concawe review

Volume 20, Number 2, Autumn 2011

The oil companies' European association for environment, health and safety in refining and distribution

Photographs: cover: Kårstø refinery, Norway, courtesy of Øyvind Hagen/Statoil; pages 8, 9 (top) and 15: Shutterstock.com; page 9 (bottom): Public Library of Science/Hajime Watanabe.

Editor: Ken Rose, CONCAWE

Design and production: Words and Publications • words@words.co.uk

Foreword

Michael Lane,
Secretary General,
CONCAWE

In 2011, CONCAWE, with the support of its member companies, successfully completed its best year ever in terms of research project expenditures (excluding REACH). We are also on track to complete more reports for publication in a single year than we have ever done before. This high level of quality output is something to be proud of given the economic and resourcing pressures facing our industry at this time.

The ongoing REACH work remains a high priority, while other important technical work at CONCAWE is continuing. This *Review* highlights some of the results of our most recent research.

Major manufacturing industries, especially electricity generators and oil refineries, are under considerable regulatory pressure to reduce greenhouse gas (GHG) emissions. Regulators hope that the future use of carbon dioxide (CO_2) capture and storage (CCS) will be an attractive technology to substantially reduce the release of CO_2 to the atmosphere. Because more than 75% of Europe's industrial CO_2 emissions come from electricity generation, the most promising opportunities for CCS are likely to be in the power sector. In comparison, all of the European refineries combined represent only about 6% of Europe's industrial CO_2 emissions; nevertheless, we decided to look at the feasibility of implementing CCS in refineries in order to prepare for the future.

CONCAWE recently published its first report (7/11) on CCS in refining. This report considers the technical hurdles for implementing CCS in refineries, including capture technologies, and the transfer of CO_2 and its storage in underground locations. The estimated costs for such projects could vary considerably, depending on the refinery, but they are likely to be significantly higher than deploying CCS technologies in the power sector. The reasons for this are detailed in the *Review* article.

Although the Water Framework Directive (WFD) dates from 2000, many of its provisions will come into effect over a 30-year timeframe. Therefore, the WFD and related legislation for water and water quality will continue to be a focus area for CONCAWE in the years to come. Understanding in detail the amount of water used and the quality of the water discharged by European refineries is essential information to help the industry further improve its performance and comply with EU and national regulations. Some considerations arising from our recent study on trends in refinery effluent discharges are reviewed here.

An important requirement for refineries and the fuel supply system is that all gasoline dispensed at service stations must meet the prevailing EU and national specifications. This task is made more complicated when ethanol is used as a blending component because of the way it changes the properties of the gasoline blend, especially the volatility characteristics. CONCAWE has completed a six-vehicle study to look at the real-world driving impacts on vehicle emissions and the performance of more volatile gasolines containing 10% ethanol. The background to this work and a summary of the study's results are presented here.

Biofuels are playing an increasingly important role in transport fuels and are expected to deliver sustainable benefits, including greater security of energy supply, stimulating the development of rural economies, and reducing GHG emissions from transport. To ensure their sustainability, however, a careful assessment of the benefits and impacts of biofuels is required across their entire production and use life cycle. Issues such as competition with food crops, encroachment on forests and other natural land areas, and increased use of pesticides, fertilisers and water are often cited as concerns associated with large-scale biofuel production. To address these issues, many groups are developing certification schemes for biofuels. One of these is the EN 16214 standard practice, being developed by the European Committee for Standardisation (CEN), and the significance of this new standard is explained in this *Review*.

For many years, CONCAWE has published an annual analysis of safety statistics for the refining industry. In earlier reports, we have focused on personal injury data and trends. For the first time in 2009, we also collected data on process safety incidents. We intend to use these results to build an historical trend for process safety in the refining industry, that will complement our annual safety statistics on personal injuries. The latest 2010 safety report is summarised here.

Contents

The deployment of CO_2 capture and storage (CCS) on a large scale is seen as one of the most promising routes to abatement of CO_2 emissions, while permitting the continued use of fossil energy resources. However, CCS raises formidable technological, economic and legal issues that must be addressed to enable its use in power generation and other manufacturing industries. A recent CONCAWE study explores the specific challenges of implementing CO_2 capture technologies in refineries, where installations of a commercial size never before tested would be required to capture CO_2 from many low-concentration sources within the refinery. The challenges associated with the transport and underground storage of the collected CO_2 are also discussed.

Enquiries to: alan.reid@concawe.org

Although the European refining industry is a major user of water, it is not a major consumer of water. While efforts are constantly made to reduce water use, the refining industry routinely discharges large volumes of process water, or effluent. All effluents are treated before discharge in order to mitigate their potential impacts on the environment and their quality is continuously monitored. Because effluents are complex mixtures, assessing the effluent quality by chemical analysis alone is not enough. CONCAWE has therefore evaluated the use of biological measures of effluents, that is, their impact on micro-organisms, as an alternative to chemical analysis. CONCAWE believes that Whole Effluent Assessment (WEA) will play a major role in improving the quality of effluent discharges and water resources through the use of biological effects measurements.

Enquiries to: klaas.denhaan@concawe.org

European and Member State mandates are encouraging the use of more sustainably-produced biofuels in transport in order to reduce greenhouse gas (GHG) emissions. For use in gasoline-fuelled vehicles, ethanol is a widely available bio-product, but it changes the properties of gasoline blends at low concentrations and can have an impact on vehicle performance and fuel production. Three vehicle studies are being conducted by CONCAWE and other partners to better understand the impact of 10% ethanol and gasoline volatility on performance in vehicles. CONCAWE's six-vehicle study on E10 gasolines is described here, including the evaluation of regulated exhaust emissions, cold starting and idling, and hot weather vehicle performance. These results are providing input to standard-setting for future ethanol/gasoline blends by the European Committee for Standardisation (CEN).

Enquiries to: ken.rose@concawe.org

The global debate on biofuels has broadened over time, from their potential to reduce GHG emissions, to questions about the sustainability and impact of large-scale biofuel production on the environment, biodiversity, society and the economy. These are major concerns for the fuel supply industry that is mandated by European legislation to blend increasing volumes of bio-components meeting stringent sustainability criteria. For several years, CONCAWE has been actively involved in efforts to create a pan-European standard practice through the European Committee for Standardisation (CEN). The use of this standard would allow all participants in the biofuel 'chain of custody' to certify the sustainability and GHG reduction potential of biofuels used for transport, and to audit the certification process for acceptable performance. This article highlights the benefits and applicability of the new CEN standard that is expected to provide 'principles, criteria, indicators and verifiers' for 'sustainably produced biomass for energy applications' (EN 16214).

Enquiries to: ken.rose@concawe.org

The 17th annual assessment of work-related safety performance has been published (CONCAWE Report No. 5/11). This report presents 2010 safety statistics on personal injuries and fatalities for the European downstream oil industry's own employees and contractors, and includes process safety indicator data. Data have been analysed from 34 member companies, representing about 93% of European refining capacity. Trends over the past years are highlighted and data are compared to similar statistics from related industries. This survey includes, for the first time, information on the causes of Lost Workday Injuries, with a comparison to the causes of workplace fatalities. Further analysis of these results will be carried out in coming years as more data are collected.

Enquiries to: klaas.denhaan@concawe.org

The potential for CO_2 capture and storage in EU refineries

CCS technology has the potential for large-scale reductions in CO_2 emissions to the atmosphere—but it also presents significant challenges for the refining sector.

CO_2 capture and storage (CCS) is seen as one of the most promising routes to a major reduction in CO_2 emissions to the atmosphere. Its deployment on a large scale would make it possible to continue using fossil energy resources while meeting the challenging emission reduction targets that are widely believed to be necessary to avoid serious climatic consequences. A 2009 McKinsey report[1] states that CCS is the largest single lever for abating oil and gas emissions, if enough resources—both in terms of capital and engineering capacity—are made available.

