How can EU refineries cope with future transport fuels demand?

The importance of the relative development of the gasoline and diesel fuel markets

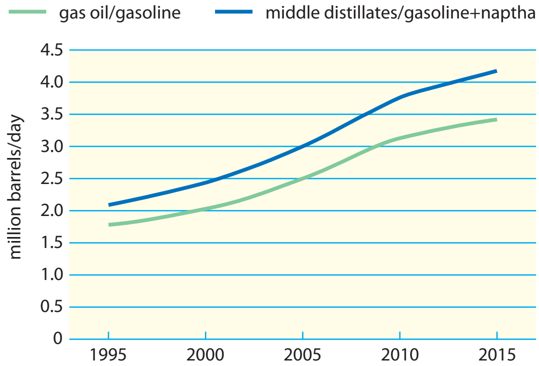
EU fuel demand and call on refineries

The petroleum product market is dominated by transport fuels, particularly gasoline and diesel for road transport and jet fuel for aircrafts. The evolution of the demand in these markets is therefore a crucial parameter for refiners when it comes to planning the size and configuration of future refineries.

Fuel demand is of course the result of demand for mobility but is in practice impacted by many other factors both technical, such as vehicle efficiency, and non-technical such as incentives for smaller vehicles or changes in behaviours, e.g. changes in driving behaviour and style. In the road transport sector there is also the flexibility to resort either to spark-ignited (gasoline) or compression-ignited (diesel) engines. Alternative fuels (particularly biofuels) may cover part of the future demand, leaving the refiners to provide the balance. Substituting more gasoline than diesel or vice versa can lead to distortion in the proportion of these two fuels that the refiners have to provide. Finally, EU refiners do not operate in isolation but have full access to the international markets for import and export of products and components.

The combination of all these factors creates a complex environment where forecasts are difficult and uncertain. The increasing imbalance between gasoline and diesel demand has been highlighted by the EU refining industry for many years and is the result of two simultaneous trends: the increasing 'dieselisation' of the European private car population and the steady increase of freight transportation. From a more or less balanced situation in 1995, demand for diesel fuel today is already nearly 50% higher than for gasoline. The full impact of the fast-rising diesel car sales of recent years is still to come as more gasoline than diesel vehicles are being scrapped. With freight transport still growing, this imbalance will inevitably continue to grow at least for some years. From the refiner's point of view this is aggravated by the simultaneous growth of jet fuel demand which puts extra pressure on the so-called 'middle-distillate' pool[1]. This trend is illustrated in Figure 1 which shows the evolution of the gas oil and middle distillate to gasoline demand ratio in the past 10 years and a forecast for the next 10 years from an industry study by consultants Wood McKenzie.

Figure 1 Historical and forecast gasoline and distillate demand in EU-25, 1995–2015



This evolution of the road fuel market is of concern to EU refiners who are already faced with several challenges such as production of sulphur-free fuels, ever tightening emission standards and CO_2 emissions restrictions. Refineries are flexible and can, to an extent, adapt their production to the market, both in terms of quality and volumes, by changing processing modes and adapting their crude oil and feedstocks diet. Within a given refinery there are obviously limits to what can be achieved and there comes a point where further changes to the production barrel require investments for new plants or major modifications to existing ones. EU refineries were mostly designed in the 1960s–70s to produce gasoline, and turning them into 'middle-distillate' machines could require major surgery.

[1] *The term 'middle distillate' applies to jet fuel, kerosenes, road diesel and other gas oils including marine gas oil and heating oil. Demand for the latter is expected to decrease, but only slowly, within the next decade.*

Thus far the market has come to the rescue of EU refiners by providing both a profitable outlet for their surplus gasoline (the USA) and a ready source of middle distillates supply (mostly Russia for gas oils and the Middle East for jet fuel). According to the IEA statistics EU gasoline exports have grown from 10 Mt in 1995 to more than 25 Mt in 2005 while middle distillates imports have progressed from hardly anything to well over 30 Mt during the same period. Whether this situation will continue to prevail and whether these markets will be able to accommodate ever growing trade volumes is a matter of debate.

