PANORAMA 2016

a look at ...

Refining outlook for 2035

The rising influence of objectives intended to address the energy transition in global industry helps to perpetuate a high degree of uncertainty about changes in the transportation sector, currently a bastion of the oil industry. How can the growing need for individual mobility be met while reducing Greenhouse Gas (GHG) emissions in a world of open international competition? The refining sector is gaining strength in Asia and the Middle East to the detriment of Europe and North America, reflecting demand and the intrinsic competitiveness of various geographic regions. The 2025 worldwide roll-out (2020 in Europe) of a bunker fuel grade below 0.5 wt% (percentage by weight) in sulphur could experience delays, given the number of installations to be completed. Finally, the reversal of the "all diesel" trend in the European transport market is a positive change for the European refining industry.

In an unsettled global energy environment where new energy sources are emerging and the Asian economy is gaining strength to the detriment of Western regions, the refining industry is faced with competing challenges: the need to meet constantly growing demand for mobility versus the need to take part in the fight against climate change. A return to the industry's fundamentals is the only way to create a long-term forward-looking vision, as proposed below.

Prospects for market development to 2035

This strategic study of the refining industry is set in scenario where global economic growth is sustained over the 2015-2035 period (on average +3%/yr) with the price of crude gradually rising to $130/bbl by the end of the period[1]. Without challenging the current individual mobility model, energy efficiency makes it possible to limit global growth of road fuels, while the global naphtha and aviation fuel markets are distinguished by sustained annual growth of 3.4% (naphtha) and 2.7% (jet). Significant improvements in thermal engine efficiency is expected (performance of today's top vehicles applied to average 2035 sales in Europe), along with a convergence of vehicle efficiency worldwide. Through these technological advances, along with greater electrification in the car population, a reduction of vehicle CO_2 emissions to levels imposed by regulations (95g of CO_2/km for Europe and 35 miles per gallon (mpg) for North America by 2020) will be possible. Continued progress, though more modest, is also expected for utility vehicles, without more structural modifications (i.e., modal shift) being taken into account here. The share of middle distillates[2] in global demand will rise only from 43 to 47% between 2010 and 2035 (Tab. 1). This primarily results from two factors: first, strong global prospects for growth in the airline industry, and second, in this scenario created before the diesel "bubble" burst, the continued historical trend toward widespread use of diesel in Europe (accompanied by the start of a shift from the "all gasoline" trend in North America). Heavy products continue their slow decline. Consequence of increasing maritime traffic and the erosion of industrial fuels, we expect a shift from "terrestrial" heavy fuels toward bunker fuels[3], which by 2035 should represent nearly two-thirds of all heavy fuels.

(1) Value slightly above 2035 price forecasts for the price of crude, which the IEA just revised to $120/bbl (New Policies-WEO 2015 scenario)

(2) Middle distillates = kerosene, aviation fuel, diesel and domestic heating oil or DHO
(3) Bunker fuels = heavy fuels used in sea-going ships

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Table 1

Demand for finished products in the baseline scenario (less oil substitutes) – 2035

	North America	Europe	Asia	World
LPG	16	20	93	188
Naphtha	20	60	362	511
Gasoline	262	34	280	864
Jet + Kero	75	86	241	470
DHO[1]	98	72	295	627
Diesel	162	190	336	967
Heavy fuels	17	14	37	164
Bunker fuels	25	42	147	269
Others	53	43	134	282
Total	729	560	1,926	4,340
2010-2035	–30%	–20%	41%	18%

(1) Unit: Mt/yr

Source: IFPEN

The main assumptions in the scenarios presented include:

- expansion of CO_2 taxes to new geographic regions (China, North America in addition to Europe) at the significant level of $100/t. This penalty is assumed to apply only above a free emissions allowance estimated at 77% for Europe and at 90% for China and North America;
- depending on the scenario, doubling or tripling of worldwide biofuel volume;
- little change in the quality of medium crude, set at 31°API before upgrading[4] from extra-heavy crude, notwithstanding a proactive scenario to develop unconventional crude (from 14 to 16 Mbbl/d according to the scenario);
- the drastic post-2025 reduction of bunker fuel sulphur content to 0.5wt% as imposed by the International Maritime Organization (IMO), along with limits on SO_2 emissions from refineries set at 600 mg/Nm^3. Although some consultants currently argue in favor of desulphurization in the refinery, in our baseline scenario it was assumed that only one-half of bunker fuel demand would be met by fuel containing less than 0.5wt% of sulphur, taking into account the existence of a credible technological alternative (flue-gas desulphurization, known as a "scrubber"). But the market's ultimate direction remains highly uncertain.

