The EU refining industry and the challenge of the IMO global sulphur limit for bunker fuels

As refineries face the prospect of a 0.5% m/m global sulphur limit in marine fuel oil by 2020, a number of studies have been carried out to assess the challenges they will face in meeting the demand for lower-sulphur marine fuels.

The International Maritime Organization (IMO) has set a global limit for sulphur in fuel oil used on board ships of 0.5% m/m from 1 January 2020. This is the biggest single specification change to ever hit the refined product market, and could cause a major disruption in supply, demand and market strains. The shipping, bunkering and refining industries are all interlinked with respect to this change, and the response by one industry will affect decisions made by others.

This article describes the regulatory situation, shares the current knowledge of experts speaking on the topic and gives an overview of a technical study being carried out using linear programming and supervised by Concawe's Refinery Technology Support Group.

Regulatory developments

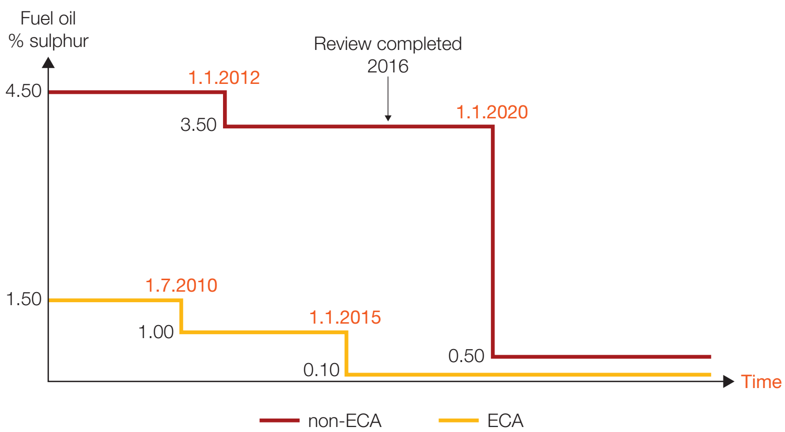
The IMO's Marine Environment Protection Committee (MEPC) was established in November 1973 with the responsibility of coordinating IMO activities aimed at the prevention of ship-source pollution. To better address marine pollution, the International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted in 1973.

MARPOL Annex VI

Several amendments to MARPOL have been made since its adoption, of which the most significant was the Protocol of 1997 which introduced the new Annex VI. Adopted in 1997, Annex VI came into force in May 2005, and applies to all ships trading internationally involving countries that have endorsed the convention. It expanded MARPOL's scope to include air pollutants contained in ship exhaust gas, and 88 states out of 197 have so far ratified the Protocol of 1997 (Annex VI). Recognizing the harmful effects of sulphur oxide (SO_x) emissions, Regulation 14 of Annex VI sought to reduce emissions by limiting the sulphur content of bunker fuels. It also mandated the monitoring of sulphur content in residual fuel oils supplied for use on board ships. Initially, it set a global limit on the sulphur content of marine fuels at 4.50%, and designated the Baltic Sea as the first Sulphur Emission Control Area (SECA) where a sulphur content limit of 1.50% in marine fuels was mandated.

Stricter regulations were adopted in a modified Annex VI in 2008 under Resolution MEPC.176(58), within which Regulation 14 states that the sulphur content of any fuel oil used on board ships shall not exceed 0.50% m/m from 1 January 2020. However, a provision was adopted which requires the IMO to review the availability of low-sulphur fuel oil for use by ships, to help Member States determine whether this new global cap on sulphur emissions from international shipping could potentially be deferred until January 2025. In addition, in 2010, MARPOL redesignated SECAs as Emission Control Areas (ECAs), adding a provision to include special limits for SO_x, nitrogen oxides (NO_x) and particulate matter (PM) within these areas.

