Changes in the automotive fuel consumption in Europe and North America and its consequence on the world-wide refining industry

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Overview

The global oil trend forecasts point out that the world oil refining industry has to face to several challenges in a close future. On the demand side, the growing activity of the transport sector will involve increasing quantities of liquid fuels as motor gasoline and diesel oil, whose specifications continue to be improved, as marine bunkers'ones, whose share in residual fuel oil become large compare heavy fuel oils'ones. In this context, European and North American demands would tend to be reduced while developping countries'ones, as China, India, but also South America and Middle-East, would know a true explosion, what would lead to move the oil product market. On the supply side, the crude oil share in the total primary energy supply should remain to around 35% until 2030. Beside the heaviness expected of the conventional crude oil supply, whose availability would be reduced, the non conventional oil supply (including tar sands, extra-heavy oil and oil shales) and the Liquefied Natural Gas (LNG) should give a significant and necessary contribution to the global crude oil availability, as technologies transforming biomass, gas or coal to liquids. Lastly, as all industrial sector, this intermediate step of the oil chain will have to meet environmental constraints to limit the carbon emissions.

Methods

Face to these various potential changes in supply and demand sides, the OURSE (*Oil Used in Refineries to Supply Energy*) model has been used in order to evaluate their influences on the world oil refining industry. Designed initially to simulate the world oil product supply for the POLES (*Prospective Outlook for the Long-term Energy System*) model of the European Commission, OURSE is a worldwide multi-areas refining model able to simulate, so quantify the impact on the world refining industry of changes in the crude oil supply (in costs and qualities) as well as in the oil product demand (in terms of level, structure and specifications). In particular, the World split into 9 major geographical areas enables OURSE to take into account the regional dimension of oil supply and demand and understand the mechanism that could lead to move the actual equilibrium in a mid/long term. These areas are: North America, Latin America, Northern and central Europe, South Europe, Former Soviet Union, Africa, Middle East, China and Pacific Asia (except China). OURSE also enables to assess the consequences of a carbon emission regulation (bounds and taxes) as the adoption of various kinds of alternative fuel policies, leading to the blending of biomass based derivatives (alcohol and ester) as well as XTL (biomass, gas and coal to liquid) products. More precisely, these impacts are evaluated for each area with regard to its refining structure (investments pattern) and operation (process unit utilisation rate, finished products blending), but also to its mass and energy balance (production and trade of petroleum products, utilities consumptions), its pollutant emissions (CO_2 and SO_2) and its costs (production, investments, etc.).

Operated with OURSE, some long term simulations of the world refining industry have been based on a business as usual and an alternative scenarios, built from oil demand and supply data observed in 2005. The refining model is so linked to, on the upstream, with an oil supply model and, on the downstream, with an oil product demand model. More precisely, the 2030 business as usual scenario is based on assumptions concerning the long term availability of the refining supply, in terms of various qualities of conventional and non-conventional crude oils, LGN, have been defined from our geological expertise of their potential development in 2030 term. Then, this supply has been "reduced" to five representative crude oils in order to limit the LP model size (that is approximately proportional to their number). Similarly, we defined the potential increase of XTL and biofuels as the maximum natural gas availability, used as refinery fuel and steam reformer feedstock. In an other hand, the oil product demand forecast have been determined through a technico-economical model. So we defined specific assumptions to the nine geographic areas in term of increase rate for demand into 12 representative oil product with one or more grades (LPG, naphtha, gasoline-4, jet fuel, diesel oil-4, heating oil-2, heavy fuel oil-2, lubes, wax, bitumen, petroleum coke, marine bunkers-2) and 13 kinds of specifications. Lastly, the objective of this paper being to study impacts of a potential dieselisation of the US car fleet on American and European refining sectors, we have estimated the automotive fuel demand of these regions thanks to a specific fleet modelling (taking into account engine types, car size and vintage) and assumptions on evolution of unit fuel consumption and miles per year.

Results

The calibration run of the OURSE model has been done for year 2005 according to refining capacities of each aggregated area considered, but also to their crude oil prices and availabilities and their oil product demand and specifications. The global production of the refineries simulated by the model is about 1.5% lower than the observed refinery throughput of year 2005, what results from the exclusion of some minor products such as white spirit from the scope of the model; simulated productions per regional area are also close since the average percentage error is only 5.1%, what has been defined fine. Lastly, the comparison of main product marginal costs per region to different market prices enabled us to be satisfied by the representativity of our model.

According to our analysis, the world refining supply could not be greater than 95 Mbd at 2030. Including 76.6 Mbd of conventional oils, 8.8 Mbd of non conventional (before upgrading) and 10 Mbd of condensates, this supply has characteristics very close to 2005 supply's one (°API 34.4 and 1.14 %m sulphur), the heaviness of conventional one being balanced by the upgrading of non conventional one and mainly by condensates. On the basis of assumptions about 2030 biomass and XTL availability, process gain and upgrading loss, the oil product demand could reach around 102.5 Mbd (incl. refinery fuel) or 4 300 Mty, that is +21% compared to 2005. Naturally, this average figure hides situations very contrasted between world regions, from more than +50% in Asia including China, South America and Africa to -5% and -12% for respectively North America and Europe. In other words, from an world demand equally split between both last ones and the rest of World, the trend to 2030 could give the predominance to this last one (near 65%) mainly thanks to China. In this context, the major part of the demand increase concerns naturally transport fuel, whose world share is near 84% with respectively 39 and 45% for light and medium products. This demand structure is quite homogeneous on all areas, except in Europe in both scenarios and North America in alternative one. Indeed, the main difference between Reference and alternative scenarios consists in the relative parts of gasoline and diesel oil in the total US oil product demand: from respectively 51 and 34% in 2005, these shares would become 45 and 42%m in the 2030 business as usual scenario and 34 and 53% in the alternative one, i.e. very close to European ones (25 and 50%m resp. in both scenarios).

