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Foreword

Michael Lane,
Secretary General,
CONCAWE

At the end of May this year, I took over from Alain Heilbrunn as the Secretary General of CONCAWE. As I had hoped and expected, I have inherited an organisation in good shape, with many strengths. We have a talented staff, well supported by our member companies. We are carrying out many important technical projects which are being fully funded by our members, despite the current economic situation.

We are preparing the common parts of the dossiers required for registration next year under the REACH Regulation. This is a large, complex project of the kind never previously undertaken by CONCAWE. The article on the refinery effluent survey in this *Review* describes one specific aspect of this work. With the considerable help of many people from our membership, preparations are progressing. We have set up a project planning and progress reporting system to ensure that critical tasks are on schedule for completion well before the first registration deadline of 30 November 2010. Unfortunately, there are important details of the registration requirements that have not been confirmed or finalised by the European Chemicals Agency (ECHA). We are in regular contact with the Agency and are cooperating with other industry sectors, such as CEFIC, to obtain definitive guidance on these outstanding issues. This is extremely important if the lack of precise guidance is not to restrict our ability to complete these tasks on time.

We are also in the final stages of preparing to license the REACH dossiers to non-member companies who will need to register imported petroleum products. CONCAWE is acting as the SIEF Formation Facilitator (SFF) for our industry sector. This will help confirm that data is available to address all end points for our products and to organise the registration process. This is another activity that is different from the traditional role that CONCAWE performs.

While REACH preparation is currently our top priority, other important technical work is continuing. The European Commission is currently preparing for the third period of the Emissions Trading Scheme (ETS) which will start in 2013. Unlike the previous periods, in which the majority of CO_2 allowances were distributed to sites without charge, the third period will mean a further restriction of free allowances and a dramatic increase in allowance auctioning. For industry sectors, including refining, that are subject to global competition, there is a risk of carbon leakage, where production may shift to other regions. Therefore, free allowances will be given to facilities based on the 'Benchmark' needs of the most efficient producers. CONCAWE, in cooperation with Solomon Associates, has developed a methodology for the benchmarking scheme to be applied for refining. This methodology is as simple as it can be, while aiming to account fairly for the diversity of refinery size and configurations and to reflect the range of CO_2 efficiencies. An article describing the methodology appears in this *Review*.

While CO_2 emissions are attracting a lot of attention, especially in the lead up to COP 15 in Copenhagen in December 2009, it is important to remember that improvements to European air quality will continue through reduction of both industrial and transport emissions. This is the subject of many proposals for new or modified European Union Directives and is also one of CONCAWE's long-standing areas of expertise. Work is currently focused on the Gothenburg Protocol, National Emissions Ceilings Directive and the refinery BAT Reference Document (BREF) revisions. The refining industry continues to make good progress on reducing emissions from its refineries. An example of this progress is the reduction in sulphur dioxide emissions which is featured in this *Review*.

Safety performance is of vital importance to everyone who works in the oil industry. Personnel safety statistics, as measured by the number and severity of injuries, have been collected and published by CONCAWE for many years. Following recent tragic events, there is rightly renewed emphasis on process safety and the development of better indicators of performance. This will help companies identify and correct weaknesses in their safety management systems and help prevent major accidents. An article in this *Review* describes the recent safety performance in refining and explores the expansion of the safety indicators to include Process Safety Performance.

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New refinery effluent survey

Additional data requirement under the REACH risk assessments — *page 7*

To acquire the required data for the REACH risk assessments, a survey on refinery effluent characteristics was carried out and completed in 2009. This work has provided a unique dataset that includes the requested information for all 119 refineries of the CONCAWE Membership across the EU, Croatia, Norway and Switzerland. In this article the high-level consolidated results of the first analysis of this dataset are provided, together with a comparison with results of an earlier survey. While the number of locations has increased from 84 in the previous survey to 119, the reported total hydrocarbon emissions are stable and water consumption is much lower.

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CONCAWE sulphur survey

Tracking the fate of sulphur through the refining process — *page 11*

The result of the latest four-yearly CONCAWE sulphur survey covering data from 2006 is about to be published. This article presents some key results highlighting the continued trends for lower SO_2 emissions from refineries as well as the steadily increasing proportion of sulphur in crude oil being recovered, as the maximum allowable sulphur content of refinery products is being gradually reduced.

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Downstream oil industry safety statistics

2007 and 2008 reports have been published — *page 14*

The 14th and 15th annual assessments of work incident performance have been published (CONCAWE Reports No. 6/09 and 7/09). These reports present statistics on work-related personal injuries and fatalities for the European downstream oil industry's own employees and for contractors for the years 2007 and 2008. Data were received from 30 and 31 companies respectively, representing more than 90% of European refining capacity. Trends over the past years are highlighted and the data are also compared to similar statistics from related industries. CONCAWE is now looking into expanding the collection of safety performance indicators to include data on process safety incidents that are deemed to lead to the more serious incidents facing our industry.

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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.