CCS does, however, raise a number of technological, economic and legal challenges. For example, it requires capture equipment, transport infrastructure, injection and monitoring facilities—bringing high complexity and cost. Beside the extra investment costs, there will also be additional operating costs because CCS will require additional resources, especially energy. The extra expenses can only be justified if CO_2 has a sufficiently high long-term price.

Technologies to collect, separate/capture, transport and inject CO_2 into geological structures are known and have all been applied in commercial ventures. Nonetheless, the scale required for widespread application of CCS and the need to combine all steps into a seamless chain raise significant technological, practical and regulatory challenges.

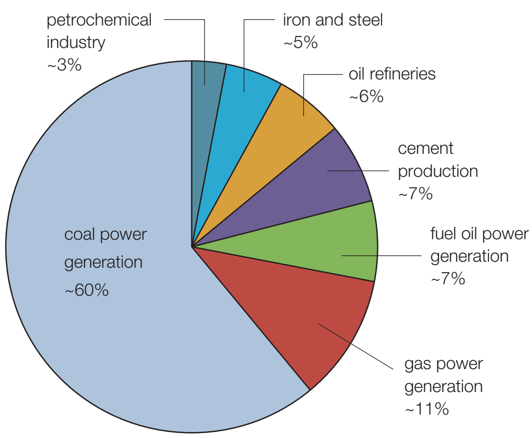
Underground storage of CO_2 over many centuries also raises specific legal issues regarding ownership and liabilities. Although governments and international institutions, particularly in Europe, are working on the development of appropriate legal frameworks, operators do not currently have a clear picture of their short- and long-term legal positions.

CONCAWE recently published a report (Report No. 7/11) which focuses on the specific challenges faced by oil refineries in Europe for the capture of the CO_2 they emit during normal operations, the availability of suitable storage sites within reasonable distances from refineries and the development of a CO_2 transport infrastructure. Information in this report is based on literature sources, particularly the comprehensive 2005 IPCC special report[2]. Some sources are already a few years old and, although technology has not evolved much over the period, estimated costs have increased significantly.

Refinery CO_2 emissions in perspective

Oil refineries require energy to convert crude oil into marketable products. In the process, they emit CO_2 by burning fuel to produce heat and power, and by producing hydrogen used for conversion processes. As shown in Figure 1, the EU refining sector currently produces approximately 6% of total European industrial CO_2, i.e. 3–4% of all anthropogenic emissions in Europe. In comparison, more than 75% of Europe's industrial CO_2 emissions come from power generation.

Figure 1 EU large stationary sources of CO_2



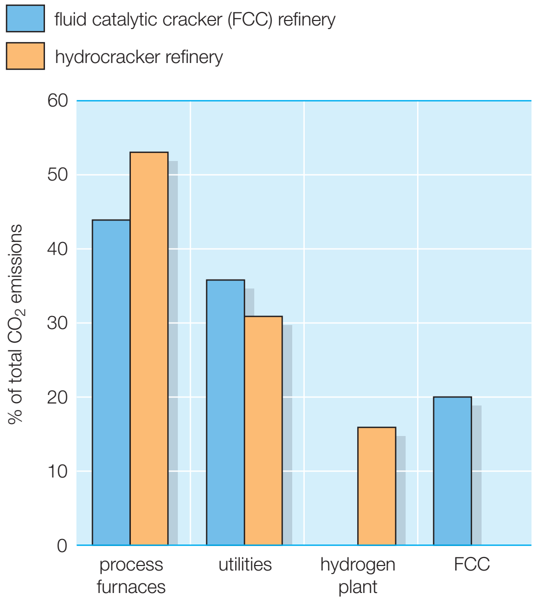
Source: IPCC SRCCS (2005)

Individual refineries are fairly large CO_2 emitters but are still, in comparison, much smaller emitters than power generation plants. Unlike these plants, refineries emit CO_2 from many dispersed and often relatively small sources, which adds a level of complexity to the capture process, particularly for post-combustion capture technologies.

1 Dinkel, J. *et al*. (2009). *Pathways to a low-carbon economy—version 2 of the global greenhouse gas abatement cost curve*. McKinsey & Company.

2 Metz, B. *et al*. (2005). *IPCC special report on carbon dioxide capture and storage*. Intergovernmental Panel on Climate Change, Working Group III. New York: Cambridge University Press

Figure 2 Typical distribution of CO_2 emissions by source in a complex refinery



Refinery CO_2 emissions are dominated by those from process furnaces and utilities, as shown in Figure 2. In practice, heat and power plants within refineries are the largest single sources, although a moderately complex refinery may have 20 to 30 separate process heaters often spread over a fairly large geographical area.

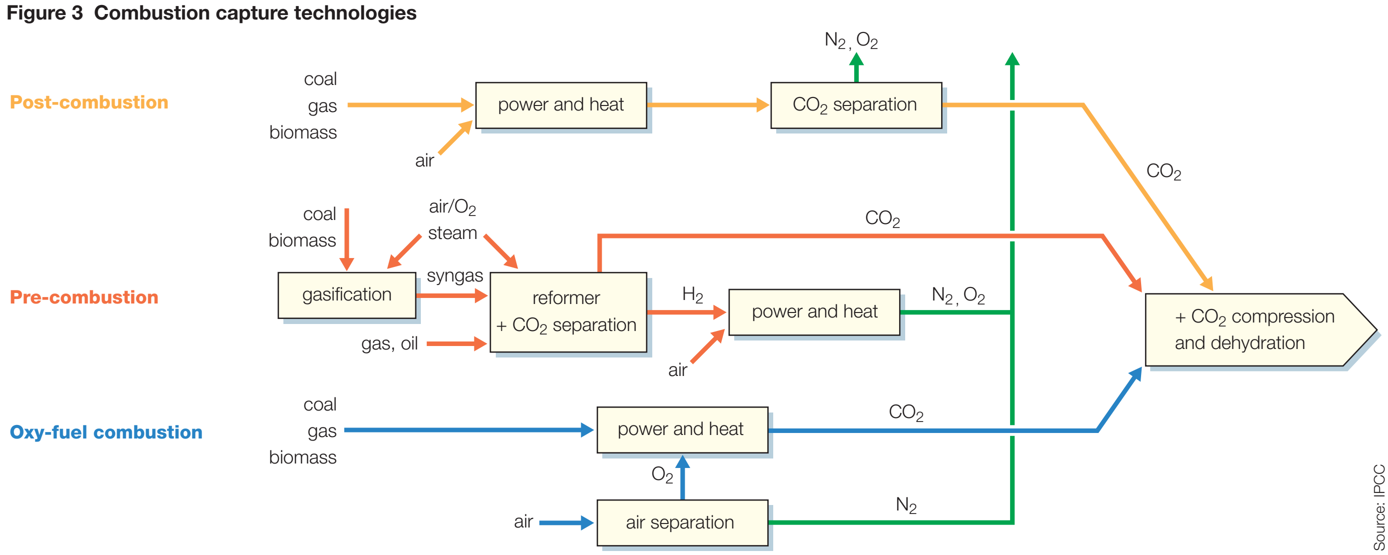
With the exception of some hydrogen plants, CO_2 is emitted in flue gases with fairly low CO_2 concentrations, typically in the order of 3–12% v/v CO_2.

Refinery CO_2 capture and associated combustion technologies

There are essentially three routes to CO_2 capture: **post-combustion**, **pre-combustion** and **oxy-fuel combustion** (Figure 3).