Deduced from the model's results over the period 2005-2030, the analysis of the oil product balance and refining operations of the nine regional areas showed up the following points:

- In the Reference scenario, USA could see their oil production balance modified through a decrease in gasoline production and imports, these last ones (about 40 Mt/y) only coming from European refineries.
- In the case of an severe US fleet dieselisation, European gasoline exports to North America could decrease a lot to only 12 Mt/y. So without new export markets, this would lead European refineries to reduce strongly their production through an large underemployment of their FCC around 70% of capacities installed (or the closure of 18 over about sixty FCC units actually installed). However, market forces could lead this results to be worse until 43 % (that would mean the closure of more than the half of FCC units actually installed in Europe).
- North American refineries would success in satisfying their increasing diesel oil demand, in the Business as usual scenario as in the Dieselisation one, without imports from external areas. In fact, they "only" would need to invest in high levels of gas oil hydrodesulfuration capacities for 28 and 38 G$ over 2005-2030 (respectively 240 and 350 Mt/y, including process revamping). Nevertheless this simple solution would be made possible thanks to two other deep changes in this area. Fistly, North American crude oil supply would be more oriented towards crude oil with high distillate yields and low sulphur content; secondly, the straight-run heavy gas oil cut would be de-routed from conversion units to the diesel oil pool, implying a net decrease of US FCC and hydrocrackers (oriented toward gasoline and jet fuel production) at 70% of their capacities installed.
- Face to a decreasing gasoline and increasing diesel oil demands, the European refining industry would invest in diesel oil HDS units (around 90 Mt/y) as North American refiners, but also in 3 new hydrocrackers (or 20 if the FCC use rate decreases strongly below 50%) oriented toward distillates. Indeed, the advantage of this unit is the production not only of an high quality diesel oil, but also of a low sulphur residue (15 ppm) that constitutes a perfect fluent of marine bunkers at very low sulphur specification (0.1%m S). For the 0.5%m S one, Europe would opt for investment in around ten new units of atmospheric and vacuum residue hydrodesulphurisation.
- Compared to relatively moderate and very selective investments in both previous areas, the rest of the World would be characterised by massive and very various investments. More precisely, Asia (incl. China) would expense 60 % (and even 75% with Middle-East) of the world investments evaluated at 330 G$ over the period 2005-2030 in the Reference scenario. These investments would consist in more than +400 Mt/y of crude unit capacities (+40% of pacific-asian capacities and 80% of the total world investment), 250 Mt/y of diesel HDS and respectively 400 Mt/y of conversion (VGO and residues). These large amounts of investment in these areas are explained by the current low level of capacity combined to their high product demand increase. Note that these investments do not include those required for upgrade extra-heavy oil, that we estimated at +400Mt/y to 2030.

Resulting from the combination of changes in levels and characteristics of crude oil supply and refining equipment required to meet world oil product demand, hydrogen and CO2 balances would be also strongly modified at 2030.

In particular, the choice of the whole of refining areas to invest largely into new hydrotreatment unit capacities (35 Mt/y for gasoline, 779 Mt/y for distillates and 186 Mt/y for residues and vacuum distillate, in the Reference scenario) would imply an additional hydrogen need around 7 Mt/y, corresponding to 100 new steam reformers (+50% compared to 2005). Consecutively, this would contribute to increase the CO2 emissions about 60 Mt/y. By adding CO2 emissions due to the increase of energy requirements related to new capacities, we would obtain a total CO2 emission additional around +190 Mt/y in 2030, that is +30% compared to 2005.

Conclusions

In this paper, we have carried out a study on the evolution of the demand for automotive fuel in North America and Europe and its consequence on the refining industry through a modelling approach for world-wide refining for 2030. Four main conclusions raise from this study:

- the improvement of car engines should strongly reduce the oil consumption in North America and in Europe. Moreover, if there is a development of diesel cars in North America this effect should be increased.
- However, some large investments should be done in the refining industry because of the evolution between diesel oil and gasoline consumption and the improvement of the product's specification. Furthermore, the improved quality of the oil products will required some increasing hydrogen needs in this industry.
- Due to the potential reduction of the gasoline demand, the international flows of oil products could be modified with less European exports of gasoline to North America and increasing flows of diesel oil to Europe
- In this context, the world-wide refining industry will have to invest in Asia and the Middle East to reach the growing demand in the Pacific-Asia region and the North American and European refineries should be affected by the regional slowdown of the automotive fuel demand.

These results give a global overview of the world-wide refining activities and changes that could occur during the two next decades. However, as they are based on the results of an aggregated optimisation model, they do not reflect the complexity and the geographical particularities of the six hundred refineries all over the World. Moreover, further analyses based on this model will have to be performed to assess the consequences of carbon taxes on refining activity.

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