Benchmarking of refinery CO_2 emissions

The CWT methodology provides a way forward

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

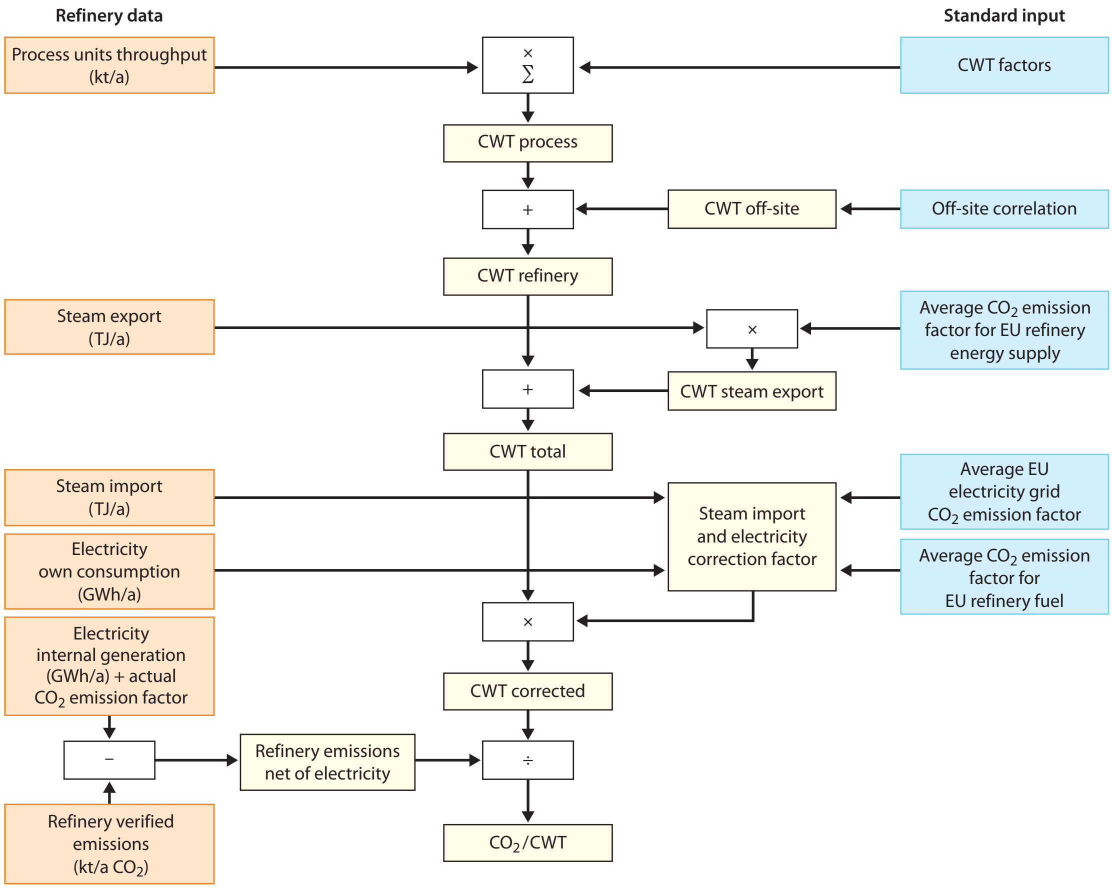


Figure 1
CWT and actual emissions need to be corrected to a common envelope to arrive at the CO_2/CWT performance indicator.

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.

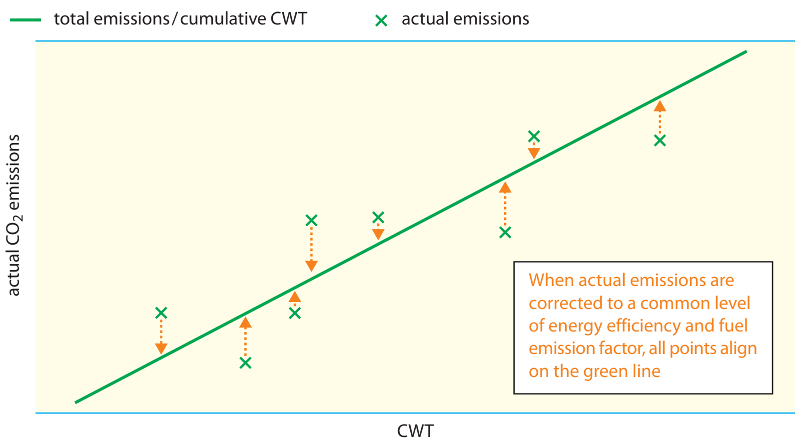
Finding the benchmark

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



Benchmarking of refinery CO_2 emissions

The CWT methodology provides a way forward

Figure 3 The CO_2/CWT performance curve for all refineries

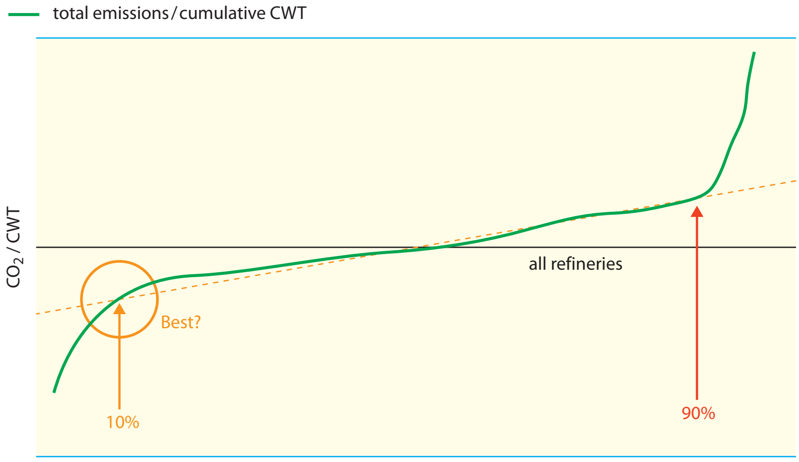


Figure 3
CO_2/CWT is the performance indicator on the basis of which the benchmark can be set.

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

$$CWT \times (CO_2 / CWT\ benchmark)$$

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.

New refinery effluent survey

Additional data requirement under the REACH risk assessments

Within the REACH registration process, registrants of a substance must submit a Chemicals Safety Report that includes a Chemical Safety Assessment (CSA). If the CSA indicates that the substance should be classified as 'hazardous' then the Report must include a Risk Characterisation[1].

Many products that are manufactured and handled by the refining industry fall under this rule. Therefore, the category reports that CONCAWE is developing to assist with the registration of these products under REACH must include a REACH Risk Assessment.

To enable this assessment the PETRORISK software has been developed, incorporating the mathematical models prescribed by the European Chemicals Agency (ECHA). These models require input on the different life stages of a product and several input parameters covering the production phase.

Some relevant data were already available in CONCAWE, having been collected to provide input into the Best Availability Techniques Reference Document (BREF) for refineries under the IPPC Directive. The information was, however, incomplete in both refinery population coverage and time period.

In order to quickly obtain the missing data up to and including 2008, a questionnaire was developed and sent to all CONCAWE member companies. The response was excellent and all data were collected within five weeks. This is a clear indication that the CONCAWE membership are well aware of their responsibility to gather the essential data regarding their environmental performance.

The initial data received was of very high quality. A limited number of additional requests for clarification further increased the quality and consistency of the dataset which covers 119 refineries representing 124 unique locations with a total of 203 independent discharges into the environment.

Survey results

As shown in Table 1, the total crude capacity reported for 2008 is 838,660 kt with 88.9% total refinery utilisation, including non-crude feedstock.

In accordance with the REACH Risk Assessment Guidelines, only the worst case effluent scenario for each location was evaluated. The rationale behind this is that if this effluent is demonstrated to be free of risks to the environment or to human health, so will be effluents under other, less extreme scenarios.