- **Post-combustion** capture does not change the combustor technology and captures CO_2 from large volumes of flue gases having low CO_2 concentrations. Existing chemical absorption technology can be used for the CO_2 capture but it would have to be implemented on an unprecedented scale. Impurities and contaminants commonly found in flue gases would also present new technical challenges. Post-combustion capture is costly from a capital perspective and requires a large amount of extra energy, mostly for desorbing CO_2 from the solvent, which in itself leads to extra CO_2 emissions. As a result, the total amount of CO_2 'avoided', i.e. prevented from reaching the atmosphere, will be about 30% less than the total CO_2 captured.
- **Pre-combustion** consists of partially or completely decarbonising the refinery fuel to produce two separate streams: hydrogen for combustion as an energy source and concentrated CO_2 for removal 'before combustion'. In practice, this approach consists of gasifying a heavy feedstock or converting fuel gas to a mixture of hydrogen and carbon monoxide (CO) known as syngas, followed by conversion of CO to hydrogen via the water-gas shift reaction in a reformer. Although the completely

Figure 3 Combustion capture technologies



decarbonised fuel chain is not used today, the process building blocks are already available as commercial technologies. These, however, can be complex and expensive installations. Retrofitting refinery heaters to burn pure hydrogen or hydrogen-enriched fuel gas could require extensive modifications, depending on the hydrogen concentration.

- **Oxy-fuel combustion** involves replacing the combustion air by pure oxygen, thereby eliminating nitrogen from the flue gases. This greatly increases the CO_2 concentration and reduces the flue gas volumes to be handled by the capture process. This approach has not been widely deployed in industry thus far and brings significant technological challenges. Retrofitting the large number of individual refinery process heaters to burn pure oxygen would also be complex and possibly expensive.

Whatever technology is selected, CO_2 capture would result in high cost and significant extra energy consumption and CO_2 production in a typical refinery. Adding large capture facilities with previously untested technology at the required scale could also affect the reliability of existing refinery installations. Although some of the developments in CCS for the power sector could be implemented in refineries, there is a need for demonstration projects using technology developed to address the specific challenges of refineries, such as specific impurities, lack of ground space, high reliability requirement, low retrofitting impact, energy consumption and energy integration.

Energy integration, in particular, is much easier in power plants, because they are steam and electricity producers and can easily be derated to provide the energy required for the CO_2 capture process. In refineries, which would need to install new utility plants for the additional energy demand, the need for improvement in energy consumption for CCS technology will be greater in refineries than in power plants. This will require special effort and support to be given to developing technologies that tackle this problem.

CO_2 transport

CO_2 can be transported in bulk either as a supercritical liquid in pipelines or as a refrigerated liquid in ships. There is already commercial experience with both approaches. For large quantities of CO_2 and short to medium transport distances, pipelines are the most cost-effective transport option.

Pipeline costs per tonne of CO_2 transported depend strongly on scale. The investment cost for a small-diameter pipeline dedicated to transporting about 2 Mt of CO_2 per year would be about 16 €/t CO_2. A larger diameter pipeline capable of transporting 5–10 Mt of CO_2 per year would cost about half this amount. Because of the cost and complexity of major pipeline projects, it will make economic and practical sense to build large pipelines serving several users, most probably around large single emitters such as power stations or in industrialised areas.

Quality specifications for the CO_2 streams will also need to be developed to address all potential impacts on pipeline performance including corrosion. Transport and handling of large quantities of CO_2 near populated areas could raise safety concerns and, therefore, public acceptance issues. The most significant safety risk is leakage of CO_2 from a pipeline into the atmosphere or the subsurface. High concentrations of CO_2 caused by a release to the atmosphere would pose health risks to humans and animals. Risk management techniques will be required to identify, mitigate and manage these risks in order to ensure the safety of CO_2 transport, handling and storage.

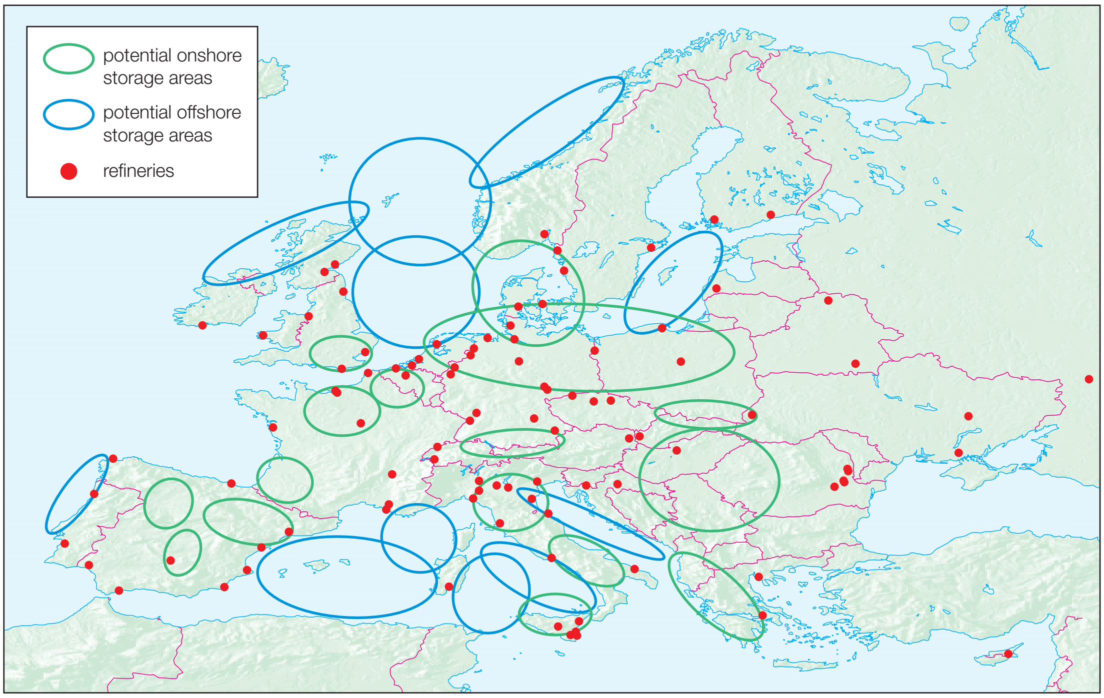
CO_2 storage

Large amounts of CO_2 can potentially be stored in various geological formations in Europe. Most of the potential CO_2 storage capacity in Europe is located offshore (68% of the total). Figure 4 shows the locations of refineries in Europe and potential onshore and offshore sedimentary basin storage sites.

Storage of CO_2 in deep saline aquifers is the most promising in terms of capacity. CO_2 can also be permanently stored in fully depleted oil and gas fields which are generally well known and documented, although storage capacity in these sites would be smaller than in aquifers.

CO_2 injection into oil and gas fields for enhanced oil/gas recovery (EOR/EGR) is a fully developed technique

Figure 4 Location of EU refineries and potential underground sites for CO_2 storage



(Source: ZEP)

Figure 4 shows the location of EU refineries and potential sedimentary basin storage sites. The red dots represent the refineries, and the areas bounded in green and blue are the potential storage areas, onshore and offshore, respectively.

through which some CO_2 can be retained. Compared to North America, where EOR and EGR are widely practised, the use of CO_2 for EOR/EGR is not expected to be economic in Europe if the crude price is consistently lower than about 100 $/bbl.

After the CO_2 has been injected underground, the integrity of the storage sites will need to be continuously monitored using a range of techniques and protocols, many of which are already well known.

Refinery CCS costs

The cost of refinery CCS is expected to be significantly higher than the current estimates for CCS in coal-fired power plants, which range from 60–80 $ (43–57 €) per tonne of CO_2 avoided. The estimated cost of CO_2 capture, which is typically about 80% of the total, will vary widely, depending on each refinery's size, complexity and location. The cost is also highly dependent on the fraction of the total emissions to be captured, because refineries usually have a small number of large emission sources and a large number of smaller, low concentration sources.

