another 50% of the system cost for a new build and potentially 100% of the system cost for a retrofit. Typically the yard will install the system for a new build however Wartsila can manage the installation for a retrofit; Alfa Laval and Yara do not install the scrubbers. Note slots at the yards could become a serious bottleneck for installations as there are only a certain number of qualified engineers that have the ability to install the scrubbers.

Exhibit 54: We assume price inflation (not deflation) in scrubbers which drives our €13bn revenue pool estimate vs. €5bn for Alfa Laval

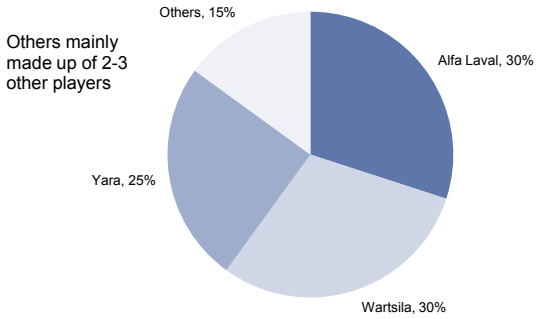
GSe vs. Alfa Laval scrubber market forecasts (€mn)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 55: The scrubber supplier market is fairly consolidated, dominated by Alfa/Wartsila/Yara

Estimate market shares of scrubber installed base



Source: Company data, Goldman Sachs Global Investment Research

Alfa Laval, Wartsila, Yara are key players

Alfa Laval, Wartsila and Yara are the three equipment suppliers which dominate the scrubber market. There are other players (we list several below), however company commentary suggests they do not have significant market share. We estimate from company disclosures that Alfa Laval/Wartsila/Yara have around c.30%/30%/25% market share of the current installed base.

Exhibit 56: Scrubber manufacturers

Company Name	Country	Listed?	Market Cap (€mn)	Description
Alfa Laval	Sweden	Yes	9,573	Engineering company focused on solutions for heat transfer, separation and fluid handling. Has been a supplier of marine equipment for over a century.
Wartsila	Finland	Yes	10,651	Wartsila manufactures and provides aftermarket services for internal combustion engines, multi-fuel engines and other products for the marine and power-generation industries.
Yara	Norway	Yes	9,558	Produces, distributes and sells Nitrogen based mineral fertilisers and related industrial products. Acquired scrubber portfolio in 2014 acquistion of a stake in Green Tech Marine.
Hyundai Heavy Industries	S Korea	Yes	6,929	Hyundai Heavy Industries (HHI) is a Korean ship-builder which possesses technology to manufacture scrubbers
AVIC International Maritime Holdings	Singapore	Yes	18	Owned by the PRC central government. They have experience in designing the emission solution for shipping company, and manufacture scrubbers themselves, by acquiring a Finnish design and engineering firm, Deltamarin Ltd in January 2013 and established a joint-venture company with Oy Langh Tech Ab to provide engineering, procurement and construction services.
Weihai Puyier Environmental & Technology Company	China	No	n.a.	-
Shanghai Bluesoul Environmental Technology	China	No	n.a.	-

Source: Company data

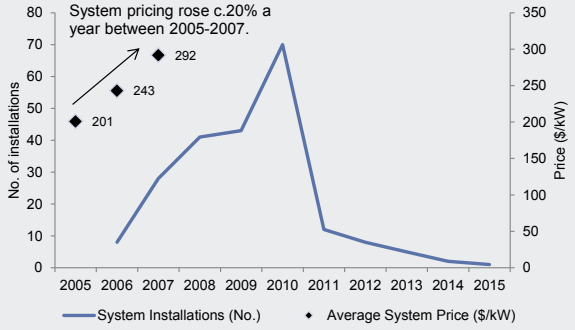
How the 'Clean Air Interstate Rule' drove significant pricing for scrubbers

Clean Air Interstate Rule: In 2005 the US Environmental Protection Agency signed into law the 'Clean Air Interstate Rule', regulation intended to limit power plant pollution that drifts from one state to another. As part of this, the EPA introduced a 'cap and trade' system on NOx/SOx emissions which started in 2009/10 respectively.