Table 1 Capacity and throughput statistics for 2008

	Crude capacity (kt)	Crude throughput (kt)	0ther feeds (kt)	Total throughput (kt)	Total utilisation (% crude)
Total	838,660	686,860	58,720	745,580	88.9%
Average	6,763	5,871	734	6,013	86.8%
Median	5,543	5,204	376	5,309	89.7%
25th percentile	3,538	3,320	120	2,904	–
75th percentile	9,700	8,204	943	8,638	–

[1] *Details may be found in the ECHA 'nutshell guidance' on* Registration data and dossier handling: *http://guidance.echa.europa.eu/docs/guidance_document/nutshell_guidance.pdf*

New refinery effluent survey

Additional data requirement under the REACH risk assessments

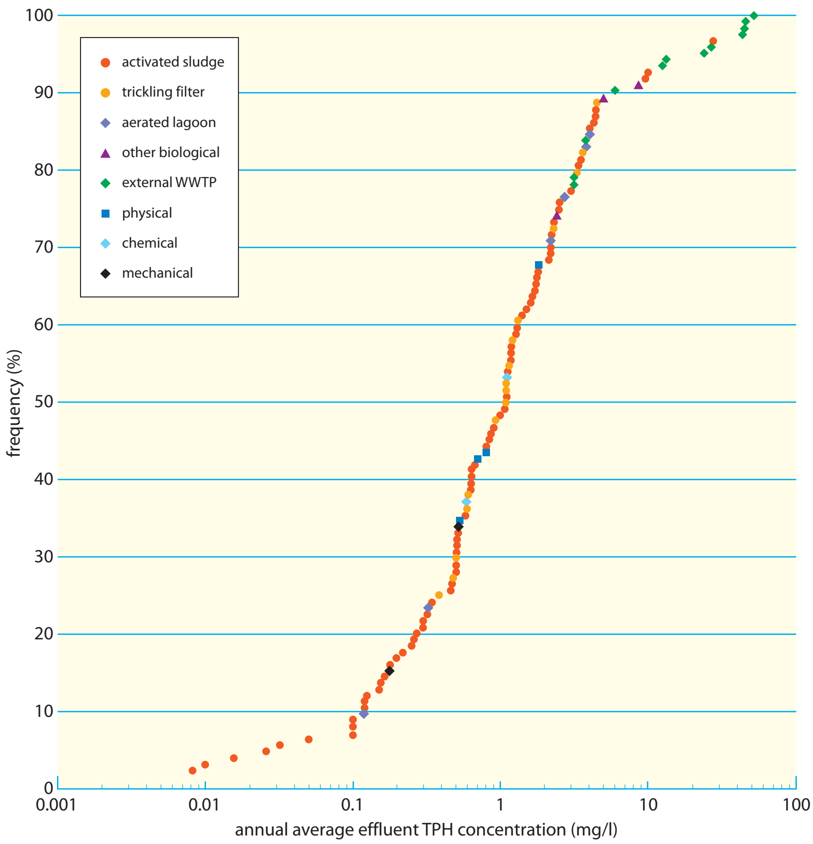
Table 2 Effluent treatment and receiving environment for the worst case discharge per location

Final effluent treatment		Type of biological treatment		Receiving environment	
3-stage biological	103	Activated sludge	77	River	50
External WWTP	13	Trickling filter	17	Canal	9
Physical	4	Aerated lagoon	5	Estuary	18
Chemical	2	Non-aerated lagoon	1	Marine	40
Mechanical	2	Fixed bed bio-film reactor	1	Harbour standing water	2
None	0	Aerated tank	1	Lagoon marine	5
		Other biological	1		
Total	124	Total	103	Total	124

Figure 1
62% of the refineries emit effluents with TPH within the BAT range of 0.05–1.5 mg/l irrespective of the treatment technique applied.

Table 2 provides an overview of the final treatment technique, the number of effluents to which this is applied, the type of biological treatment employed and the different receiving environments for these discharges. These receiving environments include those that are subject to external treatment.

Figure 1 Cumulative frequency plot of the reported TPH concentrations in effluents and final treatment technique applied



A total of 13 of the 124 locations discharge their on-site, pre-treated effluents into an external biological waste water treatment plant (WWTP) where they are subject to further biological treatment.

From the other 111 locations, 57 discharge their treated effluents into the marine environment, either directly or through an estuary. The remaining 54 locations discharge treated effluents into fresh water rivers, canals or harbours.

In Figure 1, the Total Petroleum Hydrocarbon (TPH) concentrations reported are presented in a cumulative frequency plot with an indication of the final treatment method applied. About 62% of the refineries emit effluents that are within the Best Available Techniques (BAT) range of 0.05–1.5 mg/l TPH reported in section 5.0 of the Refinery BREF[2]. Moreover, this appears to be achieveable irrespective of the treatment technique applied.

The statistical analysis of the data that will be used for the REACH Risk Assessments is provided in Table 3.

The reported TPH in the receiving environment is the ratio of the reported effluent concentration over a dilution factor estimated from the discharge volume and the flow characteristics of the receiving water. Where the latter information is not provided, a dilution factor of 10 is applied to fresh waters and of 100 for the marine environment. The discharges into external WWTPs will be subject to waste water treatment modelling as prescribed, and will therefore be reduced by approximately 90%.

In Table 4 the effluent discharge and TPH-load statistical analyses are presented. The total reported TPH load for all refineries is 1,333 tonnes in 2008 for the effluent streams that contribute to the worst-case discharge points considered for the REACH Risk Assessment. These discharge points emit 83.1% of the total reported effluent volume of 1,112.5 Mm^3 for the same period.

[2] *EIPPC-Bureau, 2003. Reference Document on* Best Available Techniques for Mineral Oil and Gas Refineries. *http://eippcb.jrc.es/reference/_download.cfm?twg=ref&file=ref_bref_0203.pdf*

Table 3 TPH load and concentrations discharged into the receiving environments

Receiving environment	Freshwater		Marine		External WWTP	
	TPH load (t/a)	[TPH] in receiving environment (μg/l)	TPH load (t/a)	[TPH] in receiving environment (μg/l)	TPH load (t/a)	[TPH] to WWTP (mg/l)
Total	221	-	524	-	588	-
Average	4.09	21.74	9.19	17.28	49.01	23.28
Median	1.27	1.02	3.80	9.00	16.45	18.65
25th percentile	0.45	0.11	1.50	3.20	4.92	5.45
75th percentile	5.65	8.22	11.90	22.71	90.44	43.90
Min	0.01	0.001	0.01	0.01	1.01	3.17
Max	33.35	378.57	72.10	100.00	166.00	52.00
Locations	54	54	57	57	12[1]	12

[1] One of the discharges into an external WWTP is sent to a treatment unit from another refinery, therefore the load and concentration of this is not included in the analysis, to avoid double counting.

A total additional TPH load of 90 tonnes is reported for other effluents (totalling 188,333 Mm^3), which are not taken into account for the REACH Risk Assessment. This is relatively low compared with the one reported above, as these concern separate cooling water, domestic sewage and storm water discharges.

These effluent discharges and the total TPH or oil-in-water loads can be compared with the previously reported values[3] covering the year 2000:

- Firstly a reduction of the total effluent volume from 2,543 to 1,112.5 Mm^3 is observed.
- Secondly, the TPH load discharged after treatment is stable at 750 compared to the previous figure of 745 tonnes. It must be noted, however, that the 2000 dataset only included 84 refineries compared to 119 in 2008. The remaining TPH releases to external WWTPs (more than 600 tonnes reported in 2008) are subject to additional treatment and are therefore reduced by a further 90 to 95% before discharge into the receiving environment. Therefore, it is estimated that the total environmental burden regarding TPH in 2008 was 850 tonnes for the CONCAWE membership refinery activities.