The capture cost for the first 50% of the total CO_2 emissions from a large, complex refinery has been estimated in a report by Shell[3] at 90–120 € per tonne of CO_2 avoided (2007 basis). The cost will be considerably higher to capture the remaining 50% of CO_2 emissions. Smaller, less complex refineries would not benefit from the economy of scale and unique configuration of the refinery in the Shell study. Taking into account the costs of transport, storage and monitoring, the total CCS cost estimate for the Shell example refinery would be in the range of 132–178 € per tonne of CO_2 avoided (on a 2010 basis).

With the current lack of experience of large-scale CCS projects and therefore limited understanding of the cost implications, there are wide variations in published cost estimates. A detailed estimate of refinery CCS costs was beyond the scope of the current CONCAWE report, requiring rigorous analysis of a wide range of variables in order to place the costs in their proper context.

[3] van Straelen, J. *et al.* (2010). CO_2 capture for refineries, a practical approach. *International Journal of Greenhouse Gas Control* 4, 2, 316–320.

Using biological methods to assess and monitor refinery effluents

Measuring biological effects from refinery effluents provides more reliable estimates than chemical analyses alone.

Rapidly increasing global population and climate change are raising concerns about the sustainability of long-term supplies of high quality water resources for consumption, farming, industry and conservation. As a consequence, environmental and regulatory pressures are building to ensure that available water resources are used efficiently and wisely.

Because oil refineries are among the largest industrial users of water, European refiners are doing their part to ensure the long-term sustainability of water resources. In spite of continuing reductions in water usage, a recent CONCAWE survey (see Report 2/11) showed that the amount of treated process-related effluent discharged from European refineries in 2008 was approximately equal to that of crude oil processed, on a weight-for-weight basis. A follow-up survey is being conducted to gain more insight into water use, and the results will help to identify good practices for future refinery operations.

Reducing the quantity of water used in refineries is obviously important, but ensuring the quality of water discharged back to the environment is equally important. A large fraction of the water used by the refining industry is ultimately returned to the environment following multi-stage water treatment, so that the effluent does not degrade the quality of the receiving water. According to CONCAWE's 2008 survey, 94% of European refineries have complex facilities that treat their process-related effluents with biological agents prior to discharge to the environment. The remaining 6% use various combinations of filtration techniques to ensure protection of the local environment and compliance with effluent regulations.

A modern wastewater treatment plant

Measures of biological effects

Over a 40-year period, CONCAWE has conducted and reported on surveys of its European member companies in order to learn more about refinery effluent discharges and water treatment facilities. The 2011 report includes results from a comprehensive survey of physical and chemical properties of refinery effluents conducted in 2005, and a more specific survey of selected effluent properties in 2008.

In addition to effluent properties, the survey also requested information on what biological effects measures were being used to monitor effluent quality, and how the results were applied in practice. A 'biological effects measure' is one that evaluates the potential biological impact of specific substances, that may be found in effluents, on organisms commonly found in the receiving water environment. These measures cover a broad spectrum including:

- toxicity studies on refinery effluents and receiving water samples;
- assessments of the persistence and bioaccumulation potential of effluent substances; and
- monitoring studies designed to determine the health of the entire ecosystem within a receiving water environment.

In some cases, these results are needed to satisfy a regulatory requirement for effluent discharge permits while, in others, they are used only for internal performance monitoring by the refinery. In either case, the use of these biological approaches is clearly increasing and will probably increase further under pressure from new regulatory requirements.

Biological effects measures and the EU refining industry

CONCAWE's surveys have shown that the use of biological effects measures is also increasing within regulatory decision-making processes. Although the basic scientific principles have not changed from those identified in earlier reports (CONCAWE Reports 5/79 and 92/56), the range and sensitivity of the measurement techniques have improved. The uses to which these methods are applied today range from toxicity assessments supporting improvements in site effluent treatment, to more specific field monitoring. Monitoring studies typically incorporate more sensitive endpoints, such as biomarkers and statistical techniques, to assess the potential impacts of effluents on biota and ecological status.

The most widely applied biological measures assess toxicity to aquatic organisms. These measures are relevant to protecting ecosystems although their interpretation ultimately depends on the tests used to assess toxicity. As shown by case studies and the feedback from the refinery survey, toxicity measurements made on undiluted effluents can be extended to the environment to complement existing analytical and biological diversity studies and improve the assessment of sediment and water quality.

CONCAWE has contributed to the development of methods to assess both the persistence and bioaccumulation of effluent components. Such tests can potentially improve the risk assessment process for effluent discharges but it is also important that their limitations are recognised and put into context. In this respect, CONCAWE has helped to develop guidance on the use of these methods which has been incorporated into OSPAR's[1] 2007 Whole Effluent Assessment (WEA) guidance.

When undertaking toxicity assessments on refinery effluents, it is also important to ensure that the test results properly reflect the effluent properties and are not influenced by confounding factors. For example, when measuring the toxicity of chemical substances on aquatic organisms, it is important that test parameters, such as pH, temperature, dissolved oxygen, water hardness and salinity, suspended solids, and colour, are all within specified ranges. These ranges may be different for different aquatic organisms.

The regulatory landscape

For many years, environmental regulations have focused on the physical and chemical properties of effluent discharges in order to set compliance limits and monitor performance. These approaches have been successful in reducing the discharge of specific hazardous substances to the environment and have contributed to substantial improvements in water quality across Europe.

As the overall quality of waters receiving effluents has improved, however, attention has increasingly turned to more complex issues such as longer-term bioaccumulation and exposure of aquatic organisms to complex mixtures of substances. These concerns are also important to the refining industry because treated refinery effluents are typically discharged over many years and can contain different hydrocarbon substances in low concentrations. Some of these substances could have a common mode of toxic action and may express their effects additively on the environment.

EU Member States are applying biological measures in different ways to regulate effluent discharges. Some adopt a risk-based approach, using the biological measures to demonstrate the acceptability of potential impacts on the environment, while others adopt a hazard-based approach to set limits or reduce emissions based on the intrinsic properties of the treated effluent. As EU environmental legislation increasingly focuses on the use of biological measures, better harmonisation of legislative approaches should be expected.

Studies to monitor ecosystems and establish the environmental quality of water bodies will almost certainly increase and, when conducted well, can provide a robust baseline to monitor future changes in water quality. Several EU refineries have been conducting such monitoring studies since the 1970s and have found them to be valuable for demonstrating the performance of their treatment facilities and the associated improvements in water quality. These also provide environmental baselines to assess impacts if unexpected spills or releases were to occur.

Until quite recently, the regulation of European water resources has been administered by EU Member States. Water use and discharge permits have often been managed by regional or local authorities, albeit within a national framework. The new EU Water Framework Directive (WFD) (Directive 2000/60/EC) will establish requirements for regulating water resources on a cross-border scale. Under the WFD, Member States will need to develop River Basin Management Plans (RBMPs) setting out specific objectives and implementation measures. The RBMPs will also link the WFD to other water-related legislation, including the Birds Directive, the Habitats Directive, the Environmental Impact Assessment Directive, the Drinking Water Directive and several others. The WFD is currently in the implementation stage with many steps still required to achieve a 'good status' rating for all European waters by 2015.

Daphnia magna*, a freshwater flea, is widely used as a laboratory animal for ecotoxicity testing.*

[1] The Oslo-Paris (OSPAR) Commission resulted from the Convention for the Protection of the Marine Environment of the North-East Atlantic.