Figure 1 Regulation 14: fuel oil used on board ships



Latest developments

At the 70th session of the IMO's MEPC held in October 2016, it was decided that the 0.50% limit should apply from 1 January 2020. This decision was supported by a study prepared by the IMO's hired consortium of consultants, led by CE Delft, which concluded that sufficient quantities of compliant marine fuels would be available by 2020. A complementary study performed by EnSys Energy and Navigistics Consulting was more cautious, highlighting the uncertainties, difficulties and risks of limited availability.[1]

[1] EnSys Energy-Navigistics Consulting *Supplemental Marine Fuel Availability Study* submitted to the IMO, July 2016. Available from: https://www.ensysenergy.com/downloads/supplemental-marine-fuels-availability-study-2

Ships may meet SO_x emission requirement by using approved equivalent methods, such as exhaust gas cleaning systems (EGCS) or 'scrubbers', which aim to remove sulphur oxides from the ship's exhaust gases before they are released into the atmosphere. Where such an equivalent arrangement is adopted, it must be approved by the ship's Administration (i.e. flag State).

Implementation and enforcement

The IMO has no regulatory or enforcement power, i.e. it develops and adopts regulations that must then be ratified by its member countries. Implementation is the remit and responsibility of the Administrations (referred to as flag State Control—the country where a ship is registered) and port/coastal State Control (PSC—the country in whose waters the vessel is sailing, anchored or docked). Ensuring the consistent and effective implementation of the 2020 0.50% sulphur limit should be considered a high priority.

The daunting task of providing uniform, international enforcement across the high seas lies with the IMO's MEPC and Pollution Prevention and Response (PPR) Sub-Committee. The PPR has the responsibility to develop enforcement of the 0.50% global sulphur cap to achieve the environmental benefits sought through Regulation 14. The scope of work, proposed to be completed during PPR sessions in 2018 and 2019 includes:

- considering the preparatory and transitional issues, as well as the impacts on fuel and machinery systems; and
- verification, control mechanisms, actions, safety implications, standard format for non-availability and any consequential regulatory amendments and/or guidelines necessary to address issues raised and to ensure compliance and consistent implementation.

Availability

MARPOL Annex VI Regulation 18.2 on fuel oil availability requires each Party to 'take all reasonable steps to promote the availability of fuel oils which comply with [Annex VI] and inform the [IMO] of the availability of compliant fuel oils in its ports and terminals'. Parties are also required to notify IMO when a ship has presented evidence of the non-availability of compliant fuel.

Notifications of non-availability of compliant fuel oil are reported on the IMO Global Integrated Shipping Information System (GISIS) database. This shows that, since the introduction of a 0.10% sulphur limit in the Baltic and North Sea ECAS on 1 January 2015 (Revised Annex VI, Regulation 14.4), there have been 9 notifications of non-availability in EU ECAs out of a total of 84 notifications from all ECAs globally. Even though compliant fuels are assumed to be available at all times due to the limited demand, it can be seen that instances of non-availability are numerous; hence the necessity to anticipate the necessary actions prior to the introduction of a global cap of 0.50% m/m sulphur in 2020.

The basics of refining in simple and complex refineries

The function of the oil refinery is to convert crude oil into the finished products required by the market in the most efficient and, hence, the most profitable manner. The four basic operations are:

1) fractionation or distillation;
2) converting or chemically transforming certain cuts into products of higher commercial value;
3) treating, i.e. removing/transforming all unwanted components; and
4) blending of finished cuts into commercially saleable products.

The methods employed vary widely from one refinery to another, depending on the crude processed, the nature and location of the market, the type of equipment available, etc. The choice of methods will depend on individual strategic decisions taken by the refiners over time.

Refineries in the EU range from simple (hydroskimming) to very complex; the complexity often reflected in the use of deep conversion units such as delayed coker, solvent deasphalting or hydrocracking units. A detailed design engineering study performed by Amec Foster Wheeler [1] lists performance levels for these typical units. Table 1 on page 19 shows the average yields from the EU refining industry (LP simulation).

Table 1 demonstrates that the challenges faced by refineries due to decreasing demand for heavy fuel oil (i.e. fuel used inland as well as bunker fuel used at sea)

Table 1 Average yields from the EU refining industry (Wt%)

	Typical refineries		Concawe LP simulation		
	Hydroskimming	Highly complex	2014 calibration	2020, no specification change	2020, global sulphur cap
Gasoline cut	18%	25%	23%	19%	20%
Distillates	45%	51%	52%	55%	58%
Bottom of barrel	29%	9%	16%	14%	10%

following the global cap will be very different from one refinery to another. Therefore, while an overall impact assessment may be possible, the local impact of the global sulphur cap could be very different; refiners will face huge difficulties because they will be unable to reduce their heavy fuel oil yields whereas demand will temporarily disappear. However, EnSys believe that the expected short-term nature of this phenomenon is likely to deter many refiners from making major investments.[2] They also expect refinery investment to be restricted because of the perception commonplace today that the wide price differentials between light and heavy fuel oils will induce a rapid take-up of scrubbers. The likely effect of this could be a reversion of demand away from 0.50% sulphur fuel oil and back toward 3.50%.

