Benchmarking CO_2 emissions from European refineries

A Complexity Weighted Tonne (CWT) approach is used to benchmark CO_2 emissions from European refineries.

The regulatory landscape

Under the European Union's Emissions Trading Scheme (ETS) Directive, industrial emitters of greenhouse gases (GHGs) must deliver emission permits or allowances every year that equal their actual GHG emissions for that year. In the first and second trading periods of the ETS Directive, the majority of these allowances were distributed free of charge using historical emissions as the distribution mechanism (so-called 'grandfathering') and with a common GHG reduction percentage.

In the third ETS trading period, starting in 2013, the distribution rule will change to auctioning, that is, emission allowances will be auctioned by governments and sold to the highest bidder. Trading of already-issued allowances on the open market will also be possible. While this auctioning process is relatively simple and provides strong market-related signals, it puts a potentially high and uncertain financial burden on industrial installations operating within the EU. This burden does not apply to equivalent installations operating outside the EU and would result in 'carbon leakage', i.e. where CO_2-emitting industries choose to move out of the EU to parts of the world where GHG emissions are not regulated.

Recognising this concern, sectors that are exposed to international competition, including the oil refining sector, will be granted a portion of their GHG emission allowances free of charge for the third ETS trading period. These free allowances will be granted on the basis of a 'best in class' benchmark developed for each industrial sector.

But, what exactly is a 'best in class' benchmark for the oil refining sector and how can it be determined?

The CO_2 benchmarking challenge

The objective of the ETS Directive is to encourage emission reductions through GHG-reducing investments and best practices. To achieve this, a refinery benchmarking scheme has to be accepted as fair and equitable, it must recognise early adopters, and it must establish differences in GHG emissions from industrial sites that are due strictly to each site's performance. This means that the evaluations driving a benchmarking scheme must assess 'how well things are done', rather than 'what is being done', due to differences in the level and type of activity from site to site.

In the refining sector, oil refineries process crude oil to manufacture a broadly similar range of products, such as petrol, diesel fuels and others. However, no two refineries are the same because of differences in their physical size, the number and types of process units, the range of crude oils that they can process, and the specific grades and volumes of products that they manufacture. Because of these differences, the energy consumption and CO_2 emissions vary from refinery to refinery and these parameters do not readily correlate with simple indicators such as the amount of crude oil processed or the volumes of refined products produced.

As an example, a simple refinery may distil crude oil into its various boiling fractions and perform a minimum level of treating (desulphurisation) and upgrading (octane improvement). The total energy consumption of such a simple refinery per tonne of crude oil will be quite low, perhaps only 3–4% of its total energy intake. Its CO_2 emissions relative to crude oil intake will also be quite low. However, such a simple refinery will not typically be able to produce the quantities and types of products that are demanded by the market.

A complex refinery, on the other hand, performs all of the same operations as the simple refinery and, in addition, converts higher-boiling molecules into lower-boiling ones. In doing so, it will make more of the products that the market demands. This extra versatility is not free, however, and a complex refinery will consume considerably more energy (at least 7–8% of its energy intake) and will have much higher CO_2 emissions per tonne of crude oil processed.

Just because one refinery uses more energy and produces more CO_2 emissions does not mean that the simple refinery is 'good' or 'higher performing' and the complex one is 'bad' or 'poorer performing'. Both types are essential parts of the entire refinery 'system' that is needed to supply Europe's demand for the volumes and types of refined products given the crude oils that are available on the global market. Thus, in order to benchmark different refineries, a common activity parameter must be used that accounts for differences in refinery complexity in a consistent way and allows the CO_2 emissions performance of refineries to be compared based on how efficiently they operate, rather than on how many operations they perform.

The CWT methodology

Working on behalf of the EU refining industry, CONCAWE collaborated with Solomon Associates, a consultant to the oil industry for more than 30 years, to develop a benchmarking scheme for EU refineries based on their 'Complexity-Weighted Tonne' (CWT) concept. A 2009 study completed for the EU Commission by the Ecofys consulting company confirmed that Solomon's CWT approach was an appropriate activity parameter that could be used to develop a refinery benchmarking scheme. With Solomon's support, CONCAWE was able to apply the CWT concept and develop a benchmarking methodology for EU ETS compliance.