In order to make sure the EU market can be adequately supplied in the future, refiners have to try and double guess all these trends in order to come up with an investment strategy that will be fit for purpose and turn out to be profitable.

A CONCAWE study to investigate the impact of different demand scenarios on EU refineries

In this context, CONCAWE has recently carried out a study to analyse the impact of various demand scenarios on the investment requirement of EU refineries and on the likely consequences in terms of energy consumption and CO_2 emissions. This article briefly summarises the methodology and analyses the main results. A full report will be published in due course.

The study considers the 2015 horizon under two main scenarios. In the Reference scenario the demand is based on the Wood McKenzie study mentioned above. It assumes vehicle efficiency improvements in line with EU objectives and a slowdown of the dieselisation trend from 2010 as a result of increased cost of diesel vehicles and technological progress of gasoline powertrains. Steady economic growth makes for a robust growth of freight transport. Introduction of alternative fuels is slow. Imports/exports remain at the current level.

An analysis of the various factors led us to the conclusion that a 'Low Demand' scenario was equally plausible as a result of a combination of continued dieselisation of the private car population, faster progress in vehicle efficiency, the success of non-technical measures to reduce demand and the sustained introduction of alternative fuels. Biofuels feature prominently in this scenario with 18 Mt/a of ethanol and 11 Mt/a of bio-diesel incorporated into road fuels[2]. Fossil gasoline and total gas oil demands of 97 and 334 Mt/a, respectively in the Reference scenario, fall to 62 and 308 Mt/a in the Low Demand scenario. This corresponds to a significant increase in the gas oil to gasoline ratio from 3.4 to 5.0. With the same assumed figures of 28 Mt/a of middle

[2] *This corresponds to 20% more ethanol than bio-diesel on an energy basis in absolute terms and considerably more when expressed as a volume percentage of either gasoline or diesel, based on our assessment of a likely higher availability of ethanol than bio-diesel within the timeframe considered.*

Table 1 Demand scenarios and resulting call on refineries (COR)

Figures in Mt/a	G	GO	G	GO	G	GO	G	GO	G	GO	G	GO	G	GO
	Reference		*R1*		*R2*		*R3*		*R4*		*R5*		*R6*	
Dieselisation			14.8	-13.4	10.0	-9.0	-13.3	12.0	-4.0	3.6	-13.5	12.1	-13.7	12.3
Import(-) / export(+)	21.9	-20.3	22.0	-20.3	22.0	-20.3	21.9	-20.3	15.9	-13.8	13.8	-13.0	5.4	-4.2
Demand	96.8	333.7	111.6	320.4	106.8	324.8	83.4	345.7	92.8	337.2	83.3	345.8	83.1	345.8
COR	118.7	313.4	133.6	300.1	128.8	304.5	105.4	325.4	108.7	323.4	97.1	332.8	88.6	341.6
GO/G production	*2.6*		*2.2*		*2.4*		*3.1*		*3.0*		*3.4*		*3.9*	
	Low Demand		*L1*		*L2*		*L3*		*L4*		*L5*			
Dieselisation			14.0	-12.6	9.0	-8.1	-4.0	3.6	-4.5	4.0	-4.4	4.0		
Import(-) / export(+)	22.0	-20.3	22.0	-20.3	22.0	-20.3	22.0	-20.3	16.0	-13.8	12.0	-10.0		
Demand	62.0	307.9	76.0	295.3	71.0	299.8	58.0	311.5	57.6	311.5	57.6	311.6		
COR	84.0	287.6	98.0	275.0	93.0	279.5	80.0	291.2	73.5	297.7	69.6	301.5		
GO/G production	*3.4*		*2.8*		*3.0*		*3.6*		*4.0*		*4.3*			

G = gasoline **GO** = gas oil

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distillates import and 22 Mt/a of gasoline export, the ratio is reduced to 2.6 for the Reference scenario and 3.4 in the Low Demand scenario in terms of actual 'call on refineries'. Note that similar ratios could result from plausible reductions of the trade volumes.