Drove nearly 10x increase in scrubber demand in four years: This triggered a need for power plants to install 'Flue Gas Desulphurization' (FGD) systems, in other words scrubbers to clean out the NOx/SOx emissions to comply with the caps. Installations went from c. 8 in 2006 to c.70 in 2010, a similar trajectory from the c.100 installations of marine scrubbers we expect in 2018 to 1,000 in 2022.

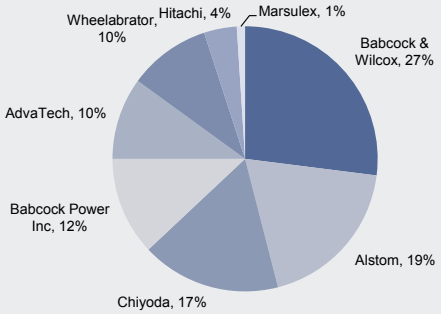
System pricing also rose significantly: In 2005 the average FGD system cost c.200 $/kW, however, over the next two years it rose c.20% a year to c. 290 $/kW in 2007. Interestingly, this is despite the market being only 'moderately concentrated' according to the DoJ definition of a market with a Herfindahl-Hirschman index of 1730 (between 1500 and 2500, see exhibit 58). This is actually a less concentrated market structure than we expect in the marine Scrubber market where we estimate Alfa Laval/Wartsila each have c.30% of the market (HHI of c.2500). That said, we wouldn't expect an aggressive pricing ramp up in marine scrubbers because ships have alternative options if scrubbers get more expensive. Further, compliance mechanisms were clearer and easier to enforce in this scenario.

Exhibit 57: As US power plants rushed to fit scrubbers ahead of the 2010 deadline, pricing for systems soared…
Planned FGD scrubber system installations



Source: Powergen magazine

Exhibit 58: …despite the market only being 'moderately concentrated' (at HHI c.1740, within DoJ definition of 1500-2500)
Market share of 'wet' FGD system suppliers (based on 2006 backlog)



Source: Powergen magazine

Chemicals: Merchant hydrogen producers to benefit

Refineries use hydrogen to produce clean products

Hydrogen is required for two key refinery process, which removes sulphur from clean products as well as increases the yield of clean products such as diesel:

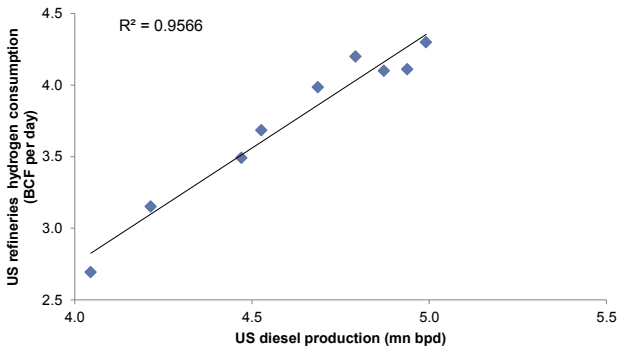
1. **Hydrodesulphurization:** Sulphur present in heavy crude oil ranges from 2% to 4% with regulation in US/Europe requires sulphur concentration of just 10 ppm in clean products. Sulphur compounds present in products such as diesel and gasoline feeds can be removed by reacting them with hydrogen at high temperature and pressure in the presence of cobalt-molybdenum or nickel-molybdenum catalysts.
2. **Hydrocracking:** Refiners are able to convert heavy feedstocks into more desirable lighter products such as diesel/gasoline by hydrocracking which combines catalytic cracking and hydrogentaion. The process requires high temperature, high pressure , hydrogen and catalysts.

Refineries also produce some hydrogen as a by-product in the reforming processes which converts naphtha into higher value products. However that supply meets only a fraction of total hydrogen needs. Thus refineries typically either directly invest in hydrogen generating capacity on site or outsource it to merchant suppliers.

