Benchmarking of refinery CO_2 emissions

The CWT methodology provides a way forward

The EU Greenhouse Gas Emissions Trading Scheme (ETS) foresees a number of mechanisms for distributing emission allowances amongst market players. In the first and second emission trading periods under the original ETS Directive, the majority of allowances were distributed free of charge using historical emissions as the distribution key (so-called 'grandfathering') with a uniform reduction percentage. In the third trading period, starting in 2013, the generic rule will be auctioning, i.e. allowances will be put on the market on a regular basis by governments and sold to the highest bidder. Trading of allowances already issued will still be possible on the open market. While this process is relatively simple and provides strong market-related signals, it does result in a potentially heavy and uncertain financial burden on EU industry, to which equivalent installations outside the EU are not subjected. This could affect the competitiveness of the EU industry. In addition, and of crucial significance in a programme designed to reduce greenhouse gas (GHG) emissions, this could result in so-called 'carbon leakage', i.e. moving of carbon emitting activities from inside the EU to other regions that are not subject to similar restrictions. Not only would global emissions not decrease, they could actually increase as a result of additional need for transport of goods and possibly of less energy-efficient manufacturing outside the EU.

The EU Commission has recognised these concerns and, as a result, those economic sectors exposed to international competition will be granted a portion of the required allowances free of charge. The amount of free allowances will be based on a sectoral benchmark developed on the basis of the performance of the '10% most efficient installations', i.e. best practice in the sector.

The ultimate goal of the policy is to reward early movers and encourage further emission reductions. For any benchmark to achieve this, it has to be seen as relevant and fair rather than arbitrary. The benchmarking methodology must seek to single out differences in emissions that are due to performance (in this case GHG efficiency), i.e. 'how well things are done', rather than to structural differences related to the level of activity, i.e. 'what is being done'.

A balanced and common measure of refinery CO_2 efficiency

The fundamental difficulty that one encounters when attempting to compare refineries is that, although most of them process crude oil to make a broadly similar range of products (LPG, gasoline, kerosene, gasoil/diesel and fuel oils), they are all different in terms of size, number and types of process units, the specific grades of products they make and the type of crude oil they use. As a result, their energy consumption and CO_2 emissions do not readily correlate with simple indicators such as crude throughput, product make, etc.

A simple refinery may just separate crude oil into its fractions and perform a minimum of treating (e.g. desulphurisation) and upgrading (e.g. gasoline octane improvement). Its energy consumption per tonne of crude will be low, maybe 2–3% of its intake, and so will its CO_2 emissions. A complex refinery will do all of the above and, in addition, convert heavy molecules into lighter ones to make more of the products that the market requires out of the same crude oil resource. That refinery will consume considerably more energy, probably 7–8% of its intake, and have much higher CO_2 emissions per tonne of crude processed.

This by no means suggests that the simple refinery is 'good' and the complex one 'bad'. The fact of the matter is that the petroleum product demand is such that complex refineries are needed to meet it. Simple refineries can survive only because complex ones exist. Both installations are complementary parts of a 'system' that is required to supply the market. The real measure of their value in emissions terms is the efficiency with which they carry out the various operations.

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In order to benchmark refineries one therefore needs a common activity parameter which irons out differences related to what the refinery does, leaving only the variability related to CO_2 performance.

To resolve this difficult problem CONCAWE cooperated with Solomon Associates, a respected consultant to the oil industry. Over many years, Solomon has developed a management benchmarking concept for refineries that is used by the majority of refiners worldwide and covers all aspects of the refining business, including energy efficiency and, more recently, carbon efficiency.

One of the indicators developed by Solomon is the Energy Intensity Index (EII®) used to compare the energy efficiency of refineries. The EII calculation involves 'standard' specific energy consumptions for each process unit present in a refinery. A 'typical overall standard' energy consumption for a refinery can be derived by summing up the products of these standard factors by the actual throughput of each process unit over a certain period of time. In 2003, Solomon extended this efficiency concept to greenhouse gases with the development of the Carbon Emissions Intensity (CEI™) metric.