In the end, two widely differing scenarios have been developed: one relatively likely scenario (baseline scenario), and a second "green" scenario which assumes proactive adoption of tighter environmental policies. In addition, alternate scenarios have also been studied, to focus on the impact of specific issues (IMO specifications, naphtha market, environmental constraints).

Prospects for global supply by 2035

Worldwide contribution of biofuels by 2035 is set at 4.7 Mbbl/d oil equivalent in the "green" scenario and at 3.6 Mbbl/d in the baseline scenario, i.e. respectively more than triple and double current consumption levels. In the baseline scenario, the assumptions result in an 11% increase in worldwide demand for refinable crude oil compared with 2014, reaching 90.2 Mbbl/d by 2035, while demand is stable under the "green" scenario (Tab. 2).

Both scenarios include the growing strength of emerging markets. Demand has risen significantly, particularly in Asia with a +41% increase in petroleum product consumption under the baseline scenario and +34% increase under the "green" scenario, and a decline in mature refining regions (North America and Europe). These mature regions, which consumed 45% of petroleum products in 2010, will not account for more than 30% of global demand by 2035. Asia moves in the opposite direction, rising from 32% to 44% over the same period.

Table 2

Supply of crude and oil substitutes according to the IEA[5] and IFPEN – 2035

Supply of liquid fuels (Mboe)	Actual	IEA-WEO-2015[1]		IFPEN-2014	
	2014	*New Policies*	450 ppm	Base	Green
Crudes (pre-) refinable[2]	81.0	86.8	66.7	90.2	81.8
CtL + GtL[3]	0.3	1.2	0.9	1.7	1.1
Total fossil fuel supply	81.3	88.0	67.6	92.5	83.4
Processing gain	2.2	2.9	2.4	2.9	2.6
Biofuels	1.5	3.6	7.6	3.6	4.7
Liquid fuels	85.0	94.5	77.5	98.4	90.2

(1) Missing data has been estimated

(2) Including condensates, extra-heavy oils and light tight oil

(3) Coal-based (CtL) and natural gas-based (GtL) oil substitutes

Sources: IFPEN/IEA

(4) Upgrading: pre-refining of extra heavy crude

(5) IEA: International Energy Agency (WEO 2015)

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Multi-regional linear programming: an original forward-looking tool

Beyond a 10 year horizon, there is no additional field data on refining projects or on the quality of produced crude. Contrary to short-term projections which primarily rely on such information, long-term forward-looking exercises, like the one described here, cannot be based on factual observations alone. In an attempt to shed light on the future of global refining in the most logical way, IFPEN has developed an original approach based on multi-regional linear programming, where input data for the linear model results primarily from previous studies. Under this model, the world is broken down into nine regions, each characterized by:

- estimated volumes and quality of crude oils produced based on an inventory of reserves;
- demand scenarios for oil products (net of substitutes, liquefied coal and natural gas as well as biofuels) relying to the maximum extent on studies of vehicle fleets;
- one aggregated refinery per region (representing all existing capacity within the region) and a full set of costs (raw materials, operating costs, new units, transport of crude and products).

Minimization of operating costs in the refining sector allows a projection, in each region, of the variety of processed crudes, the composition and quality of pools, as well as inter-regional trading of crude oil and products, necessary investments and production cost and accordingly, the supply of finished products. This purely economic approach does not take into account national or regional industrial strategies or the emergence of groundbreaking technologies. It therefore provides an overview of fundamentals in the refining industry without claiming to understand all the complexities.