The WFD requires the ecological quality of receiving waters to be assessed, and specifies that biological effects measures can be used to complete these assessments. Many tools are already available for this purpose, as described in CONCAWE Report 2/11. A new project, called NoMiracle (Novel Methods for Integrated Risk Assessment of CumuLative stressors in Europe), was initiated recently to develop models for more integrated risk assessments of chemical substances and mixtures. (See: http://nomiracle.jrc.ec.europa.eu/default.aspx.)

Learnings from case studies

In this complex area of research and regulation, learning from previous experience is very important. In the appendices to CONCAWE's Report 2/11, six case studies are described in which biological assessment methods have been applied to refinery effluents and receiving waters. Three more appendices describe methodologies and data quality issues.

The use of biological effects measures that are directly relevant to receiving water ecosystems would appear to be a logical approach. However, the case studies showed that differences in site-specific conditions require some flexibility in the selection of the most appropriate biological measures. Furthermore, the sensitivity of the methods used and the endpoints examined also need to be consistent with the purpose and objectives of the work. Measures of biological effect developed for use on specific chemicals under simple exposure conditions may not always be relevant under real-world conditions where stresses on the ecosystem can make it very difficult to establish causes and effects.

It is important, therefore, that biological measures are not used in isolation; combining their use with, for example, chemical and physical analysis of an effluent and receiving water environment can greatly increase understanding. Finding out what is 'relevant' is not straightforward, however, given the spectrum of response parameters that could be investigated at different levels and within different parts of the ecosystem. Much careful planning and expert judgment is required when designing a test or monitoring study if the results are to achieve the study's objectives.

In these case studies, the toxicity of the effluents examined did not raise any specific concerns beyond those that would be expected based solely on the effluents' hydrocarbon content. They also showed that the toxicity and impact of refinery effluents on receiving waters has been reduced through continuing improvements in effluent treatment facilities. Where biological effects measures have identified properties of undiluted effluents that are of concern, this has led to higher water treatment costs than those required to meet chemical-specific targets.

The use of standardised measurement methods within a site-specific assessment will help to ensure that the results are relevant and can be interpreted against established criteria. The use of accredited laboratories to carry out the work will also ensure that the studies are considered to be reliable by regulatory authorities.

In conclusion

It is clear that the European regulatory landscape is changing with respect to the hazards and risks of refinery effluents and the environment. Biological assessment will increasingly be incorporated into monitoring and control schemes such as the WFD, the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and the requirements of OSPAR, many of which view biological effect measures as tools to be applied in combination with (and not instead of) chemical substance-oriented approaches.

A major advantage of applying biological assessment to undiluted effluent or receiving water samples is that the data they provide can be used to assess the overall hazards and risks of complex media that are difficult to address otherwise. There are potential disadvantages, however, namely that adverse environmental effects may be incorrectly interpreted from the use of inappropriate or poorly designed monitoring studies. If this were to occur, risk reduction measures, such as additional water treatment facilities, might be demanded, even though they may provide little additional environmental benefit.

Gasoline volatility and vehicle performance

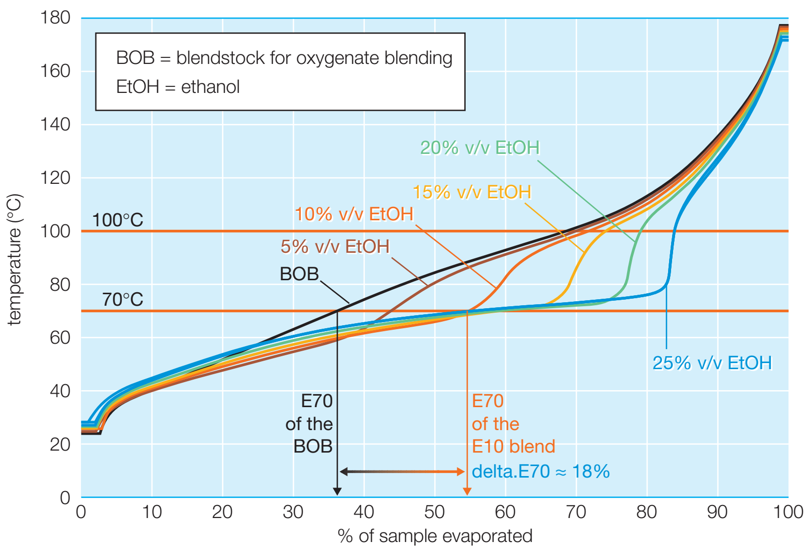
CONCAWE's six-vehicle study investigates the impact of ethanol and gasoline volatility on vehicle emissions and performance.

Passenger cars in many parts of the world are now routinely operating on blends of oxygenated molecules and gasoline. Both ethanol and ethers, such as ethyl tertiary-butyl ether (ETBE), are being used in Europe in order to improve vehicle emissions performance and enhance the fraction of sustainably produced, renewable products in transport fuels. In other parts of the world, including the United States, Brazil, Australia and other countries, ethanol is the preferred blending component and is being used in gasoline at 10% v/v or higher.

In the EU, the Renewable Energy Directive (RED, 2009/28/EC) has mandated that 10% of transport fuels on an energy basis must be derived from sustainably produced, renewable sources by 2020. During this decade, only fairly common products, such as ethanol from sugar fermentation and fatty acid methyl esters (FAME) esterified from natural oils, are likely to be available in sufficient quantities to meet the 2020 mandate. Today's EU-wide specifications allow blending of up to 5% v/v ethanol in gasoline (E5) and up to 7% v/v FAME in diesel fuel (B7), although work is progressing in the European Committee for Standardization (CEN) to increase both of these blending limits.

Ethanol imparts especially large changes when it is blended into gasoline at low concentrations. An example of the effect of ethanol on gasoline's distillation curve is shown in Figure 1.

Figure 1 Effect of increasing ethanol content on the distillation curve of an ethanol/gasoline blend



The % evaporated at 70°C (E70) and at 100°C (E100), as shown in this figure, are two important specifications for market gasoline. These values are known to have an effect on the driveability performance and tailpipe emissions of gasoline-fuelled vehicles. When gasoline is specifically manufactured for blending with oxygenates, it is usually called a 'blendstock for oxygenate blending' or BOB.

Increasing the amount of ethanol blended into the BOB changes the distillation curve of the blend, substantially increasing the E70 distillation point, as shown in Figure 1. This effect is larger at 70°C than it is at other distillation temperatures because the boiling point of ethanol is very close to this temperature. In order to ensure that the E70 of the ethanol/gasoline blend remains below the maximum values for E70 and E100 that are allowed for market fuels, the volatility of the BOB must be lowered by changing its composition. This change has an impact on refinery production because the molecules removed from the BOB to accommodate the ethanol must find a home in another petroleum or chemical product. More details on these effects were previously reported in the CONCAWE *Review,* Vol. 20 No. 1.

It is important to note that ethanol also increases the vapour pressure of gasoline at low ethanol concentrations. However, the vapour pressure of market gasoline is strictly controlled, whether oxygenates are present or not, in order to reduce the release of hydrocarbon emissions from cars when they are being refuelled or parked on a hot summer day. The volatility effects described here are those that change the shape of the distillation curve for the ethanol/gasoline, not the vapour pressure.

What did previous vehicle studies conclude?

In 2009, CONCAWE completed a major study (see CONCAWE Report 8/09), evaluating publications from Europe, the USA, Australia and elsewhere, covering the past 20 years. In this review, seven multi-vehicle studies conducted under hot weather conditions (up to +40°C) and eleven multi-vehicle studies conducted under cold weather conditions (down to -20°C) were reviewed to better understand how vehicle emissions and driveability performance changed with the volatility of the ethanol/gasoline blend.