[3] Trends in Oil Discharges with Aqueous Effluents from Oil Refineries in Europe—2000 Survey. *CONCAWE Report 4/04.*

Table 4 Discharge and TPH load statistics of the REACH effluents

	Total effluent ($1000m^3/a$)	Treated effluent ($1000m^3/a$)	Other effluents ($1000m^3/a$)	Outfall TPH load (t/a)
Total	1,112,545	611,650	312,562	1,333
Average	8,972	4,933	10,083	11
Median	2,843	2,102	1,207	3.0
25th percentile	1,399	1,029	428	0.8
75th percentile	6,693	4,775	3,967	8.3

The statistical evaluation of the TPH loads and effluent emissions, including cooling water, as a function of the crude capacity and total throughput is presented in Table 5. The numbers between brackets are the values that include the TPH discharges into external WWTP before treatment.

The average water use presented in Table 5 may appear on the high side. However, it has to be noted that these figures include process, cooling and storm water data and, when looking to the median and percentiles reported, it becomes evident that the average is skewed by some high reported values. Furthermore, the average values are higher than in earlier surveys, despite the fact that the number of participating refineries has increased from 73 in 1969 to 119 in 2008. Somewhat unexpectedly, the average TPH load of 1.96 g/t of throughput is higher than the BAT range of 0.01–0.75 g/t

New refinery effluent survey

Additional data requirement under the REACH risk assessments

Table 5 TPH load and effluent per tonne of crude capacity and total throughput

	TPH load (g/t crude)	Average load TPH (g/t throughput)	Water use (m^3/t crude)	Water use (m^3/t throughput)
Average	1.91 (3.01)[1]	1.96 (2.94)	2.23	2.53
Median	0.61 (0.71)	059 (0.66)	0.59	0.55
25th percentile	0.198(0.22)	0.18 (0.19)	0.33	0.33
75th percentile	1.55 (2.28)	1.55 (2.23)	1.37	1.45

[1] The numbers in brackets are the values that include the TPH discharges into external WWTP before treatment

indicated in section 5.0 of the Refinery BREF[2], with 55% of refineries reporting values within this range.

A further analysis will have to address this and will certainly provide more meaningful indicators enabling a distinction to be made between these different effluent streams and reported outliers.

Next steps

Further analysis of this unique dataset will be carried out and published in a CONCAWE report. This will support several other CONCAWE activities, in particular the work on the implementation measures of other EU-legislation such as the Water Framework Directive (WFD), the Marine Strategy Framework Directive, the European Pollution Release and Transfer Register Regulation (E-PRTR) and IPPC BREF revisions.

The successful collection of this dataset is a testimony to the petroleum industry's commitment to the development of sound, fact-based legislation. The results of this effluent survey, which demonstrate the ongoing positive trends in discharge reductions, can be further enhanced by gathering similar data for other relevant contaminants. This could include analytical monitoring data on WFD Priority Substances and Priority Hazardous Substances and the typical effluent markers for the refining Industry that are mentioned in the E-PRTR Regulation and its associated guidelines.

CONCAWE intends to explore the possibilities for extending effluent data gathering activities in 2010 and beyond, in order to bring further factual data from our industry into the European water quality debate.

CONCAWE sulphur survey

Tracking the fate of sulphur through the refining process

Since 1979 CONCAWE has conducted a regular four-yearly survey of its member companies to determine how the fate of sulphur through the refining process changes over time. The last sulphur survey was for the year ending 2006. The main results are presented below.

Sulphur is an intrinsic component of all crude oils and is generally undesirable in those oil products destined for combustion because of the potential environmental impact of SO_2 emissions and/or poisoning of catalytic exhaust gas clean-up systems. Over time, there has been, therefore, a constant focus on reducing both the sulphur content of commercial fuel oils and emissions from the refining process itself, which makes use of its internal streams for a large portion of its energy needs. In recent years, sulphur has all but been eliminated from road transport fuels, not because of the potentially harmful effects of sulphur, but to enable the use of exhaust after-treatment technologies for the abatement of regulated pollutants such as NO_x, carbon monoxide and particulate matter.

Table 1 shows the change in the distribution of sulphur amongst the different compartments since 1998. The proportion of sulphur in oil products sold for fuels has decreased from 37.0 to 32.5% of the total sulphur intake. An even lower figure was derived from the 2002 survey, although we believe that this was due to under-representation of refineries supplying the heavy fuel oil markets, as discussed later in this article. The proportion removed from the various refinery streams and recovered as elemental sulphur reached 45% in 2006 and is now the largest sulphur stream. The proportion of sulphur emitted directly to the atmosphere from refineries reduced to 3.7% of the total input in 2006, from about twice that figure in 1998.

Table 1 Overall balance of sulphur from 1998–2006

% sulphur intake		1998	2002	2006
Output	Products for combustion	37.0	29.8	32.5
	Products not for combustion	14.5	8.6	11.8
	Recovered as elemental sulphur	39.4	47.6	45.0
	Recovered as other compounds	1.4	5.5	0.2
Emitted at refinery	All sources	7.2	5.5	3.7
Balance		**99.5**	**97.0**	**93.2**

A trend towards less liquid refinery fuel and with a lower sulphur content

The reduction in sulphur emissions from refineries has come largely from combustion installations as is shown in Table 2, and this has been achieved in two ways—a reduction in the sulphur content of the internal fuel oil used in refineries and a greater penetration of gas firing from both internally generated gas and purchased natural gas. In 2006 refineries accounting for almost 20% of combustion energy use were gas fired (see Figure 1). Only a very small amount of pure oil firing remains in 2006, typically in specialist bitumen refineries. In most EU refineries today, liquid fuels account for less than 50% of the total fuel burnt.