As it quickly became clear that the gas oil/gasoline ratio plays a central role in determining what investment would be required in refineries, we also explored the sensitivity of each scenario to more extreme changes in that ratio as a result of different levels of dieselisation of the car population and changes in import/exports. The resulting demand and call-on-refinery figures are shown in Table 1. Cases R1/2 and L1/2 depict a future where dieselisation of the car population is reversed (note that a switch of some 15 Mt/a from diesel to gasoline would require a very quick fall of diesel car sales down to some 20% of the total by 2010). Cases R3/L3 consider high dieselisation and constant trade flows. Cases R4/5/6 and L4/5 explore the impact of reduced trade. In the most extreme cases (R6, L5) total elimination of the trade flows resulted in an infeasible case. Some import/export was therefore reinstated to obtain feasible scenarios. Although some of the sensitivity cases are a little extreme they are still based on combinations of plausible individual trends.

Figures 2 and 3 indicate that the gas oil/gasoline production ratio is the single most important parameter determining the process configuration that will be needed.

All these cases were modelled with the CONCAWE EU-wide refining model with fixed demand and minimum crude and feedstock flexibility. The model includes olefins and aromatics production which, although they belong to the chemical industry, are closely associated with refineries. The model delivered an optimised solution for each case, essentially based on investment in new plants and best use of existing ones.

The gas oil to gasoline ratio is the key

The total demand for oil products is only expected to grow by a few percent between now and 2015 in the Reference scenario. In the Low Demand scenario, curtailment of the road fuel market leads to a contraction of the total oil product demand in 2015. As a result it is not expected that Europe will require new primary distillation capacity, any marginal increase being covered by minor revamps of existing units and capacity creep. The way refineries process crude oil must, however, be adapted in order to cope with changes in the product slate, particularly with regard to the relative demands for middle distillates and gasoline.

The gas oil/gasoline production ratio (GO/G) is the single most important parameter determining the process configuration that will be needed. This is illustrated in Figures 2 and 3 which show the required refinery capital investment and total CO_2 emissions as a function of the gas oil to gasoline production ratio and for each demand scenario.

Figure 2 Capital investment required in EU refineries for different demand levels and different gas oil to gasoline ratios (Base 2005)

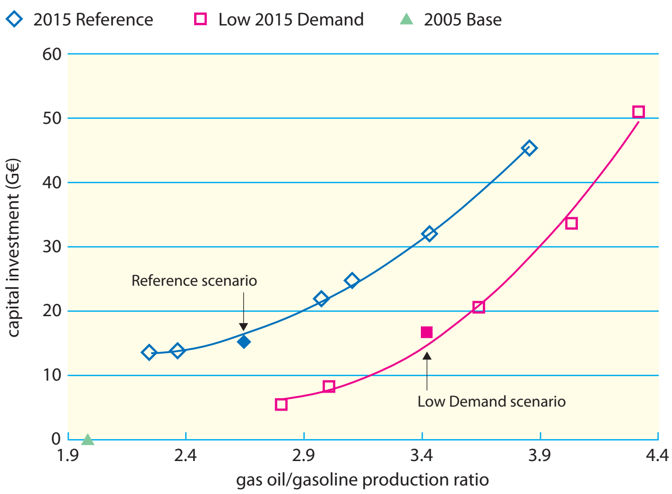
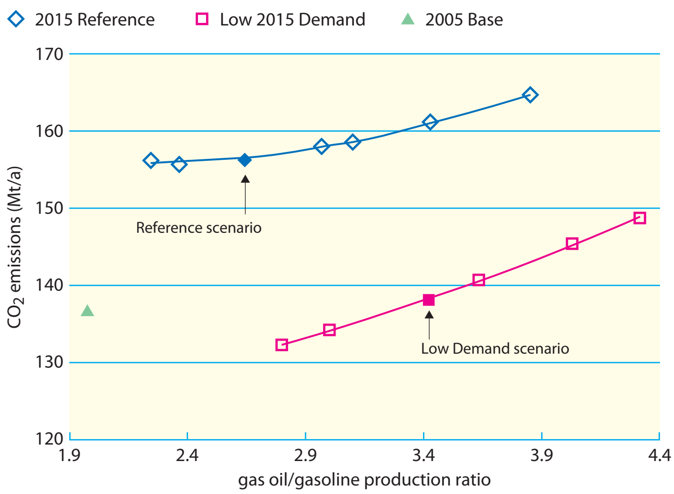