The CWT approach was explained in CONCAWE *Review* Vol. 18, No. 2. This article also explained how the methodology was validated against historical refinery data. Although the CWT calculation has not changed since then, important changes were made to the total refinery emissions based on clarifications from the European Commission during the benchmark development process.

For a given refinery and a given time period, the CWT is calculated by first multiplying the throughput of each refinery process unit by a factor that is characteristic of the typical CO_2 emissions for that unit. These products are then summed to give the overall CWT for the refinery. An additional term for 'off-site' operations is added to account for ancillary operations such as blending, storage and others. CWT accounts for all emissions that are related to the energy demand of the process units whether the energy is produced on-site or imported to the refinery in the form of heat or electricity.

After some debate, the Commission decided that the simplest and fairest way to deal with the transfer of heat energy was to allocate its GHG emissions to the consumer of the heat. This means that the actual GHG emissions from a refinery site must be corrected by excluding any emissions that are associated with the production of heat exported from the refinery and including any emissions associated with the production of imported heat.

Because no free allowances may be granted for electricity production under the ETS Directive, a refinery's actual emissions and its CWT must both be corrected. To do this in line with the Commission's guidelines, an 'electricity utilisation factor' (EUF) was defined. The EUF is calculated by first taking the refinery's emissions excluding those from all electricity production and exported heat and including those from imported heat (U). This value is then divided by the same refinery's emissions including any additional emissions from electricity consumption, assuming a standard emission factor (EC). The complete CWT algorithm, including the calculation of the final performance indicator (CO_2 emissions divided by the corrected CWT) is shown in Figure 1.