Refiners acting in strict compliance with competition law do not share their strategic decisions upfront, so the future remains uncertain.

Concawe modelling study: marine fuel supply in 2020

Modelling methodology

The study was carried out using Concawe's EU-wide refining model, which uses the linear programming technique to simulate the whole of the European refining industry. It encompasses the EU-28 members plus Norway, Switzerland and Iceland. The modelling of Europe is segmented into nine regions, each of which is represented by a composite refinery having the combined processing capacity of all the refineries in the region, as well as the complete product demand slate relevant to that region.

Main hypothesis

The first step in this type of study is to assemble a set of assumptions that will essentially be common to all cases, and to describe the expectations in terms of crude and feedstocks slate, product demand (quantity and quality), refinery configurations and plant capacities, and all other relevant constraints that need to be taken into account. The main features and assumptions relevant to this study are summarised as follows:

- 'Scrubbed marine fuel' equals 14% of the demand (initial hypothesis from EnSys), although this is currently under discussion and likely to be reviewed downward due to scrubber uptake at ~-50% of expectations one year ago; the current assessment is 400 ships/year (Exhaust Gas Cleaning System Association).
- About 25 million tonnes/year of residual marine fuel (RMF) to switch from 2.9% sulphur (no specification changes) to 0.50% sulphur (global sulphur cap).
- No non-compliance considered for the EU demand (compliance is expected to be high in EU waters but, on average, low in other parts of the world; experts show figures around 70% compliance).
- Middle distillate imports and heavy fuels exports allowed as per 2014 real data.
- Crude slate with fixed ratios according to 2014 data.

[2] '2020: Refining Industry Perspective—Ability to Meet Demand and Quality'. Presentation by Martin Tallet, President, Ensys Energy, at the S&P Global Platts 14th Annual Bunker and Residual Fuel Conference, 20–21 June 2017.

Table 2 Evolution in demand for the primary products (tonnes per year)

	2014	2020*	Evolution
LPGs	44	57	13
Aromatics	13	13	0
Gasoline	83	74	-9
Jet	55	60	5
Diesel	205	202	-3
Heating oil	53	49	-4
Marine gasoil	10	18	7
Low-sulphur fuel oil	16	10	-6
Marine fuels (RMF)	36	31	-5
Bitumen, lubes, wax	26	22	-5
TOTALS:	**542**	**536**	**-6**

Middle distillate demand: steady

Bottom of the barrel demand: -21%

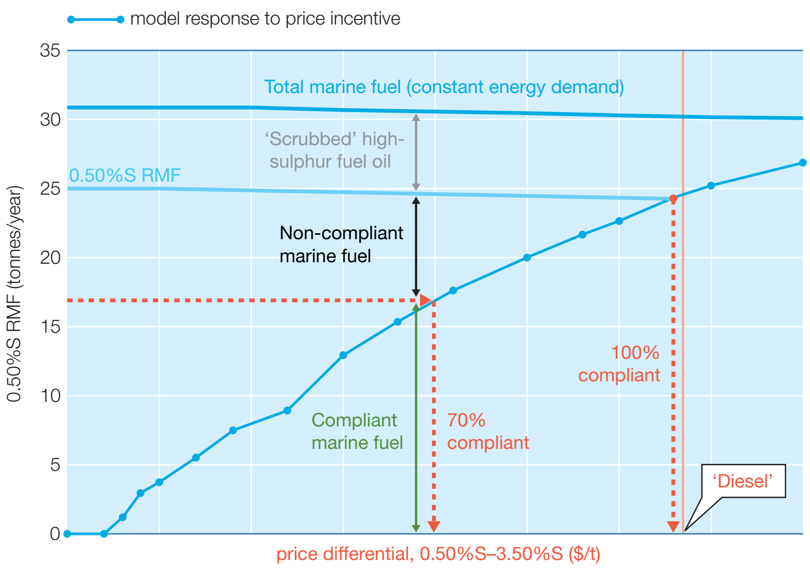
* Source: WoodMackenzie forecast.
Note: figures may not add up exactly due to rounding.