This review concluded that the hot weather performance of modern vehicles, especially fuel-injected engines from the mid-1990s onward, are much less susceptible to fuel volatility than older carburetted vehicles. Vapour lock, which was a common problem for carburetted vehicles, is much less frequent in modern fuel-injected cars. Cold weather performance was also not expected to be a problem, although slightly higher carbon monoxide (CO) emissions were reported under some conditions. Overall, the effect of a small increase in the volatility of E10 gasoline was not expected to introduce unanticipated vehicle problems.

What about the newest vehicle studies?

Because of the dramatic effects of ethanol on gasoline volatility, some refineries can be expected to experience difficulties meeting the current EN 228 limits when manufacturing E10 gasoline blends. For this reason, the responsible CEN Working Group is considering a CONCAWE proposal to relax the maximum E70 and E100 volatility limits for E10 gasolines. This proposal would increase the maximum E70 by 4% (from 48% to 52% for summer fuels) and the maximum E100 by 2% (from 71% to 73%).

Table 1 Vehicles selected for the CONCAWE test programme

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6
Vehicle class	Upper medium	Medium	Small	Lower medium	Mini	Small
Registration	2007	2009	2007	2009	2008	2010
Emissions level	Euro 4	Euro 5	Euro 4	Euro 4	Euro 4	Euro 4
Maximum power (kW)	140	118	57	81	50	60
Engine size (litres)	2.5	1.8	1.4	1.6	1.0	1.25
Cylinders and valves	6 and 24	4 and 16	4 and 8	4 and 16	3 and 12	4 and 16
Injection system	Direct injection	Direct injection	Multiport injection	Multiport injection	Multiport injection	Multiport injection

To support the technical decisions of this Working Group, three major vehicle test programmes, one by CONCAWE, one by the European auto industry, and one by a third-party testing laboratory, are investigating whether the proposed volatility relaxation will introduce any new emissions or driveability performance problems. The results from these studies will be reviewed in early 2012 in order to inform CEN's technical decisions on the future specifications for E10 gasoline blends.

What did CONCAWE's study conclude?

As shown in Table 1, CONCAWE evaluated six modern vehicles spanning many European manufacturers, engine technologies and weight classes. The vehicles selected were representative of the current EU fleet and were confirmed by the vehicle manufacturer's information to be fully compatible with 10% v/v ethanol.

E10 gasolines were specially blended for this study (Table 2). In order to test a 'worst case' scenario, CONCAWE's study compared performance on 'Baseline' and 'Step 2' E10 gasolines in which the volatility (the E70 and E100 values) were at the maximum limits of the EN228 specification and higher than the maximum limits, respectively. If the results showed only small effects in this 'worst case', then there would be confidence that results at the lower level of volatility relaxation proposed to CEN would also be acceptable.

Vehicle tests covered the full range of performance requirements (Table 3) using the regulatory procedures wherever possible. These requirements included tailpipe emissions at +23°C and -7°C over the New European Driving Cycle (NEDC), evaporative emissions, cold starting and idling at -20°C, and hot weather vehicle performance at +40°C. This has been one of CONCAWE's most extensive vehicle testing programmes in many years and was completed to the original design specifications and protocols within just one calendar year!

Overall, the results for all six vehicles provided the following conclusions:

- There were no operational problems observed on any vehicle or on any fuel. All vehicles were able to comply with the test cycle procedures with no false starts, no misfires, no stalls, no failures and, very importantly, no faults recorded by the vehicles' on-board diagnostics systems.

- Overall, the impact of fuel differences on vehicle emissions and driveability performance were small compared to vehicle-to-vehicle differences.
- No major differences were observed between fuels in the fleet average tailpipe emissions and evaporative emissions using the regulatory procedures.
- Under cold weather starting conditions, all of the vehicles started easily on all fuels without idling problems. Slightly richer fuelling conditions and slightly higher CO emissions were observed with the more volatile fuel in the first few hundred seconds before the oxidation catalyst had warmed up.
- Under hot weather driving conditions, there were essentially no fuel-related problems that would be noticed by an untrained driver, i.e. someone who has not been specifically trained to detect minor engine effects. Five of the six vehicles showed better driving performance on the higher volatility fuels, due to fewer engine stumbles and surges and less idling instability.

CONCAWE's report on this six-vehicle study will be available in early 2012.

What is the next step for European gasoline after E10?

In addition to providing input to the current revision of the European gasoline specification, these vehicle studies will also set the stage for any future increases in ethanol content which may be needed in order to meet EC and Member State mandates. Before this can be done, vehicles must be fully compatible with higher ethanol/gasoline blends, and fuel producers must be able to manufacture and distribute the fuel blend to specification.

Although the results of this vehicle study did not show emissions or driveability problems for E10 gasoline blends, there are still open questions about blends containing higher than 10% v/v ethanol. As already illustrated in Figure 1, the E70 volatility values become much less easy to measure precisely as the ethanol content increases and the distillation curve flattens. This suggests that more analytical and vehicle work will be needed to evaluate the most appropriate parameters to define volatility and ensure good driveability performance under both hot and cold weather conditions. Once specified, the fuel suppliers and auto manufacturers will then need time, perhaps several years, to implement these changes for higher blending levels.

A new working group has been formed within CEN in order to consider what problems might lie ahead for ethanol blending higher than 10% v/v. The work of this group is just beginning and a final report is expected by the end of 2012.

Table 2 Gasolines containing 10% v/v ethanol tested in this study

Summer class E10 gasolines	Winter class E10 gasolines
Gasolines at today's maximum E70/E100 volatility limits	
Baseline E10-A DVPE[1]: 57.1 kPa Target: Volatility at maximum summer class limits + Target: E70max: 48% v/v and E100max: 71% v/v + Measured: E70: 49.7% v/v and E100: 68.4% v/v Other parameters within EN228 limits	**Baseline E10-E** DVPE: 97.0 kPa Target: Volatility at maximum winter class limits + Target: E70max: 50% v/v and E100max: 71% v/v + Measured: E70: 51.9% v/v and E100: 67.1% v/v Other parameters within EN228 limits
Gasolines exceeding today's maximum E70/E100 volatility limits	
Step 2 E10-A DVPE: 61.0 kPa Target: E70max +10% and E100max +4% + Target: E70: 58% v/v and E100: 75% v/v + Measured: E70: 59.4% v/v and E100: 75.7% v/v Other parameters within EN228 limits	**Step 2 E10-E** DVPE: 94.1 kPa Target: E70max +10% and E100max +4% + Target: E70: 60% v/v and E100: 75% v/v + Measured: E70: 60.6% v/v and E100: 73.9% v/v Other parameters within EN228 limits

[1] Dry Vapour Pressure Equivalent

Table 3 Vehicle measurements completed

	Summer grade E10 gasolines		Winter grade E10 gasolines	
	Baseline E10-A	**Step 2 E10-A**	**Baseline E10-E**	**Step 2 E10-E**
Regulated tailpipe emissions plus CO_2 at +23°C	✓	✓		
Regulated tailpipe emissions plus CO_2 at -7°C			✓	✓
Evaporative emissions	✓	✓		
Cold engine starting and idling at -20°C			✓	✓
Hot weather vehicle performance at +40°C	✓	✓		

EN 16214: A new European standard for sustainable biofuels

CONCAWE has been actively involved in the development of a CEN standard on sustainably produced biomass for energy applications.

Over the past decade, biofuels have become part of the road fuel supply, driven by legislation aimed at reducing the carbon footprint of road transport. The EU has led the way, first with an indicative target for biofuels blending in 2003, and subsequently with the Renewable Energy Directive (RED) in 2009, that mandates 10% renewable energy in road transport by 2020.

The debate about the benefits of biofuels, which was originally focused on their ability to reduce greenhouse gas (GHG) emissions, has progressively broadened to include concerns about the potential direct and indirect impact of their large-scale production on environmentally sensitive areas, biodiversity and societal costs. Some of these concerns have been recognised by European legislators, for example in the RED which limits where biofuels can be grown and still qualify for RED compliance blending targets.