Merchant hydrogen suppliers to benefit from IMO Sulphur Cap

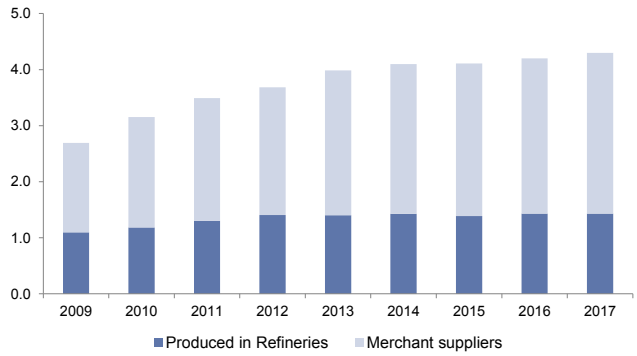
Hydrogen demand in refineries have been growing with the increasing need to remove sulphur from refinery products and increasing diesel productions. We note in the US the increase in demand has been exclusively met by merchant hydrogen suppliers such as Air Products (APD)and Praxair (PX). Given the need for higher diesel production once IMO sulphur cap regulation kicks in, we expect hydrogen demand will increase in 2020. Hydrogen supply from merchant suppliers is mostly exclusive with individual refinery customers. Hence an increase in hydrogen demand would most likely drive higher volume but not necessarily higher price.

Exhibit 59: Refinery hydrogen consumption has high correlation with diesel production
US refinery hydrogen consumption versus diesel production



Source: EIA

Exhibit 60: Merchant hydrogen producers are the key source of hydrogen for US refiners
Source of hydrogen consumed in US refineries



Source: EIA

Metals & Mining: Cost inflation likely to be passed on to consumers

Authored by Trina Chen, China Basic Materials Analyst

Aluminum – 5% price hike for pass through

Refineries produce a variety of coke, and one of them is anode grade coke (called GPC or Green Petroleum Coke). GPC is typically a low sulphur coke and is suitable for producing anodes which is a key input in aluminum production. As we approach the IMO 2020 sulphur cap deadline, the low sulphur products from refineries may start to get priced together with diesel, as they can potentially be diverted to marine fuel pool and this may potentially tighten the anode grade coke market. We estimate a 50% increase in production cost of anode grade coke could increase the global aluminum production cost by US$6 bn.

We estimate a potential 50% price hike in anode grade coke could lead to US$0.04/lb changes in the production cost of aluminum, using Chinese current spot prices of anode grade coke as a base for our estimates. A potential 50% increase in anode grade coke price would drive carbon anode prices higher by 31%, after its 42% rise in the past one year, putting further inflationary pressure on the cost of aluminum.

Given our view on a mostly balanced outlook of the global aluminum market and improving S/D of the Chinese aluminum market, we expect most of the cost would be passed on to consumers, implying a 5% aluminum price hike in China or 4-5% increase in LME aluminum price, based on the current spot market.

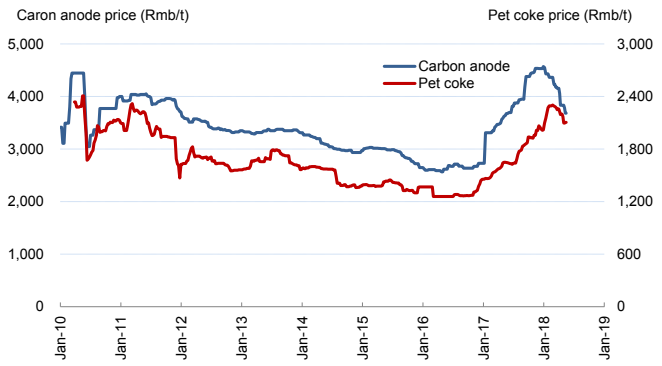
GS global commodity team expects a mostly balanced S/D outlook for aluminum, and estimated a supply deficit of 180kt in the global aluminum market in 2018E, followed by 500-900kt surplus in 2018E-2020E. In China, we are incrementally more positive on the Chinese aluminum sector, driven by a continued positive view on the supply outlook, combined with additional upside risks due to the impact of Rusal sanctions. With muted new capacity approvals, we expect improvement in supply/demand (S/D) in 2019E, after the tail-end of new capacity additions completes (we estimate there are likely 2-3mnt leftover from prior approvals or exchanged through replacement quota).

