Switching world shipping to marine diesel?

A wholesale shift to distillate fuel would have a momentous impact on the refining sector and fuel markets worldwide

In 2006 CONCAWE published the results of a techno-economic study analysing the impact of the reduction of the sulphur content of residual marine fuels (RMF) in Europe (CONCAWE report 2/06). The study contended that, when faced with a low sulphur limit on residual marine fuels, the most economically attractive alternative for refiners would be to exit that market and either convert or export the surplus residual material.

A new debate was sparked off by a recent proposal from one of the shipping associations for a wholesale shift from RMF to distillate fuel for all ships worldwide. Such a shift would undoubtedly have a momentous impact on the refining sector and fuel markets worldwide. In order to better understand the possible consequences for European refineries, CONCAWE has now extended the 2006 study to include this option. This article describes the new study and discusses its main results.

Table 1 shows the model cases considered in the discussion, all relating to 2015. In cases 0 to 2 the production of marine fuel is kept constant and fixed, and only the quality changes from a mix of low and high sulphur RMF (reference case 0), first to 100% low sulphur RMF (case 1) then to 100% marine diesel (MD, case 2). In case 3 no RMF production is allowed, nor are surpluses of any other products, but meeting the MD demand is now optional. In all the above cases the model is free to invest in any new plant. Finally in case 4, MD production is fixed again but export of various key products (heavy fuel oil (HFO), gasoline, LPG) is allowed to provide an outlet for surplus productions while investment in major conversion plants is blocked.

Production and margin

The projected 2015 production of marine fuels and other residual fuels in EU-25 is shown in Figure 1, together with the required crude oil intake. The net refinery margin (i.e. including capital charge), which drives the model, is shown in Figure 2. The margins shown are based on a price scenario representative of 2004, i.e. about 40 $/bbl and a moderate price differential of 10 $ per tonne and per percent sulphur.

Producing low sulphur RMF (case 1) does not generate a sufficient return to support the required investment (negative net margin). This is in line with the 2006 study which concluded that this option would only be attractive with a large increase in the LS-HS RMF price differential. Within this price scenario, production of MD generates a small positive margin (case 2). This is, however, not the economic optimum as a higher margin can be generated by 'not producing' the MD, and instead converting the surplus residual material into products to meet the core demand (case 3), thereby requiring less crude oil.

Table 1 Model cases under discussion for a shift from RMF to marine diesel

Case	Description
0 EU Directive (reference)	Reference case assuming provisions of MARPOL Annex VI and EU Directive 2005/33/EC are in place
1 RMF 0.5%	All RMF production at 0.5% sulphur
2 Marine diesel 0.5%	All RMF substituted by marine diesel (MJ per MJ) at 0.5% sulphur
3 Optional marine diesel	No RMF production and optional production of marine diesel at 0.5% sulphur
4 Marine diesel 0.5% + exports	All RMF substituted by marine diesel (MJ per MJ) at 0.5% sulphur, no investment in conversion, exports of key products allowed

Figure 1 2015 production of HFO and marine fuels, and crude oil intake (EU-25+N+CH)

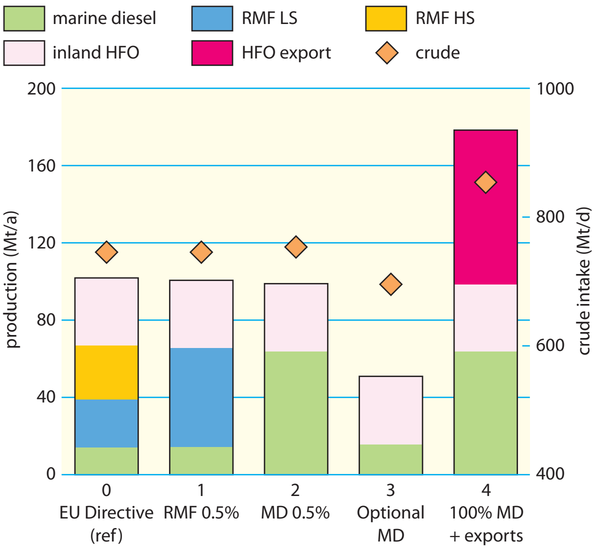

Figure 2 Cumulative net margin of European refineries (EU-25+N+CH)