With regard to such demand, fossil fuel supply (excluding ethane and LPG[6] generated by gas production) under the baseline scenario is 92.5 Mbbl/d, including 9.3 Mbbl/d of extra-heavy crude, 6.8 Mbbl/d of light tight oil[7], 8.4 Mbbl/d of refinable condensates and 2.3 Mbbl/d of coal and natural gas-based synthetic fuels, i.e. an increase of nearly 11.2 Mbbl/d compared with 2014. Due to the voluntary tightening of demand, fossil fuel supply remains predominant under the "green" scenario, but is reduced to 83.4 Mbbl/d primarily through production of extra-heavy oils, light tight oil and synthetic fuels. It should be noted that the two IFPEN scenarios flank the IEA "New Policies" scenario, but remain higher than the IEA "450 ppm" scenario, which is more proactive.

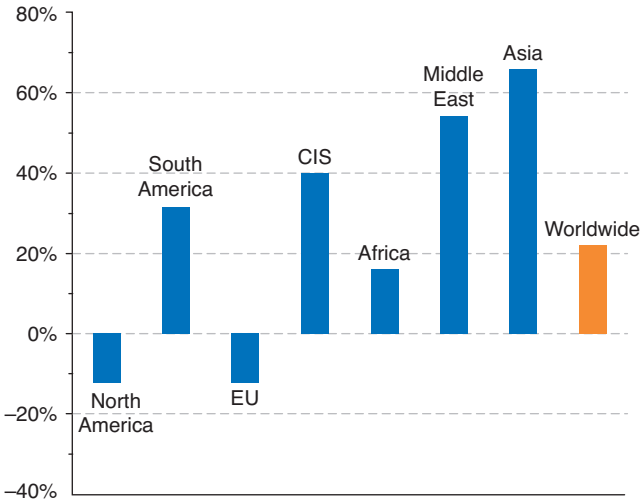
Impacts on the refining industry

2010 serves as the reference year when evaluating these impacts. The results presented are based on a purely economic approach which minimizes only product production costs, including the cost of purchasing and processing crude oil, the cost of refining capacity, and interregional transport costs (for crude and products).

Shift toward the CIS[8] and the Middle East

This methodology results in a low-cost global supply strategy, without taking into account industrial or geopolitical strategies (see inset). It shows that it is more economical to locate refining capacity as close to the end-product consumers as possible, or in regions which currently export oil that will transition to the export of finished products. Thus, refining capacity has declined (Fig. 1) in regions where the industry is mature – North America and Europe – while new refineries are being built in all other regions, led by Asia.

Fig. 1 – Change refined crude volume between 2010 and 2035



Source: IFPEN

North American refining facilities, supported by both abundant and inexpensive raw materials (both oil and gas), are relatively resistant to the significant decline in local demand, notwithstanding a reduction in capacity that should not exceed –12% over the 2010-2035 period. This stems from the region's transformation to a global

(6) LPG: Liquefied Petroleum Gas (propane and butane)
(7) Light tight oil, otherwise known as shale oil

(8) Community of Independent States, or the Former Soviet Union

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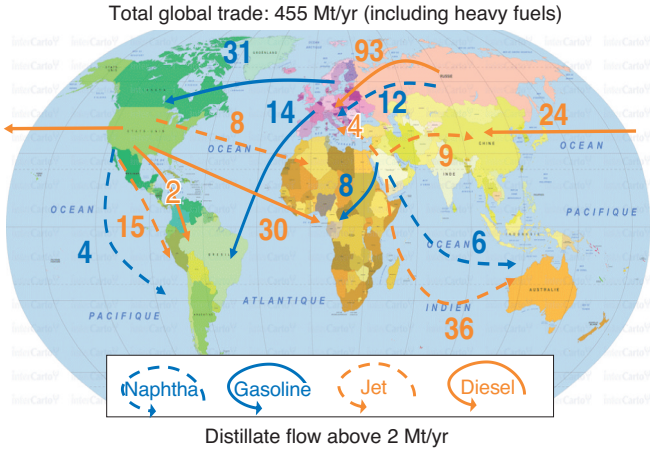
exporter of diesel and kerosene (79 Mt/yr) which it produces at low cost with a customized refining facility... and the existence of a structural gasoline surplus in Europe, which is also available at low cost and is easy to transport to North America. Against this background, maintaining high levels of net European exports of gasoline and naphtha (33 Mt in 2035, similar to the situation in 2010) remains vital for the European industry, to the point that it is a determining factor for maintaining operations and curbing the trend for closures which was observed in recent years. In Europe, where the diesel market remains tight under any scenario, the retention of a gasoline surplus is linked to a lack of profits from diesel-related investments, as well as a structural diesel surplus in Russia (Fig. 2), whose exports to Europe (with low transport costs) could at least double by 2035 in our diesel-oriented baseline scenario (93 Mt in 2035). However, it has been shown that certain regions (including the Middle East) are also able to produce the volumes of gasoline required by North America at nearly equivalent cost. Against a background of strong international competition, it is unclear whether European gasoline exports will remain at current levels, a point we will address below.