For this benchmarking exercise, Solomon proposed a concept termed 'Complexity Weighted Tonne' (CWT) focused on CO_2 emissions but based on a similar principle:

- A list of generic process units is defined, representing the diversity of processes applied in the refinery population to be benchmarked.
- Each process unit is assigned a factor relative to crude distillation representative of its propensity to emit CO_2 at a given level of energy efficiency and for a standard fuel type (the factor includes both combustion and process emissions).
- For each process unit the factor is multiplied by its throughput during a given period and all such products are summed up. The sum total is the 'process' CWT of the refinery.
- An allowance is added for so-called 'off-sites', i.e. additional refinery facilities (tankage, blending, etc.).
- Appropriate correction factors are applied to the total CWT to ensure the final metric is consistent with the requirements of the ETS Directive in terms of boundaries for import and export of energy.

EU refineries operate a wide variety of process units, in excess of 150 different processes. Developing a CWT factor for each of these processes would be a big task and result in an overly complex methodology. Streamlining is therefore unavoidable and must be a compromise between accuracy of the representation and practicality. During the process of developing the method, a number of opportunities for simplification, mostly by pooling similar process units, were identified and most of them implemented. The final list includes just over 50 CWT 'functions', the majority of which are only used by a handful of refineries. A typical complex refinery may refer to about 15 functions.

Corrections are required for two reasons:

- The factors used to calculate CWT relate to the total energy required to drive a given process, irrespective of the source of that energy. Because the ETS Directive specifies that an operator is only responsible for his 'direct' emissions, i.e. those generated on the site, CWT has to be adjusted to reflect the effect of energy imports (which contribute to the site's energy balance but do not produce site emissions) and exports (which do produce site emissions but do not drive the site processes).
- The ETS Directive also stipulates that no free allowances can be granted for electricity generation, irrespective of where and how it takes place, with the exception of electricity produced from waste gases and some transitional measures related to the modernisation of electricity generation. The site emissions must therefore be corrected to remove those emissions that correspond to electricity generation for either own consumption or export, while CWT must be corrected to exclude the effect of electricity consumption.

Figure 1 summarises the CWT calculation procedure. CWT is a measure of the propensity of a refinery to emit CO_2 assuming a standard level of energy efficiency. Because all factors are calculated as a fraction of the crude distillation factor, they are independent of the type of fuel used. CWT correlates with actual CO_2 emissions for the same time period (Figure 2). The correlation