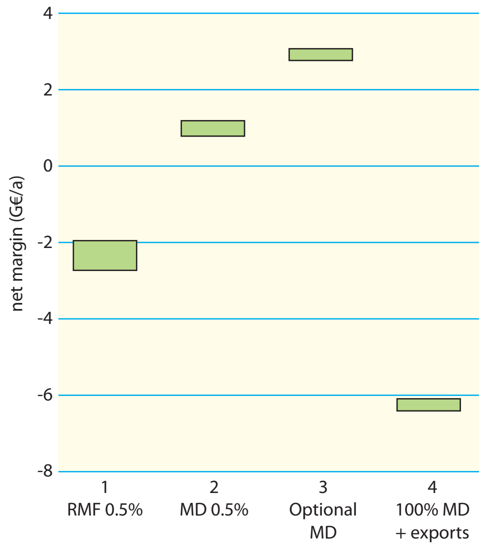

Figure 1
The scenario has a large impact on the production of marine fuels and other residual fuels as well as on crude intake.

Figure 2
The economics do not favour marine fuel production.

Case 4 produces a strongly negative margin as the lack of access to conversion capacity forces processing of 15% more crude oil (over 100 Mt/a) to produce the additional diesel in a very low conversion mode, while a large surplus of HFO (and smaller amounts of gasoline and LPG) needs to be exported.

It is worth noting that, although a different price scenario would lead to different margins, the ranking of the cases would essentially be unaffected.

Capital investment and new plant capacities

Figure 3 shows the capital investment required in the various cases. From the 2005 base case, around 13 G€ investment are needed to cover the evolution of the demand and fuel quality changes. Desulphurising RMF would entail another 7 to 12 G€[1], whereas converting residues to supply MD only would add as much as 30 G€. Although MD is not produced in case 3, significant investment is still required in order to convert the now unused residue into mainstream distillates. Note that case 4 also requires investment in crude distillation and thermal cracking, as well as various treating units.

It should be noted that these investment figures are based on typical numbers collected at the beginning of this decade. In recent months the high demand for new plants and the soaring cost of raw materials such as steel have lead to a substantial increase in the cost of new construction by factors of up to two compared to a few

Figure 3 Cumulative investment in European refineries (EU-25+N+CH)

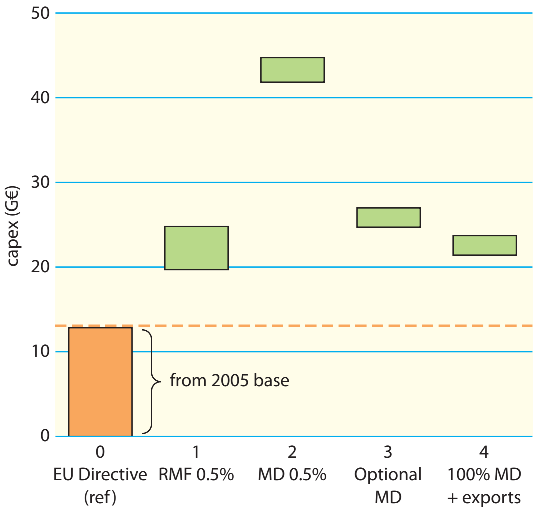

Figure 3
All cases will require significant additional investment beyond the 2005 base case.

[1] *The range of investment represents two extremes where there is either perfect foresight and no regret investment compared to the reference case or no foresight leading to maximum regret investment*

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Table 2 Conversion intensity and gas oil/gasoline ratio

	Case 1 RMF 0.5%	Case 2 MD 0.5%	Case 3 Optional MD	Case 4 MD 0.5% + exports
Conversion intensity	83.5%	90.7%	90.0%	82.0%
Gas oil/gasoline ratio	2.6	3.1	2.6	2.7
Capex (no regret) *(G€)*	7.0	28.8	12.0	8.6

years ago. Whereas one cannot be sure how this will evolve, the general world economic outlook suggests that higher costs will be with us for the foreseeable future.

Table 2 illustrates the underlying reasons for these large differences in new process unit requirement and therefore investment. One of these reasons is the 'conversion intensity' defined here as the percentage of distillates produced relative to crude intake. The higher the conversion, the more plants required to achieve it. A second reason is that the gas oil/gasoline production ratio is strongly increased by the MD demand, which represents over 20% of the road diesel demand. In the European situation where there already is a serious imbalance between demands for gas oils and gasoline, any worsening of that ratio induces a need for major adaptation of the refineries.