Exhibit 61: Higher carbon anode prices will likely be passed on to consumers given balanced aluminum markets

Impact of potential petcoke (anode grade) price hike on aluminum cost		
Spot petcoke price (anode grade)	Rmb/t	2,105
Potential changes in petcoke (anode grade)	%	50%
	Rmb/t	1,053
Usage of petcoke per tonne of carbon anode	t/t	1.1
Potential cost increase in carbon anode	Rmb/t	1,158
Usage of anode per tonne of Al	t/t	0.5
Potential cost increase in aluminum	Rmb/t	579
	US$/t	0.041

Source: WIND, CEIC, Goldman Sachs Global Investment Research

Exhibit 62: Carbon anode prices track petcoke prices



Source: WIND, CEIC, Goldman Sachs Global Investment Research

Iron ore – 6% cost hike likely to pass through

As shipping companies switch from HSFO to diesel in 2020, we estimate sea-borne freight to increase by 30%. Such a hike in freight cost would lead to 6-7% higher cost to the China CIF iron ore prices (taking the freight cost of Brazil to China as an example) , and potentially a 1-2% cost hike to steel prices, based on the estimates from our GS global commodity team.

Our discussion with large Chinese iron ore traders suggests that regardless of the cycle, higher freight costs have historically been passed through onto the steel mills, instead of being absorbed by the miners. Nevertheless, we see a mild risk of the partial pass through in the coming years, given our outlook of a rising surplus in the seaborne iron ore market – our GS global commodity team projects global supply to increase by 1.7% in 2018, leading to a seaborne surplus of 27mt, followed by 39mt and 60mt surplus in 2019E and 2020E, respectively. A potential lower than expected Chinese steel demand post 2019E could lead to widened surplus and further deterioration in the market. On a relative basis, we believe the higher cost hikes could put Brazil supplier at US$2-3/t less advantaged than its peers in Australia.

The met coal market appears more balanced than the iron ore market, as the impact of Chinese new expansions remains muted. Our GS global commodity team projects met coal prices to range from US$210/t to US$145/t between 2018E-2020E, and the potential changes in freight cost would be 1-2% of overall pricing, much lower than that in iron ore.

Exhibit 63: Higher freight would require 6-7% higher cost to the China CIF iron ore prices and potentially a 1-2% cost hike to steel prices.

		spot	2018E	2019E	2020E
Iron ore (China CIF)	US$/t	67	68	63	60
Freight cost-spot Australia-China	US$/t	19.0	19.0	19.0	19.0
Potential 30% hike	US$/t	5.7	5.7	5.7	5.7
Cost hike as % of IO price	%	8.5%	8.4%	9.0%	9.5%
Assuming fully pass through					
Potential impact to steel cost	US$/t	9.1	9.1	9.1	9.1
Chinese HRC	Rmb/t	4310	4228	3960	3778
Cost hike as % of steel price	%	1.3%	1.4%	1.5%	1.5%

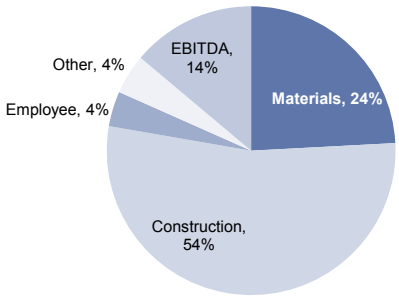
Source: WIND, CEIC, Goldman Sachs Global Investment Research

Bitumen/asphalt consumers to benefit

Lower bitumen price could lead to lower road builders costs

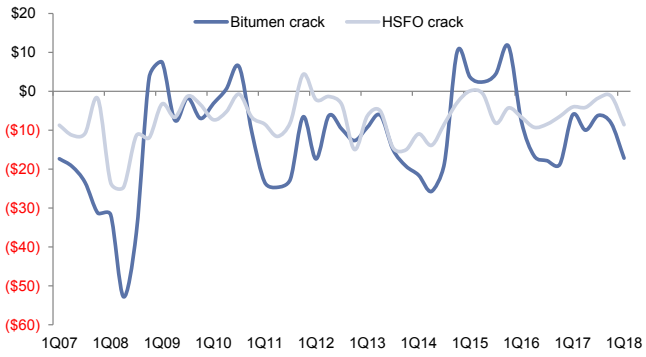
Bitumen is another residue from petroleum distillation and is typically high in sulphur content. It is a key ingredient in making roads and typically accounts for 5-10% of road building companies production cost. Our conversation with refining companies suggests that high sulphur fuel oil yields could be changed marginally in some refineries to instead produce more bitumen. Given the global bitumen market size is much smaller (almost one-third) than fuel oil, the oversupply in fuel oil market typically translates into a bigger price reduction for bitumen historically. As such, we expect bitumen prices to come down as IMO 2020 sulphur regulation kicks in. Assuming a similar price decline (c.$20/bbl) as high sulphur fuel oil in 2020, we calculate that cost for building roads globally could come down by US$10-15bn.