Figure 1 The CWT calculation procedure

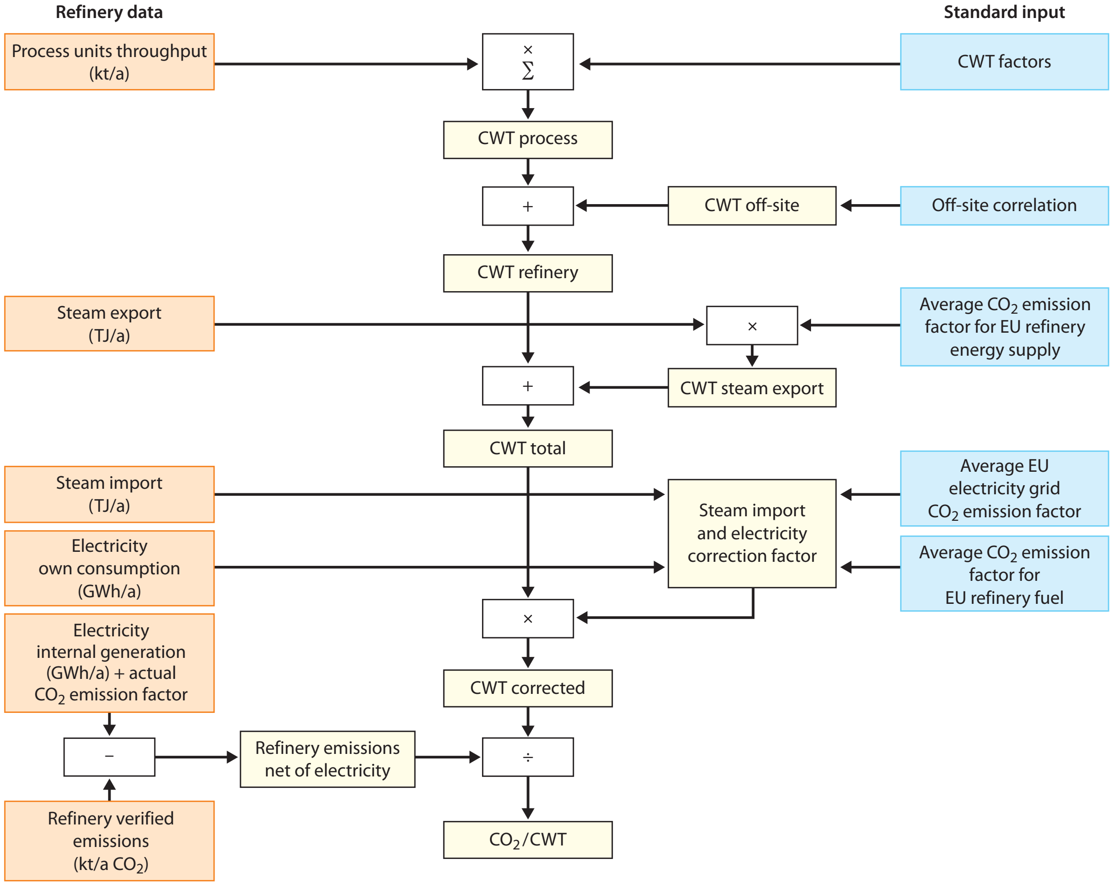

Figure 1
CWT and actual emissions need to be corrected to a common envelope to arrive at the CO_2/CWT performance indicator.

cannot be perfect, however, because each refinery has its own level of energy efficiency and fuel emission factor. Solomon were able to demonstrate that over 99% of the scatter is eliminated when actual emissions are corrected to a common level of energy efficiency and fuel type, thereby validating the concept as a true representation of performance differences.

Finding the benchmark

CWT is not a benchmark in itself but it enables a benchmarking methodology to be developed. The performance indicator of a given refinery is the ratio between its actual emissions and its CWT (CO_2/CWT) for the same period and ensuring that the boundary conditions are the same (amongst others, in terms of energy import/export). Indeed this parameter can be compared between refineries because it specifically represents the CO_2 performance of a site, irrespective of its size or complexity. A low ratio depicts better performance than a high ratio.

A plot of CO_2/CWT for all refineries arranged in ascending order (Figure 3) shows the range of performance in the population from the best to the worst performer. The best performing population provides the basis for setting the benchmark.

Figure 2
Actual emissions loosely correlate with CWT — the scatter is due to different CO_2 efficiencies.

Figure 2 Correlation of CWT with CO_2 emissions for the same time period

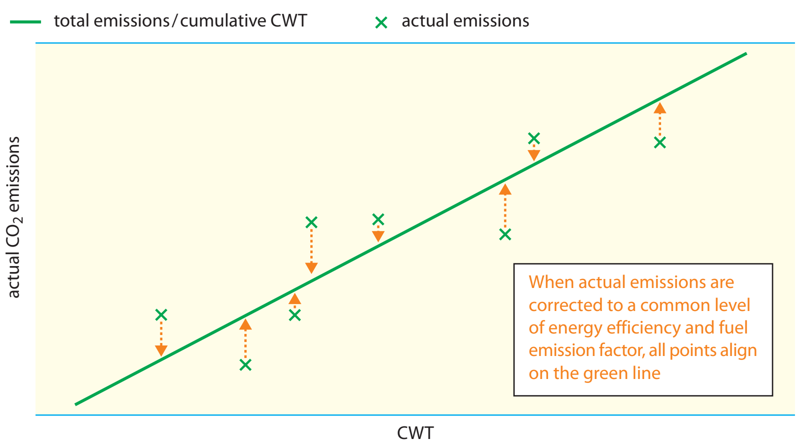

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Figure 3 The CO_2/CWT performance curve for all refineries