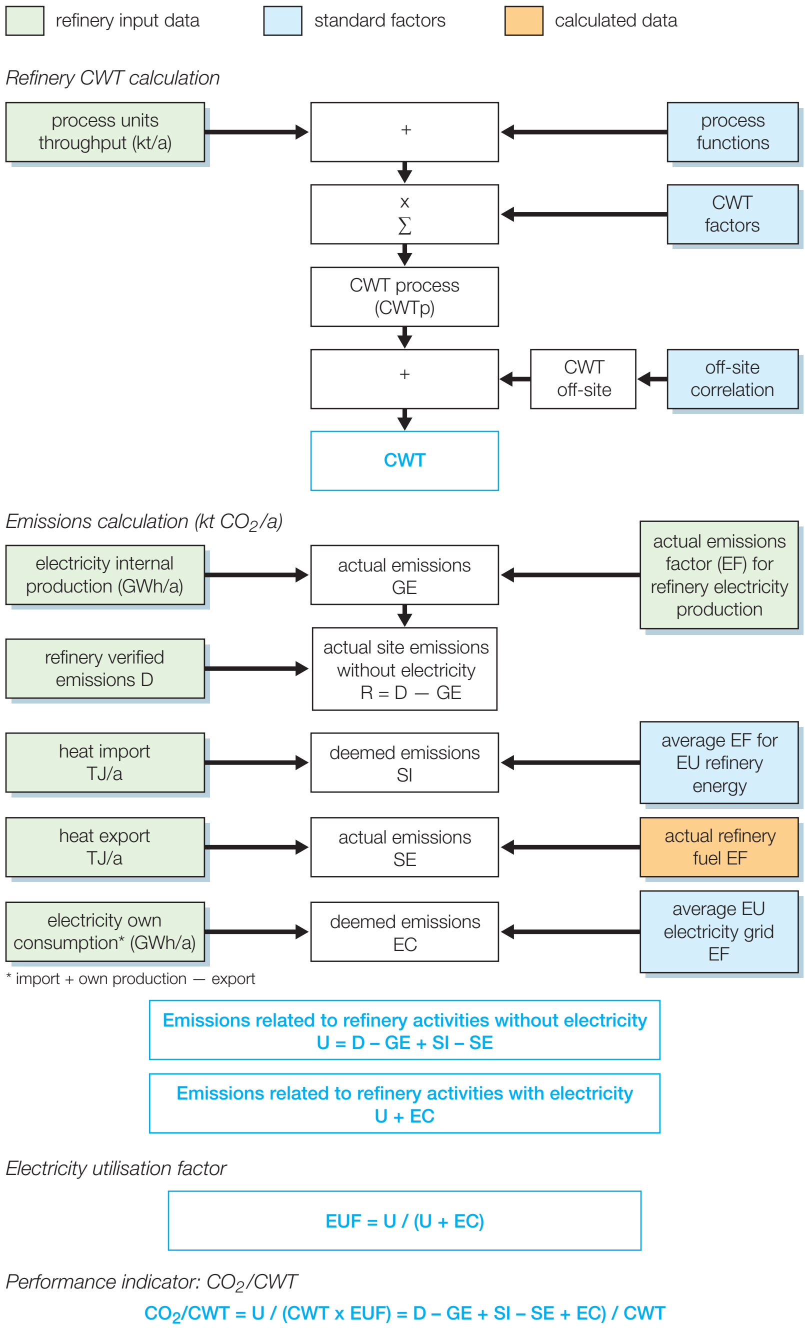
Determining the benchmark

The ETS Directive states that the benchmark must be based on 'the average performance of the 10% most efficient installations in a sector in the Community in the years 2007–2008'. Although this seems clear enough, the EU Commission further clarified that the benchmark must be the arithmetic average of the 10% best (that is, lowest) values of the performance indicator in the entire sector population.

To determine the benchmark, the first task was to collect data from refineries in order to calculate both the CWT and all appropriate emission terms from all refineries. CONCAWE undertook this task for the refining industry and developed a template to facilitate the data collection process. It became apparent that fairly detailed data were needed to ensure consistent reporting, and also fairness and credibility of the benchmarking scheme. Some issues arose with the systematic and consistent 'mapping' of real process units to the simplified CWT process unit functions, and with the consistency of data needed to estimate emissions from internally generated electricity.

The second task was to establish the refinery population. Primarily from information provided to CONCAWE

Figure 1 The complete CWT algorithm



by its members in 2010, 113 sites in the EU and Norway were classified as oil refineries. This number included some smaller sites that performed specialised tasks, such as bitumen and lube oil manufacturing. Applying the CWT methodology to these sites gave somewhat unpredictable results because the CWT database did not include installations of this sort. Including these 'atypical' sites in the benchmark population would distort the benchmarking process and result in unrealistic rankings and GHG allowances for some sites.

Of these 113 refineries, 98 'typical' refineries were identified that processed mainly crude oil to produce at least 40% light refined products, such as gasoline, diesel and heating oil. The other 15 'atypical' refineries were removed from the benchmark population and received their allowances based on their energy consumption over the baseline period using the energy benchmarks defined by the Commission.

Process unit data were collected from European refineries in the second half of 2009. These data were based on earlier years when the need for such detailed and high quality information had not been anticipated, which proved to be a data-reporting challenge for many refineries. In order to keep to the tight deadlines set by the Commission to finalise the refinery benchmark by May 2010, independent verification of data from the 20 best performing refineries was completed, that is, about twice the number of refineries that would set the benchmark. This exercise resulted in only small changes to the data originally submitted by the refineries to CONCAWE.

Figure 2 shows the performance curve for all 98 'typical' refineries, and the benchmark population of the 10% best performers on the left-hand side, yielding a benchmark value of 29.5 kg CO_2/CWT. This benchmark is about 20% lower than the average of 37.0 kg CO_2/CWT from all refineries. Taking into account GHG emissions associated with electricity production which do not qualify for free allowances, it is clear that the refining sector will receive a much smaller fraction of free allowances than would have been expected by the overall ETS objective of a 20% reduction by 2020.