Fig. 2 – Principal trade flows of distillates – 2035



Source: IFPEN

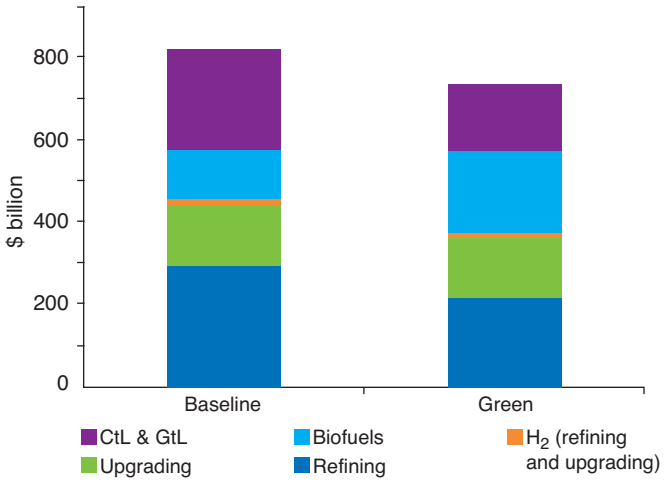
Investment in refining

Under the baseline scenario, some $300 billion in investment is required worldwide in the refining industry between 2010 and 2035, with only $200 billion required under the "green" scenario (Fig. 3). These amounts exclude the cost of maintaining and replacing older units and are undoubtedly "marred" by the over-optimization which is inherent in the applied methodology (i.e. aggregated modeling). They correspond to an annual average of $12 and $8 billion respectively, and are significantly lower than the $23 billion annual reported during the period of euphoria between 1999 and 2008. In another clear sign of an active energy transition, conventional refining represents only 36% of total worldwide investment during the 2010-2035 period to ensure mobility of internal combustion vehicles, with the remainder provided by gas and coal liquefaction (30%), extra-heavy oil upgrading (18%) and biofuels (14%), despite the fact that refineries continue to provide nearly 95% of global fuel supply under the baseline scenario. Under the more proactive "green" scenario, the biofuel sector's share nearly reached that of conventional refining, at nearly 30% of total required investment. In order of relative importance, refining investments are as follows:

- in Asia (46% of the total), reflecting the strength of local demand;
- in the Middle East and in Russia (26%), where gasoline production greatly exceeds local demand for finished products;
- in the entire American continent (nearly 20%), characterized by a moderate increase in oil production and demand for finished products.

In Europe, required investment is limited to $6 billion, i.e. what is strictly necessary to handle a share of low-sulphur bunker fuel production.

Fig. 3 – Structure of investments needed to handle liquid fuel production by 2035



Source: IFPEN

Conversion processes represent nearly one-half of investment needs worldwide, one-third of which is reserved for deep conversion, reflecting production requirements for LSFO bunker fuels (containing less than 0.5% sulphur). The modest amount devoted to diesel desulphurization (only 15%) shows that this issue has reached maturity. Finally, crude distillation and gasoline refining processes represent nearly 37% of worldwide investments and are focused in

emerging countries. In keeping with significantly lower demand, worldwide investment under the "green" scenario falls one-third below the baseline scenario with no impact on the hierarchy of the various process types, aside from biofuels.