European standards, developed by multi-stakeholder teams through the European Committee for Standardisation (CEN), have long been used to underpin EU-wide legislation with fit-for-purpose specifications and test methods. For road fuels, CEN specifications for gasoline (EN 228) and diesel fuel (EN 590) were developed more than 20 years ago and have been continuously updated to keep pace with changing emissions legislation and vehicle developments. Similar standards for bio-derived blending components have also been developed. These Europe-wide specifications are very important to ensure that the same procedures, test methods and limit values are used in all Member States, guaranteeing that consumers can drive their vehicles anywhere in Europe with confidence that the fuels they buy will be fully compatible and of consistently high quality.

In addition to its renewable energy mandates, the RED also includes guidance on the compliance requirements for bio-derived blending components. Although biofuel sustainability criteria and some calculation rules were included in the RED, a useable standard practice was not, and is clearly needed to provide biofuel producers and fuel suppliers with a pragmatic guide to the RED's biofuel sustainability expectations. For the same reasons described above for road fuel specifications, CEN is an appropriate forum for developing such a standard practice.

EN 16214: sustainably produced biomass for energy applications

In 2008, following a proposal from the Dutch National Standardisation Body, CEN created a new Technical Committee (CEN/TC383) to develop a standard practice on sustainability criteria for biomass. Although the scope of the original proposal was quite broad, the CEN stakeholders agreed early on that the standard should be fully compatible with the RED expectations and should not include any additional requirements. This was seen as essential in order to quickly develop a practical tool to help all economic operators comply with the RED. Accordingly, the standard practice being developed by CEN applies to biofuels and bioliquids and their production chains but it does not apply to solid biomass when used as a fuel.

CONCAWE has been actively involved from the very beginning as a liaison organisation and has contributed to the TC383 discussions by providing technical support to the working groups developing this standard.

What is the EN 16214 standard?

The new standard, titled 'Sustainably produced biomass for energy applications—Principles, criteria, indicators and verifiers for biofuels and bioliquids', has been developed in four separate but connected parts:

Part 1 on ***Terminology*** defines important terms used in the other three parts including those for biomass 'residues' and 'co-products'. These definitions are essential in order to complete the GHG calculations required by the RED.

Part 2 on ***Conformity assessment including chain of custody and mass balance*** provides a practical scheme to complete an assessment of a bio-product's conformity with the RED. This includes requirements for economic operators and also auditors who will be responsible for checking the compliance of these economic operators. This part of the standard also specifies a 'chain of custody' as required by the RED, to ensure that auditable information is collected at each step in the bio-product manufacturing and fuel blending process and is passed along to the next economic operator in the chain for compliance purposes.

Part 3 on ***Biodiversity and environmental aspects*** provides guidance on agricultural areas where limits on the cultivation and harvesting of biomass apply.

Part 4 on ***Calculation methods of the GHG emission balance using a life cycle analysis*** clarifies many aspects of the GHG balance methodology that is included in the RED. This part provides a detailed and practical guide to GHG calculations for use by all economic operators.

Parts 1 to 3 of EN 16214 went to public enquiry in early 2011. Part 4 is currently under public enquiry and is expected to be published in 2012. Parts 2 and 3 of this standard have now been endorsed by the European Commission. A similar status is expected for Part 4 as soon as the CEN approval process has been completed.

Benefits and applicability of the EN 16214 standard

The uniform and consistent application of the RED legislation in all 27 European countries is essential to provide a level playing field for all economic operators.

The RED provides a comprehensive legal framework for the assessment of biofuels. This is, however, a complex piece of legislation involving many requirements for which there is limited practical experience. There are also many areas where interpretations can vary and where guidance to economic operators is highly desirable.

By clarifying the more complex aspects of the RED and by providing detailed guidance, EN 16214 is expected to play an important role in ensuring that the RED's expectations are successfully and consistently implemented across EU Member States. This pan-European standard practice will also make it more likely that RED expectations can be met in a cost-effective way.

While this standard was being developed, a number of existing and new certification schemes for bio-products were submitted to the European Commission for recognition as 'voluntary schemes', conforming to the RED requirements. At least seven such schemes have been accepted by the EC as covering all or at least some aspects of the RED requirements, and many more schemes are being reviewed. These 'voluntary schemes', however, vary considerably in scope and have been developed from quite diverse starting points.

EN 16214, on the other hand, is expected to provide all of the elements that are needed to set up and audit a certification scheme for sustainably-produced biofuels and bioliquids. The four parts of the EN 16214 standard address terminology, chain of custody, biodiversity and GHG calculations. This means that the voluntary schemes that have already been recognised by the European Commission can benchmark themselves against EN 16214—and they are encouraged to do so!—in order to demonstrate that they are in full compliance with a pan-European standard practice.

A complementary international standard?

Of course, extending a European standard's approach to other parts of the world would help to ensure that common practices are increasingly used in the future for importing and exporting bio-products. Such an approach would encourage trade in bio-products that are properly certified as meeting accepted sustainability criteria and have been audited for the protection of economic operators in the chain of custody.

Through the encouragement of Brazil and Germany, the International Standards Organisation (ISO) endorsed a new work item in 2008 on 'sustainability criteria for bioenergy' and formed a new ISO Technical Committee (TC248). Work is ongoing within this committee, with a view to publishing a new ISO standard in 2014.

The objectives and scope of the ISO standard are, however, quite different from those of EN 16214. While the EN standard does not cover aspects beyond the RED, the ISO standard is expected to be more generic, setting out the ground rules for developing and applying sustainability criteria for bioenergy.

Nonetheless, complementary CEN and ISO standards can be expected to go a long way to satisfying immediate RED and economic operator expectations while encouraging future trade in sustainably produced bio-products.

Downstream oil industry safety statistics for 2010

The 2010 safety statistics report analyses personal injury and process safety statistics.

Safety management systems are widely recognised by the oil industry as an essential tool for collecting and analysing safety incident data, and continuously improving the safety of personnel and operations. To support this effort, CONCAWE has been compiling statistical safety data since 1993 for the European downstream oil industry in order to:

1. provide member companies with a benchmark against which to compare their own company's safety performance; and
2. demonstrate how responsible approaches to safety management can help to ensure that accidents stay at low levels in spite of the hazards that are intrinsic to refinery and distribution operations.

Most importantly, CONCAWE's annual safety data report enables companies to evaluate the efficacy of their own management systems, identify any shortcomings, and take corrective actions as quickly as possible.

What safety data do we evaluate?

CONCAWE's 17th report on our industry's safety performance (CONCAWE Report 5/11) presents statistics on work-related personal injuries sustained by oil industry employees and contractors during 2010. It also highlights trends over the past 17 years of data collection and compares the oil industry's performance to that of other industrial sectors.

The 2010 report compiles safety data submitted by 34 CONCAWE member companies, representing about 93% of the refining capacity of the EU-27 plus Norway, Switzerland and Croatia. The statistics are reported primarily 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 types of manufacturing industries. These indicators are:

- number of work-related fatalities;
- Fatal Accident Rate (FAR) per 100 million hours worked;
- All Injury Frequency (AIF) expressed as the number of injuries per million hours worked;
- Lost Workday Injuries (LWIs) and the Lost Workday Injury Frequency (LWIF) calculated by dividing the number of LWIs by millions of hours worked;
- Lost Workday Injury Severity (LWIS), the average number of lost workdays per LWI;
- Road Accident Rate (RAR), the number of road accidents per million km travelled; and
- Process Safety Performance Indicators (PSPI) that report the number of Process Safety Events (PSEs) expressed as unintended Losses of Primary Containment (LOPC).