Refinery SO_x emissions can be regulated under the 'bubble' concept

The Large Combustion Plant Directive (LCPD) of October 2001 gives refineries the option to adopt a combustion 'bubble' representing the average stack concentration

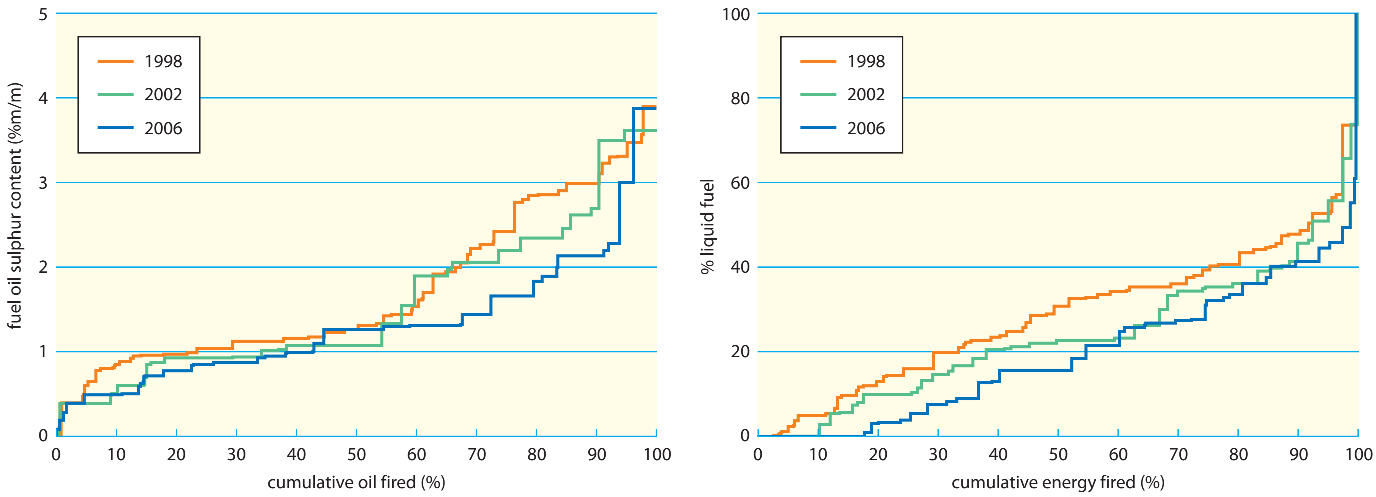
Table 2 Distribution of refinery sulphur emissions from combustion

Emissions (% sulphur intake)	1998	2002	2006
Stacks	4.6	3.1	1.8
FCCU	0.4	0.2	0.4
SRU	0.8	1.3	0.6
Flares	1.0	0.6	0.8
Miscellaneous	0.4	0.2	0.2
Totals from all sources	**7.2**	**5.5**	**3.7**

CONCAWE sulphur survey

Tracking the fate of sulphur through the refining process

Figure 1 Distribution of refinery fuel oil sulphur content and fraction of fuel oil burned

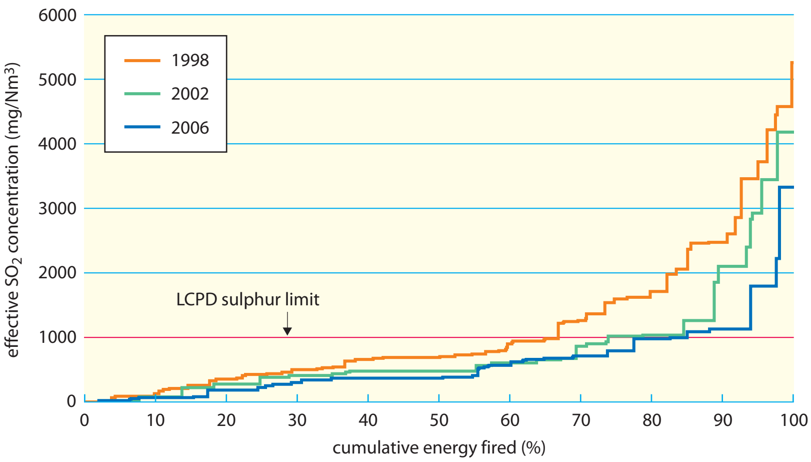


over all large combustion installations on the site (defined as having a design firing rate exceeding 50 MW thermal). The evolution of the combustion bubble over the period 1998–2006 is shown in Figure 2. In 1998 refineries representing about 60% of energy fired had a bubble concentration below the LCPD limit of 1000 mg/m^3 SO_2. In 2006 that had increased to nearly 90%. The latest date for implementation of the LCPD was 1 January 2008 so we might expect to see further reductions in the bubble concentration in the next survey.

The results shown so far reflect the cumulative results over all of Europe, whereas there are locations where emission regulation is tighter to reflect the higher environmental sensitivity to acid gas emissions. The evolution of the LCP bubble on a regional basis is shown in Figure 3 where the horizontal axis is now the cumulative energy fired in each region. In 1998 refineries in the Mediterranean area and in Spain (marked ME), and Northern France and the UK (marked AT) had much greater SO_2 LCP bubble values than those in the Benelux and Northern and Central Europe (marked NW). By 2006, the gap had very much closed even though the trend for continued reductions in the NW area is evident. The group labelled OT is the LCP bubble for other refineries in the survey. The geographic location covered by this group is different in 1998 and 2006, so these results are not directly comparable.

Figure 2 Large combustion plant bubble (plants over 50 MW)

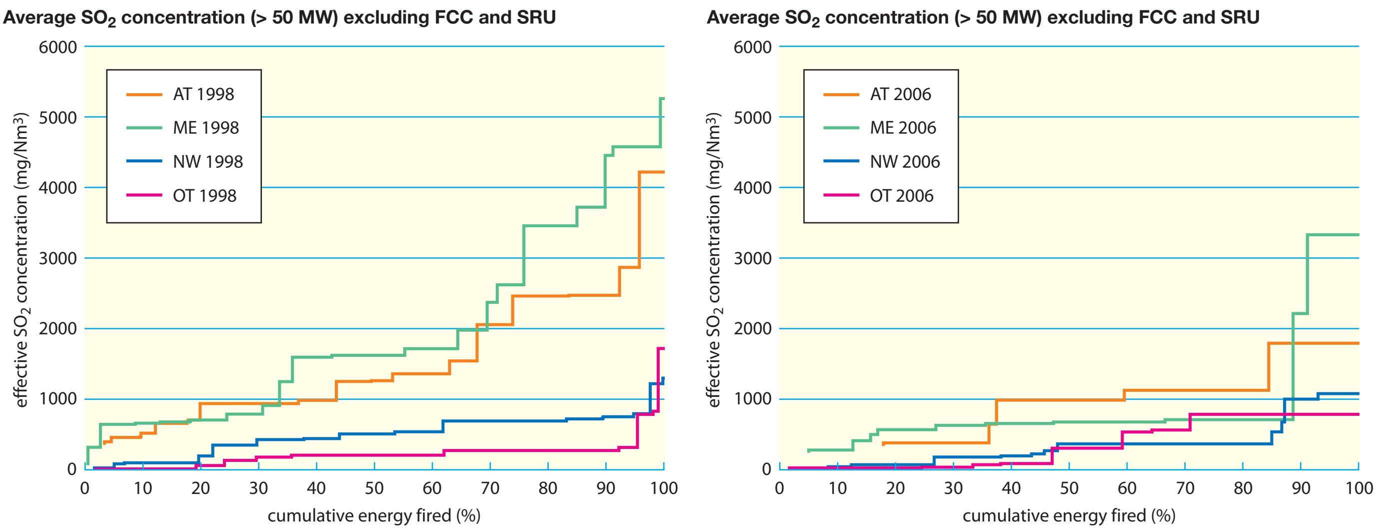
Average SO_2 concentration (> 50 MW) excluding FCC and SRU



We have seen that, overall, the sulphur content in oil products for combustion has decreased over the period. This is mainly the result of legislated changes in the maximum sulphur content of road fuels, gasoils and inland heavy fuel oils.