Focus on bunker fuels

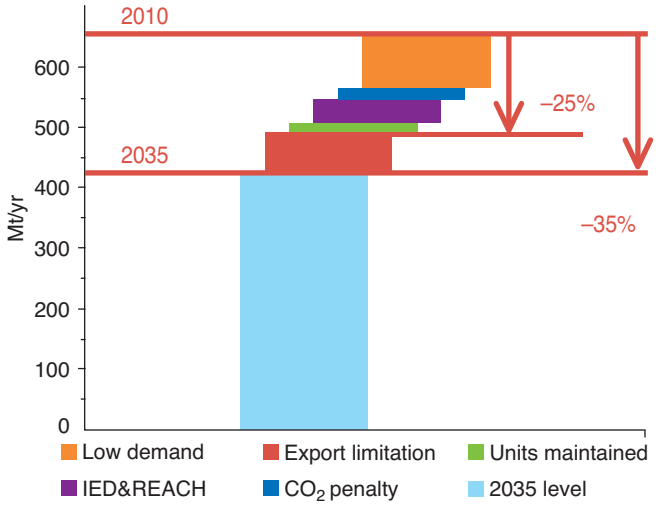
The drastic post-2025 reduction in the sulphur content of bunker fuels worldwide (IMO specification) presents technical and economic issues. Contrary to gasoline and diesel desulphurization which is based on proven technologies and is economically feasible, desulphurization of bunker fuels uses cutting-edge processes, operating at very high pressure with elevated catalyst consumption which impacts profitability. In our baseline scenario (half of the bunker fuel market is supplied by fuel with less than 0.5% sulphur), the optimal formulation for this new fuel would be based on worldwide average (other than solvents) for one-half of desulphured residual cuts, and for one-quarter of non-desulphured residual cuts, one-half of which are from very low-sulphur crude oils. In Europe, where the impact of economic restraints makes such investments relatively unattractive, the IMO specification creates an additional threat to refining. In addition, the number of announced projects for heavy fuel desulphurization installations remains low, whether in refineries or on ships, and leaves lingering doubt about achieving worldwide compliance with this specification by 2025. More generally, limited availability of low-sulphur crudes (specifically certain Libyan and West African crudes) to produce IMO fuels without desulphurization, and the reorganization of the refinery layout for this type of production, is a strategic challenge for many refineries around the world.

Focus on Europe

The results of this forward-looking study quantify the inexorable decline of European refining. Europe has a number of distinct characteristics when compared with its direct competitors: in terms of crude oil and gas supply, both of which are imported; with regard to domestic consumption, whose decline is directly tied to the fight against climate change (specifically through the RED[9] and FQD[10] directives) and which is marked by a gasoline/diesel imbalance; and lastly, by more stringent environmental and tax constraints than those faced by its neighbors.

In the end, European refining will decline by 25 to 35% within 25 years, depending on the volume of gasoline exports it is able to retain (Fig. 4). This drop, 10 points greater than domestic consumption, simply reflects the attractiveness gap between Europe and its main competitors. The main factors in this decline in operations include the drop in European consumption, the decline of the exported gasoline market, as well as the cost of defensive investments made to comply with local pollution standards (REACH and IED). Conversely, costs incurred due to CO_2 emissions (ETS[11] system) have a modest impact in our scenarios, where CO_2 trading schemes similar to ETS were introduced in North America and China on a smaller scale. However, starting from processed crude volume of nearly 660 Mt/yr in 2010 (source: Concawe), European refining should represent only 430 to 500 Mt/yr by 2035 under our baseline scenario, an average reduction of some 30%.