As part of the benchmarking analysis, it was crucial to demonstrate that there was no fundamental bias towards a certain type of refinery and that the benchmark population was reasonably representative of the full range of refineries. No particular relationship between CWT and the performance index CO_2/CWT could be detected. This means that there are good and less good performers in all sizes of refineries, although the worst performing refineries were generally found to be among the smallest and simplest refineries. This was to be expected because these refineries usually have less opportunity for capital investments and efficiency improvements. In addition, the average fuel emission factors were found to be similar in both the total and best performing populations, as was the proportion of own electricity production. Finally there was no indication that the larger and more complex refineries were at a particular disadvantage using the benchmarking methodology, which was confirmed by Solomon in their own analysis of refinery performance parameters.

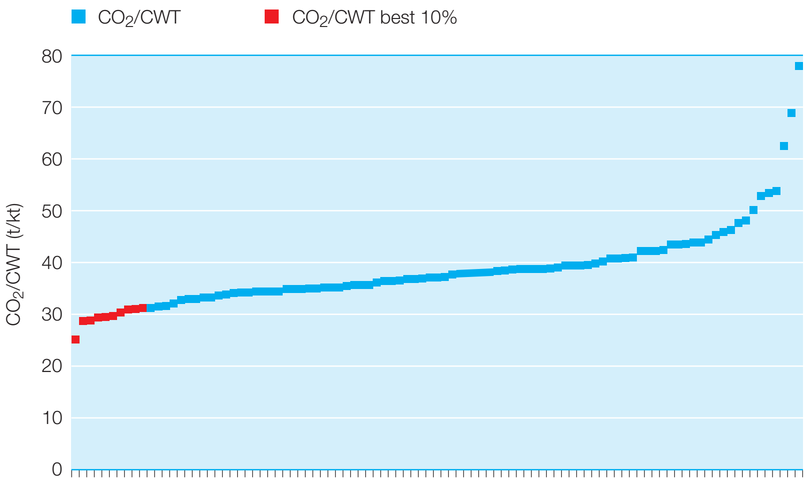
Many process units found in refineries can also be found in the petrochemical or gas production sectors. Such plants should receive a similar benchmarking treatment regardless of where they are operated. For example, a hydrogen plant, supplying a refinery, can be either inside or outside of the refinery perimeter depending on its ownership and historical permit. CONCAWE therefore established contact with other sectors to explore alternatives and arrive at the best solutions, which resulted in the adoption of the same CWT concept for all such process units.

Although 2007–2008 was the reference period for establishing the benchmark, major changes in refinery capacity that occurred after this reference period must also be taken into account. Fortunately, the CWT methodology is a simple and effective solution to this problem because plant capacity changes translate simply into a change of the CWT activity level.

Collecting baseline activity data

The benchmark established the level of performance that would be the basis for granting allowances in the third ETS trading period. The activity level to which this benchmark would be applied for the entire 2013–2020 trading period was to be based on a so-called 'baseline' period, eventually defined by the Commission as the median annual activity from either 2005–2008 or 2009–2010. Significant capacity changes during the period were to be taken into account, for which a specific methodology and significance threshold were developed by the Commission.

Figure 2 Performance curve for all 98 'typical' refineries plus the 10% best performing benchmark refineries



To facilitate reporting, a generic, cross-sectoral template was developed by the Commission and used by most Member States while CONCAWE adapted its original template to include capacity change calculations and provide refineries with a simpler and more effective tool. The generic formula for calculating the preliminary free allocations to each EU refinery is:

$$A = CWT \times EUF \times B$$

where:

- A is the refinery's annual free allocations (in kt CO_2/a);
- CWT is the median of the refinery's annual actual CWT values for the baseline period including adjustments for capacity changes (in kt/a);
- EUF is the refinery's electricity utilisation factor, averaged over the baseline period; and
- B is the EU refining CO_2/CWT benchmark value of 29.5 kg CO_2/CWT.

A further adjustment to free allowances may have to be brought in to allow for the so-called 'cross-sectoral' correction. When sectoral benchmarks have been defined and free allocations calculated for individual installations across the EU, the sum of all free allocations will be compared to the total emissions allowed by the ETS Directive reduction path. This may result in a correction that is uniformly applied to all sectors and all installations.