One area for further sulphur reductions is the marine fuels market. The sulphur content of marine fuels is regulated on a worldwide basis through the International Maritime Organization (IMO). An agreement under the International Convention for the Prevention of Pollution from Ships (MARPOL), known as MARPOL Annex VI, introduced a global sulphur content cap of 4.5% m/m as of May 2005. It also introduced the

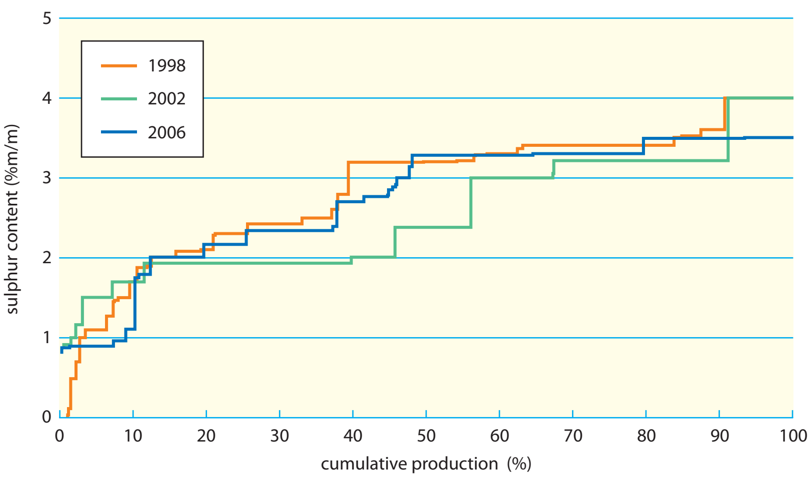
Figure 3 Evolution of the LCP bubble by region, 1998–2006 (plants over 50 MW)



concept of Sulphur Emission Control Areas (SECAs) which are special sea areas where ship sulphur emissions must be consistent with a fuel having a maximum sulphur content of 1.5% m/m. Following its ratification in 2005, MARPOL Annex VI came into force in May 2006 for the Baltic Sea and November 2007 for the North Sea. In addition, the EU adopted Directive 2005/33/EC which extends the 1.5% m/m sulphur limit to 'passenger ships on a regular service to or from an EU port' (further referred to as 'ferries') and which came into effect in August 2006. The Directive includes a review clause whereby the possibility can be envisaged for the extension of the sulphur limit to all EU waters, and to its further reduction. The IMO recently adopted a proposal to decrease the maximum sulphur content in SECAs to 1.0% by 2010 and 0.1% by 2015, and to decrease the global marine fuels sulphur cap to 3.5% by 2010 and to 0.5% by 2020 or 2025 at the latest (subject to a review in 2018).

Figure 4 shows that the distribution of marine fuel sulphur content was virtually identical in 1998 and 2006. The 2002 survey results appear to have under-represented the number of refineries that produce marine fuel oil, as can be seen by the smaller number of steps in the curve, and this is probably also the reason for the anomalous trend observed in Table 1.

Figure 4 Sulphur content of marine fuels, 1998–2006



This article has described some aspects of the 2006 sulphur survey, the full results of which will shortly be published as a CONCAWE report. Emission regulations have successfully driven refinery emissions down, slowly eliminating geographic variations. As the limits on the maximum sulphur content of refinery products have been tightened, sulphur recovered as elemental sulphur from the desulphurisation of refinery streams has increased and is now the biggest endpoint for sulphur in crude. The sulphur content of marine fuels, which shows no change in the period 1998–2006, is now entering a period of change which will no doubt be reflected in the 2010 survey.

Downstream oil industry safety statistics

2007 and 2008 reports have been published

The collection and analysis of incident data is an essential element of a modern safety management system, and its importance is recognised throughout the oil industry. CONCAWE has been compiling statistical data for the European downstream oil industry since 1993 and the purpose of this activity is twofold:

- To provide member companies with a benchmark against which to compare their performance, so that they can determine the efficacy of their management systems, identify shortcomings and take corrective action;
- To demonstrate that the responsible management of safety in the downstream oil industry results in a low level of accidents, despite the hazards intrinsic to its operations.

The reports for the years 2007 and 2008 were published earlier this year (CONCAWE reports 6/09 and 7/09) and are available on CONCAWE's website. Beside the 2007 and 2008 data, the reports also include a full historical perspective from 1993, as well as comparative figures from other industry sectors. Data for these two reports was submitted by 30 and 31 companies respectively, accounting for more than 90% of the refining capacity of the EU-27 and EFTA member states.

In line with previous reports, the results are reported in the form of key performance indicators that have been adopted by the majority of oil companies operating in Western Europe as well as by other branches of industry. These are: Lost Workday Injury Frequency (LWIF); Lost Work Injury Severity (LWIS); All Injury Frequency (AIF); Road Accident Rate (RAR); and Fatal Accident Rate (FAR). The statistics include companies' own employees as well as contractors, and are split between 'manufacturing' (i.e. mostly refineries) and 'marketing' (i.e. distribution and retail). The results are presented in Table 1 together with all the previous statistics gathered since 1993.

The analytical results are of most interest in the form of historical trends, assisting the safety management efforts for continuous improvement. Figure 1 shows the evolution of the three-year rolling average for the four main indicators over the past 15 years.

Table 1 Historical evolution of the EU downstream oil industry safety performance indicators reported by CONCAWE since 1993

Year	Fatalities	FAR	AIF	LWIF	LWIS	RAR
1993	18	5.0	7.9	4.7	27	18
1994	19	5.4	7.4	4.0	25	19
1995	13	3.5	11.2	4.6	24	13
1996	14	3.3	10.7	4.7	19	14
1997	15	3.4	11.4	4.6	23	15
1998	12	2.6	9.9	4.5	22	12
1999	8	1.8	9.4	4.3	21	8
2000	13	2.7	8.8	4.3	25	13
2001	14	2.8	9.5	4.3	24	14
2002	16	3.3	6.9	3.9	23	16
2003	22	4.1	6.3	3.2	30	22
2004	12	2.3	6.3	3.2	33	12
2005	11	1.9	4.5	2.6	35	11
2006	7	1.5	4.6	2.5	25	7
2007	15	2.8	4.1	1.9	28	15
2008	11	2.0	3.7	1.7	23	11

Downstream oil industry safety statistics

2007 and 2008 reports have been published

These indicator trends show a steady performance over the years with a slow but constant reduction of LWIF, which has now remained below 3.0 for the fourth consecutive year, being further reduced to 1.9 in 2007 and to 1.7 in 2008. This 2008 LWIF value is the lowest ever reported since CONCAWE started gathering these safety statistics. The figures suggest that the AIF peaked around 1995-97, but this is also related to incomplete reporting of this indicator in the early years, as it was not formally in use in all companies. Nevertheless, the trend is definitely on a downward slope and AIF figures have improved for all categories.