Modelling results—an overview

Without additional capacities, the model could not find a feasible solution to produce sufficient marine fuels to meet demand at the new sulphur specification. The main bottlenecks were hydrogen manufacturing units (HMUs) and sulphur recovery units (SRUs).

Allowing for investments in these units, Concawe incentivised the model to produce 0.50% sulphur RMF by increasing the differential price for 3.5% sulphur RMF. Figure 2 shows the step by step analysis.

Figure 2 Step-by-step analysis of the results of the Concawe modelling study



The model shows a highly constrained system, as the model hardly reaches the 0.50% suphur RMF demand (evaluated at 25 million tonnes/year). It also shows a potentially significant gap between demand and production, which may be an indication of the level of 'non-availability' of compliant fuel. On an open and balanced market driven by supply-demand, which is the case for petroleum products, the differentials between products is a fine equilibrium between the product demand and the incentive for the refiner to produce.

Evolution towards distillates

Figure 2 may also indicate that, as refiners increasingly blend more and more distillate molecules to increase the production of 0.50% sulphur RMF, the price differential (0.50%–3.50%) may increase to reach the 100% compliance case.

The demand for high-sulphur marine fuels (burned in ships equipped with scrubbers) in 2020 is around 6 million tonnes/year; maximum density and viscosity remain constant, but sulphur content goes up from 2.90% to 3.90%.

The blending of 0.50% sulphur marine fuel (25 million tonnes/year in 2020) results in multiple products, which can be divided into two categories:

- Heavy fuels at 0.50% sulphur:
  - Will most likely represent 30–50% of the demand.
  - Quality: pour point and sulphur will be maximised, density will be around 0.97 and viscosity ~25 cSt@100°C.
- Distillate type:
  - Will most likely represent 50–70% of the demand
  - Quality: pour point will be around 0°C and sulphur maximized, density will be around 0.87 and viscosity ~6 cSt@100°C.

In 2020, the ship operator/owner will order marine fuel containing 0.50% sulphur. The refiner/supplier will then supply the fuel at a quality which will depend on its own process and economic incentives. The study indicates that the range of quality will vary from heavy fuel (having either a very low sulphur crude slate or having residue desulphurisation capabilities) to a much lighter marine fuel with properties very similar to those of distillate fuels (such as marine gasoil). Refiners might be tempted to bring to the market a very light fuel to supply the demand for 0.50% sulphur RMF if the differential vs distillate makes this practical. This will be the individual refiner's decision.

Preliminary conclusions

Full compliance with the 0.50% sulphur limit for marine fuels across the EU28+3 refining system by 2020 will not be straightforward:

- SRU and HMU capacities are seen as a constraint by the Concawe model (both the EnSys-Navigistics Supplemental Study and the CE Delft IMO study (their Tables 92 and 93) also highlighted major deficits of H_2 and SRU capacity).
- Main conversion and hydrotreating units will need to be maintained at a high throughput.
- The model indicated that there will need to be a strong incentive for refiners to supply the demand for marine fuel at 0.50% sulphur.
- A key uncertainty will be world region trade flows (middle distillates imports and HSFO exports).
    - Hence, the ongoing collaboration with EnSys, who are performing simulations with their 'World Model', will be of benefit in providing Concawe with new input based on a broader simulation.

The crude slate ratios in the Concawe model are fixed, nevertheless it is intended that a sensitivity analysis will be performed based on simulations by EnSys who are evaluating the potential evolution for EU refineries based on world refining constraints and incentives.

The new marine fuels blending formulations should be treated with some caution, bearing in mind that the LP model is 'blind' with regard to issues such as compatibility, stability, lubricity and cold flow properties.

A key uncertainty is the rate of scrubber take-up, as this will have a dramatic influence on demand evolution and the decision-making process for refiners.

Reference

1. SINTEF (2017). RECAP Project: Understanding the cost of retrofitting CO_2 capture to an integrated oil refinery. Published 15 June 2017. See *Description of reference plants* by Amec Foster Wheeler. http://www.sintef.no/recap