Table 3 Requirement for new refinery plants

	0 EU Dir (ref)	1 RMF 0.5%	2 MD 0.5%	3 Optional MD	4 MD 0.5% + exports
(Figures in Mt/a)	Relative to 2005 Base	Relative to Reference			
Crude distillation	69.2	0.1	6.0	-41.7	106.2
Thermal cracking/coking	10.7	-6.6	-6.9	-6.4	39.6
Catalytic cracking	0.0	0.0	0.0	0.0	0.0
Hydrocracking	34.8	-27.8	98.7	45.6	11.2
Residual conversion	4.8	52.9	64.0	25.6	-4.8

Table 4 Refinery energy consumption and CO_2 emissions

	2005 base	0 EU Dir (ref)	1 RMF 0.5%	2 MD 0.5%	3 Optional MD	4 MD 0.5% + exports
Energy consumption *(toe/t crude)*	6.9%	6.8%	6.9%	7.5%	7.4%	7.0%
		Relative to 2005 Base	Relative to Reference			
CO_2 emissions *(Mt/a)*						
From site	138	18	5	33	13	33
Total	2046	121	3	21		

An analysis of the extra capacities required for producing MD in case 2 reveals the full magnitude of the challenge (Table 3). Beyond the 35 Mt/a of hydrocracking capacity required to reach the reference case, another 100 Mt/a or so would be needed, as well as 64 Mt/a of residue conversion capacity (most of it being residue desulphurisation and mild conversion). We estimate that this would translate into between 50 and 70 new hydrocrackers and some 50 residue desulphurisation or conversion plants i.e. more or less one major conversion unit in each EU refinery. Even assuming financing was available, this is clearly not practically feasible in any foreseeable future scenario.

It may seem surprising that such a large amount of additional capacity be required to produce 'only' 50 Mt/a additional diesel. This has, however to be viewed in the prevailing context of an existing shortage of diesel. First, hydrocrackers do not produce 100% diesel or middle distillates. Second, they need feedstock which, in the model, is rerouted from the FCCs. FCC utilisation is reduced by 20% and the residue desulphurisation plants provide an alternative FCC feedstock. This is of course only one of many solutions and case 4 illustrates the fact that, with some flexibility in the demand, the requirement for new plants can be dramatically reduced (albeit at the expense of profitability and with higher use of crude oil resources).

Energy and CO_2 emissions

All this extra activity in refineries would obviously have consequences on the energy consumption and CO_2 emissions, which are shown in Table 4.

In case 2, the specific energy consumption increases by 10% compared to the reference case. The increase in CO_2 emissions represents a higher percentage at 33 Mt/a because of the large process emissions related to hydrogen production, an increase of 20% at a time when refineries are under pressure to reduce total emissions! Even taking into account the lower emissions incurred when burning MD compared to RMF, the net effect is still an increase of CO_2 emissions by 21 Mt/a. This represents close to 15% of the refinery emissions in the reference case and more than 10% of the combustion emissions of the affected marine fuel.

It is worth noting that case 4 generates a similar increase in refinery CO_2 emissions because of the increased crude intake.

Conclusions and outlook

The above analysis demonstrates that a switch from RMF to MD would have momentous consequences for EU refining. Although Europe's circumstances are in many ways specific, this analysis can serve as a blueprint for the rest of the world. Many other regions do not have the same acute diesel shortage as Europe and may find it less onerous to increase gas oil production. However, finding such an additional amount of gas oil (the current worldwide RMF market is around 200 mt/a and inceasing) would still be a major challenge for world refining and would be likely to create a serious global shortage, with disruptive consequences on all middle distillate markets (diesel, heating oil, jet fuel). This would in turn limit the opportunities for imports to resolve the issue on a regional basis.

Meeting the new demand would involve major refinery adaptations, mostly increased residue conversion but also primary crude distillation capacity, which could not occur overnight. In all likelihood, this would generate additional crude processing. Based on the EU analysis (case 4) and scaling up to worldwide RMF demand figure, this could represent up to 400 Mt/a additional crude or 8 Mbbl/d (about 70% of the production of Saudi Arabia). The additional volumes of gasoline and HFO would have to find a home. In the case of the latter, the most likely scenario would be substitution of either gas or coal in power generation. The impact would therefore go beyond oil markets into energy markets in general.

This proposal has been put on the table on the basis of environmental benefits that are not clearly demonstrated. Even if these benefits were proven, there are other options to reduce the impact of shipping, such as on board flue gas desulphurisation, that should be considered on an equal footing. The proposal cannot practically be implemented in the near or medium term without creating major disruptions in the middle distillate markets and, more generally, the oil and energy markets. The real benefits of such a move should therefore be thoroughly considered in the light of potentially serious consequences.

Above: a commercial vessel being refuelled from the tanker moored alongside—an operation referred to as 'bunkering'.