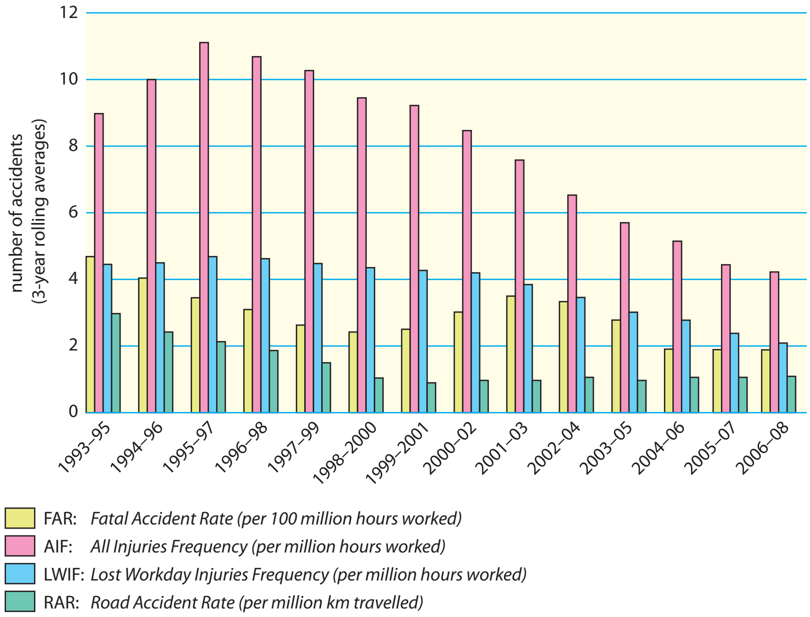
Sadly, a total of 15 fatalities were reported for 2007 and 11 for 2008. These values are higher than for 2006 which, at 7, was the best ever reported. Following a steady downward trend during the 1990s, fatality numbers began to increase in the first years of this decade, peaking in 2003. The reverse in this unfavourable trend since 2004 appears to stabilise, as the three-year rolling average FAR has become stable around 2.0 for the last three years.

Over the last five-year period, road accidents (41%) and incidents during construction/maintenance activities (41%) remain the principal causes of fatalities. Calculated over the complete period that CONCAWE has been gathering these statistics, such incidents represent 46% and 34% respectively of the total fatality numbers. The third major cause of incidents resulting in fatalities appears to be burns, explosions and electrocution (12%).

Figure 2 shows the relationships between the AIF, LWIF and FAR. The blue line shows a very stable relationship between AIF and LWIF indicating that nearly half of all incidents lead to a LWI. Because of the inherent high variability of FAR, the other two ratios appear less stable but still indicate roughly a fatality for every 100 LWI. This suggests that the classic 'safety pyramid' with an order of magnitude difference between AI, LWI and FAR, appears not to be applicable to our industry.

Despite the positive trends in LWIF and AIF, the severity indicator LWIS, that expresses the average number of days lost per LWI, does not show the same continuously decreasing trend (Figure 3).

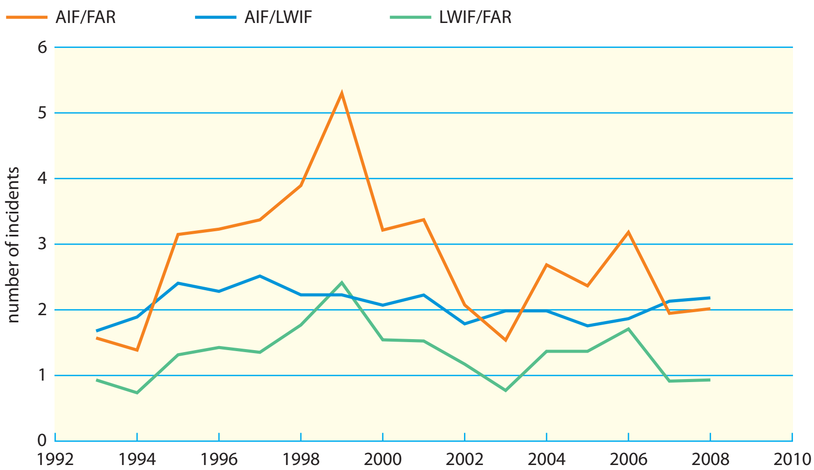
Figure 1 Three-year rolling average personal incident statistics relating to the European downstream oil industry



Together with the observed increase in the number of fatalities, this may be indicative that although the overall safety performance in the downstream oil industry is still improving with respect to the frequency of incidents and their absolute number, there is little change in the overall impact of those incidents which do occur.

This has triggered a discussion in CONCAWE about whether the performance indicators currently in use are sufficient, or if the set should be extended. CONCAWE

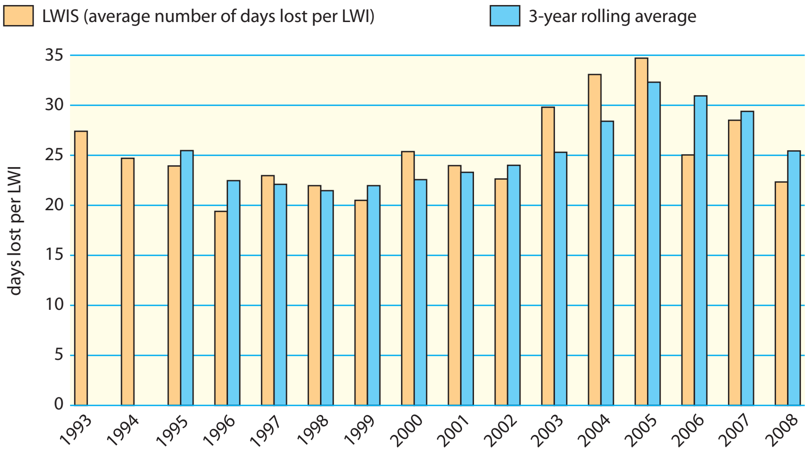
Figure 2 Incident and fatalities frequencies relationships for the European downstream oil industry



Downstream oil industry safety statistics

2007 and 2008 reports have been published

Figure 3 Lost Work Injury Severity (LWIS) from 1993–2008 and the three-year rolling average in the European downstream oil industry



experts are of the opinion that the observations described above justify gaining a better insight into the nature of the incidents which continue to occur. Many companies now routinely monitor indicators related to process safety, which may be one major factor.