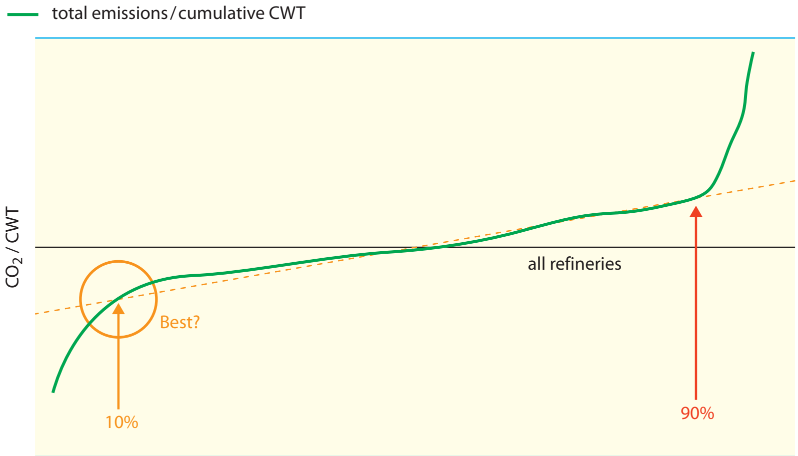

Figure 3
CO_2/CWT is the performance indicator on the basis of which the benchmark can be set.

Once a benchmark has been set, CWT can be used as a key to determine the free allowances due to each refinery as :

$$CWT \times (CO_2 / CWT \text{ benchmark})$$

New entrants

The ETS Directive also foresees allocation of free allowances to new entrants, i.e. new installations coming on stream during the trading period. In the EU refining sector these are most likely to be new process plants in existing sites rather than entirely new refineries.

The CWT method can be used to allocate free allowances to new entrants. The appropriate individual CWT factor can be used to compute a CWT for a new process plant (based on its capacity and a standard utilisation factor). The allocation can then be based on the CWT corrected by the ratio between the general refinery benchmark and the average CO_2/CWT.

Ongoing work

At this stage the CWT methodology described briefly above is developed in principle and has been proposed to the European Commission. CONCAWE has collected data from virtually all EU refineries and is analysing the figures to build the performance curve. There are, however, still many points to be resolved and CONCAWE is actively pursuing these towards a satisfactory resolution.

One crucial issue is the interpretation of the '10% most efficient installations' principle enshrined in the ETS Directive. Several options have been proposed and are under consideration. One element to take into consideration is the extent to which the 'benchmark' sub-population is representative of the diversity of the total population. Even with the hundred or so refineries operating in the EU, 10% only represents 10 installations and some form of bias is possible. Some sites may benefit from specific local circumstances that cannot be reproduced in the majority of sites, thereby creating an effectively unachievable benchmark. Use of low temperature heat for urban heating is one such example.

The distribution shown in Figure 3 is typically an 'S-curve' where a small number of points are significantly below the general trend. One way to eliminate such distortions and avoid giving too much credit to a few specific sites is to consider the general slope of the curve as the true representation of the variability. If the slope is defined by the 10% and 90% points, this effectively sets the benchmark at the 5% point of this line.

Determination of CWT requires data (plant throughputs, utility generation data). Reliability of the data used and consistent application of the algorithm are essential for the credibility of the scheme, which must therefore be well documented and provide for data verification.

The ETS Directive clearly stipulates that electricity must be eliminated from the benchmarking exercise. Accordingly a site does not receive allowances for electricity generation and is treated in the same way irrespective of the source of the electricity it consumes (self generated or imported). The situation is less clear for steam or heat. Because the Directive only caters for direct emissions (i.e. those generated by the installation), imported steam does not provide allowances, whereas self-generated steam does. Unless a similar number of allowances are granted to external steam producers this is clearly a source of discrimination and unfair treatment. The Commission and its consultants have recognised this issue and are seeking solutions.

In summary we believe that the CWT methodology provides an appropriate and workable basis for benchmarking CO_2 emissions at EU refineries.