Fig. 4 – Determining factors in European refinery closures by 2035



Source: IFPEN

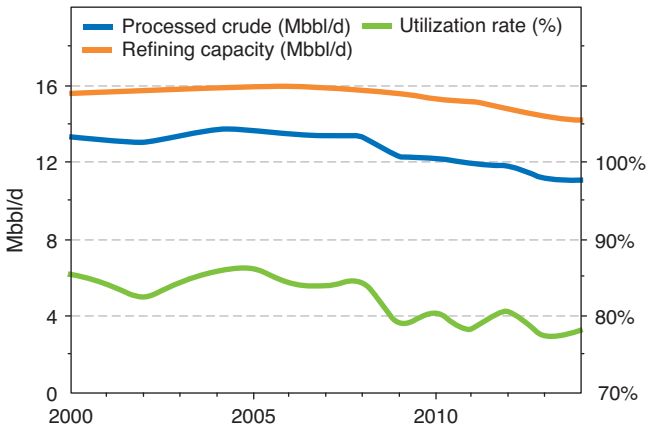
At this stage, it is important to realize that the current state of European refining does not allow it to address operational slowdowns without shutting down sites. This industry appears unable to bear an utilization rate below 75-80%. Achieved since 2010, this minimum rate can be sustained by shutting down sites: it seems clear that in the future, any additional decline in the sector's activities will automatically lead to new refinery closures (Fig. 5). This downward trend in European refining capacity observed over the past five years has borne out and could persist over the long term. Although European refineries are among the best in terms of CO_2 emissions (0.29 metric tons of CO_2 generated per metric ton of refined crude, compared with an average of 0.35 metric tons in the rest of the world, according to the Solomon firm), the likelihood of more rapid decreases in European emissions caps could increase CO_2 leakage[12] toward non-regulated regions. Under these conditions, a gasoline/diesel rebalance that allows refineries to sell their

(9) RED: Renewable Energy Directive
(10) FQD: Fuel Quality Directive

(11) ETS or European Trading System: European CO_2 exchange
(12) CO_2 leakage or displacement in countries not subject to environmental constraints on industries that generate CO_2

fatal gasoline production on the local market (of which we see signs in Europe) seems to be a determining factor in restoring competitiveness to this industrial sector and maintaining its capacity.

Fig. 5 – Change in operating rate for European Union refineries



Source: BP

At the same time, the study suggests specialization for European refineries in the processing of very low-sulphur crude. This would minimize the number of costly heavy fuel desulphurization projects in Europe that are considered more profitable in the CIS and the Middle East which, though they traditionally export crude oil, could focus greater attention on the export of finished products. Thus, in our baseline scenario, European investment in refining is limited to only $6 billion, with LSFO crude representing approximately one-quarter of crude oil supply in this region by 2035. This result is comparable to a study conducted by Concawe ($14 billion for a double LSFO bunker fuel market and without optimizing the variety of crude oil processed in Europe). Thus, in the scenario envisioned, without accounting for any geostrategic or logistical constraints, European refineries could take over nearly one-half of total African production of LSFO crude to sustain its operations. This issue is simply an additional aspect of the industry's lack of robustness in the long-term.

In conclusion

This work quantifies a number of fundamental trends in the refining industry, specifically in Europe, with regard to long-term energy-related challenges and future economics:

Energy transition: visible impacts

The effects of the energy transition are starting to be felt, with an increase in finished product consumption by 2035, breaking from historical trends (low or zero growth according to the scenario). The refining industry's share of investment fell to 36% of the total amount required for the period to ensure production of fuel for internal combustion engines. The development of unconventional liquids (extra-heavy oils, light tight oil, CtL and GtL[13]) continues to face major uncertainty due to growing environmental concerns. But their resistance to low prices seems to indicate that, over the long term, they will retain a significant proportion of worldwide supply. The availability of hydrocarbons, combined with efficiency and substitute energy sources, will push the notorious "peak oil" event beyond 2035[14].

The problem of bunker fuels

To date, consensus has not been reached on the best technical solution to meet IMO specifications for bunker fuels. Given the time needed to roll out industrial solutions of this type, uncertainties remain concerning the worldwide applicability of this new specification by 2025.

Shift in the refining industry's center of gravity

Reflecting their decline in fuel consumption, Europe, and to a lesser extent North America, are reducing their refining capacity, which is relocating to Asia to meet growing demand, as well as to the CIS and the Middle East, which are well-positioned to supply crude oil and energy. The European sector has been particularly affected and could see its activity drop by nearly 30% by 2035 if European consumption of road fuels is not rebalanced in favor of gasoline, or if its direct competitors (particularly the CIS and the Middle East) do not adopt more stringent environmental regulations.

(13) CtL and GtL: Coal to Liquid and Gas to Liquid or synthetic fuels produced from coal and natural gas
(14) Peak oil: market limited by oil production

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