Exhibit 64: Material cost accounts for c.25% of revenue for Indian road builders
Margin analysis for Indian road builders



Source: Company data

Exhibit 65: Bitumen cracks related to HSFO crack have wider swings due to the smaller market size versus HSFO
Bitumen and HSFO crack



Source: Datastream, Company data, Goldman Sachs Global Investment Research

Disclosure Appendix

Reg AC

We, Nikhil Bhandari, Neil Mehta, Vinit Joshi, Patrick Creuset, Trina Chen, Jonathan Hanks, CFA, Venetia Baden-Powell, Carly Davenport, Theo Kim and Jen Jiang, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Growth is based on a stock's forward-looking sales growth, EBITDA growth and EPS growth (for financial stocks, only EPS and sales growth), with a higher percentile indicating a higher growth company. **Financial Returns** is based on a stock's forward-looking ROE, ROCE and CROCI (for financial stocks, only ROE), with a higher percentile indicating a company with higher financial returns. **Multiple** is based on a stock's forward-looking P/E, P/B, price/dividend (P/D), EV/EBITDA, EV/FCF and EV/Debt Adjusted Cash Flow (DACF) (for financial stocks, only P/E, P/B and P/D), with a higher percentile indicating a stock trading at a higher multiple. The **Integrated** percentile is calculated as the average of the Growth percentile, Financial Returns percentile and (100% - Multiple percentile).

Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

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America-Refining & Marketing: Andeavor, Calumet Specialty Products Partners, CVR Energy Inc., CVR Refining LP, Delek US Holdings, HollyFrontier Corp., Marathon Petroleum Corp., PBF Energy Inc., Phillips 66, Valero Energy Corp..

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Extended Reality

Drones

Factory of the Future

Precision Farming

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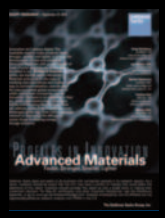


AI Hardware

Blockchain

Space

Rethinking Mobility

The Store of the Future

Digital Divergence

The Genome Revolution

GS SUSTAIN

The PM's Guide To The ESG Revolution

50 Quality Companies

Macro, Markets & PM Resources

Bear Necessities

A taste of the high (vol) life

Unlocking Value in Europe

The European Conviction List

European Passport

Top of Mind

Fortnightly Thoughts

Healthcare

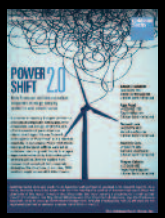
Diabetes

The Low Carbon Economy

Promising Tech

New Era for Euro Utilities

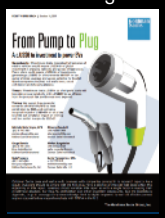
Power Shift 2.0



More Lean, More Green

NextGen Power: Solar

From Pump to Plug



Powering up e-Mobility

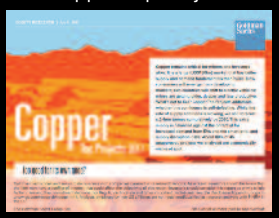
Music

Opportunity

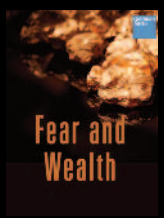
Commodity Corner

Top Oil & Gas Projects

Copper Top Projects



Gold Primer



Oil: Age of Restraint

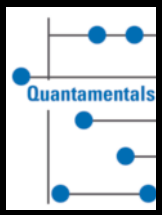
Rising Asia

Rise of China FinTech

China's Rise in AI

Mapping China's Credit Vol2

Quantamentals



Consumer Currents

Supermarket Shift: Expect Measured Disruption

European Business Services

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