Figure 3 CO_2 emissions from EU refineries for different demand levels and different gas oil to gasoline ratios (Base 2005)



The large investment costs required to install additional capacities correlate remarkably well with the GO/G ratio for a given level of demand. The trend is similar in both demand scenarios. Noting that the Reference scenario requires 15.2 G€ of investment (from the 2005 Base case where the GO/G ratio is close to 2), increasing the GO/G ratio from 2.6 to 3.4 virtually doubles this cost.

The main investments required are in hydrocracking, with some residue desulphurisation or conversion capacity, particularly in the most extreme cases. This has already started as several major conversion projects have been announced in EU refineries.

Meeting the Reference scenario demand would result in an increase in EU refinery CO_2 emissions by about 20 Mt/a while the Low Demand scenario would be about neutral compared to the 2005 Base case. Note that these scenarios were run with an assumption of constant refinery energy intensity compared to 2005. Historically, EU refineries have improved their energy intensity by between 0.5 and 1% per year. Although further improvements are gradually becoming more difficult and costly, some further reductions are expected in the future. This would partly offset the extra energy consumption (and CO_2 emissions).

A more extreme GO/G ratio could increase these emissions by another 10 Mt/a. It must also be noted that the picture is similar in terms of specific CO_2 emissions (in t/t of crude processed), i.e. the higher the GO/G ratio, the higher the specific energy consumption and therefore CO_2 emissions.

A continued increase of the GO/G ratio would present a very serious challenge to EU refiners in terms of adaptation of their refineries, choice of processes and magnitude of required investments. It would also lead to a further increase in refinery energy consumption and CO_2 emissions.

Where the change in GO/G ratio stems from increased dieselisation, these significant CO_2 emissions increases can be compared to what would potentially be saved in the car fleet by more efficient diesel rather than gasoline powertrains. At the 2015 horizon, it is generally considered that the efficiency gap between spark-ignited and compression ignition engines will narrow from the current 15–20% to possibly as little as 5%. In all sensitivity runs we have assumed a value of 10%, i.e. a reduction of 1 Mt of the gasoline demand is compensated by an increase of 0.9 Mt of the diesel demand. On this basis, one can estimate the CO_2 emission savings from cars resulting from a certain rate of dieselisation. The net 'well-to-wheels' CO_2 emissions are the combination of the decrease in emissions from vehicles and the increase in refinery emissions. For those sensitivity cases where the change in demand is due to changes in the rate of dieselisation, Figure 4 shows the net CO_2 impact as a function of the GO/G ratio, compared to either the Reference or the Low Demand scenario.

For the Reference scenario series, increasing dieselisation (i.e. higher GO/G ratio) does result in lower net CO_2 emissions over the studied range, i.e. the benefit of the more efficient vehicle fleet is higher than the debit due to additional refinery energy use. For the Low Demand scenario series, however, the curve is at best flat or even slightly reversed: more dieselisation results in the same or slightly higher net CO_2 emissions. Although this calculation is only approximate, it highlights the fact that the CO_2 benefit of diesel vehicles could reach a limit and extreme dieselisation actually lead to increased overall CO_2 emissions.

More diesel cars could eventually lead to increased CO_2 emissions.

Figure 4 Net incremental CO_2 emissions resulting from different rates of dieselisation of the EU car population