In recognition of this trend, CONCAWE is planning to add a Process Safety Performance Indicator (PSPI) to the existing set of key performance indicators it monitors. The selected PSPI will be the lagging indicator defined by the American Petroleum Institute (API) in their report API *Guide to Report Process Safety Incidents*[1]. This defines a reportable process safety incident as:

Loss of Primary Containment (LOPC), which occurs on a Company wholly-owned or operated facility and which results in one or more of the following:

a. A Fatality or Days Away From Work Incident;

b. A fire or explosion;

c. An acute release of flammable or combustible liquid, gas or vapour; or

d. An acute release of a toxic chemical.

This indicator is already in use by many member companies and will enable a comparison on a regional scale within our Industry.

CONCAWE will request its members to initiate the gathering of information on this PSPI as of 2010 to gain initial experience, and aspires to include this process safety indicator in future safety performance reporting.

[1] *http://www.api.org/ehs/health/upload/API_Guide_to_PSI_FINAL_12_20.pdf*

Abbreviations and terms used in this CONCAWE *Review*

AIF	All Injury Frequency
API	American Petroleum Institute
BAT	Best Available Techniques
BREF	Best Availability Technique Reference Document
CEI™	Carbon Emissions Intensity
COP 15	United Nations Climate Change Conference, Copenhagen, 7–18 December 2009
CSA	Chemical Safety Assessment
CWT	Complexity Weighted Tonne
ECHA	European Chemicals Agency
EFTA	European Free Trade Association
EII®	Energy Intensity Index
EIPPC	European Integrated Pollution Prevention and Control
E-PRTR	European Pollution Release and Transfer Register Regulation
ETS	Emissions Trading Scheme
EU-27	The 27 Member States of the European Union
FAR	Fatal Accident Rate
FCCU	Fluid Catalytic Cracking Unit
GHG	Greenhouse Gas
IMO	International Maritime Organization
IPPC	Integrated Pollution Prevention and Control (EU Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control)
LCP	Large Combustion Plant
LCPD	Large Combustion Plant Directive
LOPC	Loss of Primary Containment
LPG	Liquid Petroleum Gas
LWIF	Lost Workday Injury Frequency
LWIS	Lost Work Injury Severity
MARPOL	International Convention for the Prevention of Pollution from Ships
NO_X	Nitrogen oxides
PSPI	Process Safety Performance Indicator
RAR	Road Accident Rate
RCR	Risk Characterisation Ratio
REACH	Registration, Evaluation and Authorisation of Chemicals
S	Sulphur
SECA	Sulphur Oxide (SO_x) Emission Control Area
SIEF	Substance Information Exchange Forum
SFF	SIEF Formation Facilitator
SO2	Sulphur dioxide
SO_x	Sulphur oxides
SRU	Sulphur Recovery Unit
TPH	Total Petroleum Hydrocarbon
WFD	Water Framework Directive
WWTP	Waste Water Treatment Plant

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CONCAWE staff changes

After almost ten years with CONCAWE, Jean-François Larivé will retire at the end of 2009, both from CONCAWE and from Shell, his 'home' company. When Jean-François arrived at CONCAWE in May 2000, he took over responsibility for the Refinery Technology area then quickly added Oil Pipelines and Safety to his Coordinator portfolio. In addition to these roles, Jean-François will be remembered as one of the founding fathers and major contributors to the Well-to-Wheels studies, a multi-year research collaboration between CONCAWE, the European Council for Automotive R&D, and the Joint Research Centre of the European Commission. Outside CONCAWE, Jean-François has been an active contributor to public consultations, conferences, and sister organisation activities. His recent contributions as a CEN/TC383 Working Group Convenor are helping to shape the complex task of certifying sustainable biofuels. During his CONCAWE tenure, Jean-François has been responsible for overseeing the publication of more than 80 CONCAWE reports and 20 CONCAWE *Reviews*, contributing some 35 articles, including the one on refinery benchmarking included in this *Review*.

While providing these technical contributions, Jean-François has also substantially contributed to enhancing CONCAWE's reputation through the annual CONCAWE Symposium started in 2002, the CONCAWE *Review*, the CONCAWE Newsbrief (an internal newsletter for Member Companies), and the Communications Group. We can safely say that life at CONCAWE will not be quite the same without him, at least initially, but we all wish him well in his retirement and in his new adventures.

Fortunately for CONCAWE, Alan Reid joined our organization in September from his position as Senior Refining Strategy Analyst at TOTAL. Alan is rising to the challenge of taking over Jean-François' Refinery Technology responsibilities and he has our very warm welcome and wholehearted support. With Jean-François' departure, Klaas den Haan will be looking after Oil Pipeline and Safety issues, in addition to his current areas of activity, while Ken Rose will become responsible for Communications issues, including the CONCAWE *Review*.

Sophie Bornstein has relinquished her position of Office Manager to concentrate on giving support to the REACH-related work in a new position as REACH Legal and Administration Advisor. We have welcomed Didier de Vidts as our new Finance, Administration and HR Manager.

CONCAWE publications

Reports published by CONCAWE from 2008 to date

2008	
1/08	Impact on the EU of SO_x, NO_x and primary $PM_{2.5}$ emissions from shipping in the Mediterranean Sea: Summary of the findings of the Euro Delta Project
2/08	European downstream oil industry safety performance. Statistical summary of reported incidents—2006
3/08	Guidelines for blending and handling motor gasoline containing up to 10% v/v ethanol
4/08	Advanced combustion for low emissions and high efficiency: a literature review of HCCI combustion concepts
5/08	Report of a toxicology forum symposium on air quality and cardiovascular health effects: what's the impact—October 24, 2007
6/08	Optical methods for remote measurement of diffuse VOCs: their role in the quantification of annual refinery emissions
7/08	Performance of European cross-country oil pipelines—Statistical summary of reported spillages in 2006 and since 1971
8/08	Impact of product quality and demand evolution on EU refineries at the 2020 horizon—CO_2 emissions trend and mitigation options
2009	
1/09	Air pollutant emission estimation methods for E-PRTR reporting by refineries—2009 edition
2/09	Comparison of particle emissions from advanced vehicles using DG TREN and PMP measurement protocols
3/09	Impact of marine fuels quality legislation on EU refineries at the 2020 horizon
4/09	Refining BREF review—air emissions
5/09	Additional human exposure information for gasoline substance risk assessment (period 2002—2007)
6/09	European downstream oil industry safety performance. Statistical summary of reported incidents—2007
7/09	European downstream oil industry safety performance. Statistical summary of reported incidents—2008
8/09*	Volatility and vehicle driveability performance of ethanol/gasoline blends: a literature review

* Available shortly

Up-to-date catalogues of CONCAWE reports are available via the website: www.concawe.org

New reports are generally also published on the website.

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