Modelling the European refining industry

Focus on cost and CO_2 emissions

Ten years of modelling experience

It is now nearly 10 years since CONCAWE decided to develop a tool to model the European refining industry and evaluate the likely impact of future changes such as legislative measures affecting the quality of refinery products.

There are about 85 refineries in the current EU and an additional 10 in the so-called accession countries. Each refinery has a unique combination of geographic location, access to feedstocks and markets, process units, storage facilities etc. Comparing refineries is a difficult exercise and there is no such thing as a 'typical' EU refinery.

A model with nearly 100 refineries may not be impossible to create but would be rather unwieldy. It would, in any case, only be of interest if all actual circumstances could be specified in terms of crude oil supply, product demand, exchanges with other refineries and/or chemical plants and so on. Such detailed data is not normally available. The model needs, therefore, to be a compromise, including enough detail to be realistic but requiring input data which are readily available.

From the outset, CONCAWE decided to represent Europe through a number of regions covering one or several countries. The model originally covered seven regions and has now been extended to nine regions to include the accession countries (EU-25).

Region	Countries
Scandinavia	Denmark, Finland, Norway, Sweden
UK and Ireland	Great Britain, Ireland
Benelux	Belgium, Luxembourg, Netherlands
Mid-Europe	Austria, Germany, Switzerland
France	France
Iberia	Portugal, Spain
Mediterranean	Cyprus, Greece, Italy, Malta
Eastern Europe	Baltic States, Czech Republic, Hungary, Poland, Slovakia, Slovenia
South Eastern Europe	Albania, Bosnia, Bulgaria, Croatia, Macedonia, Romania

In the model, each region has its own market that the refineries must serve. Exchanges between regions are allowed, at a cost and within limits that are considered feasible in practice. Within each region the refining industry is represented by a single 'virtual' refinery having, for each process unit, the cumulative capacity actually installed in the region. This is of course a simplification that can lead to over-optimisation. Consequently a further level of detail has been added whereby each region can be modelled separately as four refineries. The main purpose of this was originally to study the vulnerability of different refinery configurations to certain measures (e.g. simple versus complex, hydrocracker versus catalytic cracker). As product specifications have tightened, refineries have, however, increasingly had to exchange key intermediates and blending components to minimise investment costs so that 'regional optimisation' is nowadays close to being achieved.

The original objective of the model was to assess the potential cost to the industry of legislative measures affecting product quality, particularly road fuels. The model makes use of the Linear Programming technique and is driven by a financial objective function based on feed and product prices, operating and investment costs. Individual refineries have, in principle, the option of meeting new requirements or constraints either by modifying their feed diet or by investing in new processing facilities. The extra cost is related to price differentials between feed types in the former case, and to investment in the latter case. Forecasting the future developments of crude oil and product prices is highly speculative and the model is normally used to focus on investment as a means to meet the requirements. We believe this approach is fully justified to represent the effects for Europe as a whole because:

- at the European level, the medium-term scope for increasing the proportion of high quality crudes (light, low-sulphur) is virtually non-existent; and
- the individual decisions to invest or not will influence the development of price differentials between different qualities of crude oil.

In other words the decision of one refinery to improve its feed diet will be compensated by investment in another refinery allowing the use of more low-quality crude, driven by an increasing price differential.

The new focus on energy and CO_2 emissions

If cost remains an important issue, the aspect of energy usage and CO_2 emissions, both at the refinery site and globally, has become essential in the past few years. The CONCAWE model was recently overhauled in order to be able to estimate the impact of measures on the energy used by the refineries and on both the local and global CO_2 emissions. This new requirement implies that the model is balanced, not only in terms of mass but also of energy, sulphur, carbon and hydrogen. This has been successfully achieved and allows us to give a complete description of the potential impact of a measure in terms of energy and CO_2 emissions.

As an example, most of the recent legislation on road fuels quality has resulted in products that contain an increasing proportion of hydrogen compared to carbon. The refinery provides this additional hydrogen by 'decarbonising' hydrocarbons as well as using some of the hydrocarbon energy to split water, and produces CO_2 in the process. The energy used in the refinery is the sum of the net chemical energy required for the reactions and of the losses related to the thermodynamic efficiency of the processes. The refined products contain more hydrogen and therefore more energy per unit mass so that the chemical energy is recovered when these products are burned. CO_2 emissions are effectively displaced from the end-user to the refinery. Unless the latter enjoys higher fuel efficiency as a result of the change, the global CO_2 emissions increase.

From a modelling point of view, this is represented by expressing the demands for fuel products in energy rather than mass terms. The demand figures will generally be constant except in those cases when the quality change under study is expected to have an impact on the efficiency of the final energy converter (engine, power plant, etc.).

This new feature of the model makes it invaluable for estimating the global 'well-to-wheels' impact of measures affecting the quality of fuels and forecasting their effect on energy consumption and CO_2 emissions from refineries.