Process Safety Performance Indicators

Several major industrial accidents, like the Toulouse explosion (2001), the Buncefield fire (2005) and the Texas refinery explosion (2005), have led to increased attention on the causes of such events. This has led to several initiatives that focus on the gathering of Process Safety Performance Indicators. The lagging indicators for these events are Process Safety Events, mainly Loss of Primary Containment, because these have frequently been shown to be the initiating events for major accidents.

As part of the 2010 survey, PSPI data were collected for the second consecutive year, following the publication of the latest guideline by the American Petroleum Institute. These additional data provide insights into the types and causes of process safety incidents. PSPIs also enable the refining and distribution industry to compare their European process safety performance with similar data from other regions of the world.

Twenty-four CONCAWE companies provided PSPI data in 2010, which was a significant increase over the eighteen that reported in 2009. From these responses, a Process Safety Event Rate (PSER) indicator of 2.3 was recorded for all PSEs. Although this is a notable reduction compared to the 2009 PSER of 4.1, this improvement may be partly due to more companies responding with data. The overall results of the PSPI survey are presented in Table 1. Fortunately, none of the reported PSEs resulted in a major accident that the understanding of PSE causes is trying to prevent.

Personal Safety Indicators

Accident frequencies in the European downstream oil industry have been quite low historically and the 2010 data show that this trend is continuing. The 1.9 LWIF for 2010 has stayed below 2.0, which has been the case since 2007.

In general, performance indicator results are of greatest interest when these can be analysed for historical trends. The evolution of safety performance over a period of time provides indications on how well safety management efforts are working. Figure 1, for example, shows the changes and improving trends in the three-year rolling averages for the four main performance indicators mentioned above.

The trends in these indicators show a steady performance improvement over the past 17 years, with a slow but constant reduction in LWIF that has stayed below 2.0 for the fourth consecutive year. Although the data suggest that AIF peaked around 1996–97, this could also be due to better data reporting. This is because the AIF indicator was not formally used in all companies in the early years of CONCAWE's data gathering. Since 1997, the trend in AIF has generally been downwards except for a slight increase in 2010.

Regrettably, 14 fatalities in 14 separate incidents were reported in 2010. Two of these fatalities were due to road accidents, three were due to three different confined space entry incidents, and one was caused by a fall. Of the remaining eight fatalities, two resulted from hazards directly associated with maintenance and construction activities while five were caused by burning/electrocution and one was a result of other industrial activities.

The 14 fatalities in 2010 are higher than in 2006, which was the best year over the entire 17 years of data collection (Figure 2). After a steady downward trend during the 1990s, fatalities began to rise again in 2000 with a very high value of 22 fatalities in 2003. Fortunately, this unfavourable trend was reversed in 2004–6 and the fatality numbers have shown little variation since that time. The three-year rolling average for FAR has also stayed at about 2 for the past four years.

In 2010, contractors in the manufacturing sector of the European oil industry were the most vulnerable work group, experiencing 10 fatalities. This is clearly a con-

Table 1 Results of the 2010 PSPI survey

Sector	Manufacturing	Marketing	Both sectors
Companies reporting			
Total	34	23	23
Process safety data	24	11	11
Percentage	71%	48%	48%
Hours worked (Mh)			
Total	237	285.1	522.2
Process safety data	201.7 (177.7)[a]	200	401.7
Percentage	85% (75%)[a]	70%	77%
Tier 1 PSE: *No. of PSEs*	175	32	207
Tier 2 PSE: *No. of PSEs*	546	169	715
Tier 1 PSER: *PSE/Mh reported*	0.87	0.16	0.52
Tier 2 PSER: *PSE/Mh reported*	2.71	0.85	1.78
Total PSER: *PSE/Mh reported*	3.57	1.01	2.30

[a] Figures in brackets are the hours reported by the companies that provided Tier 2 PSE data.

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

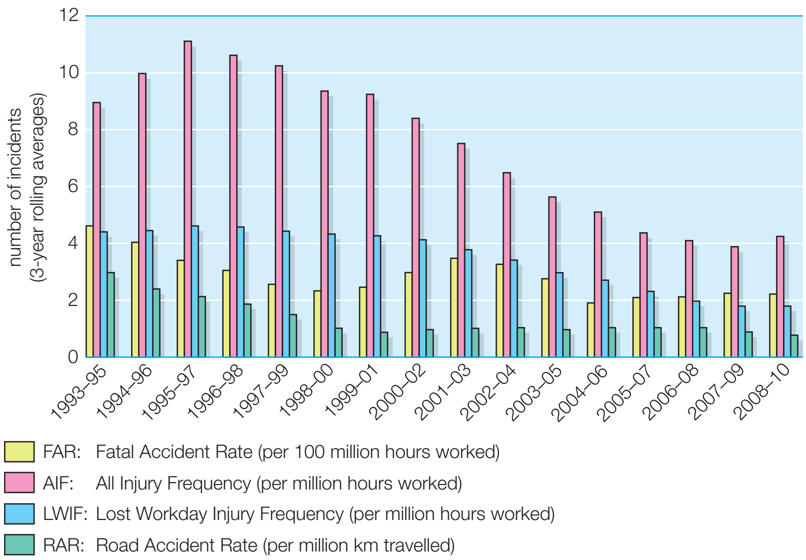


Figure 2 Numbers of reported fatalities since 1993

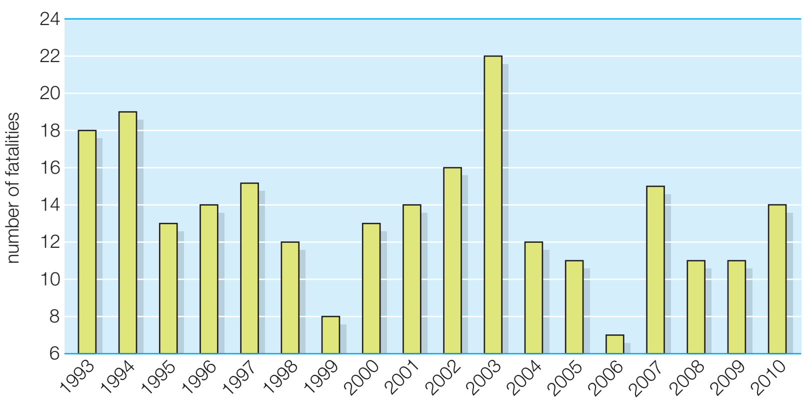


Figure 3 Relationships between incidents and fatalities for the European downstream oil industry

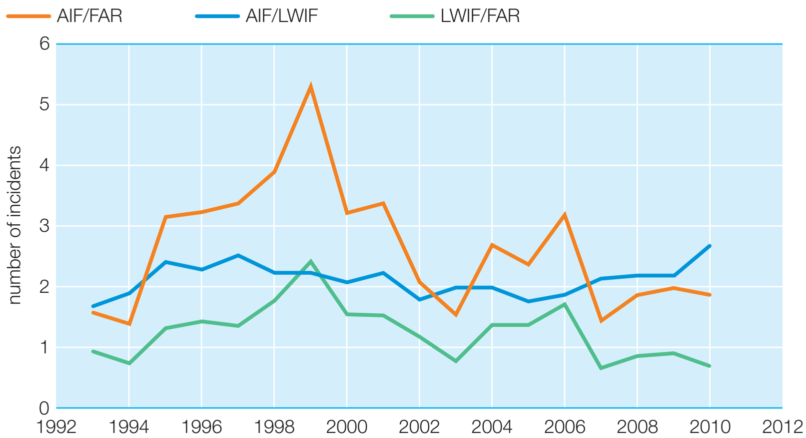


Figure 4 Lost Workday Injury Severity (LWIS) from 1993–2010 and the three-year rolling average in the European downstream oil industry

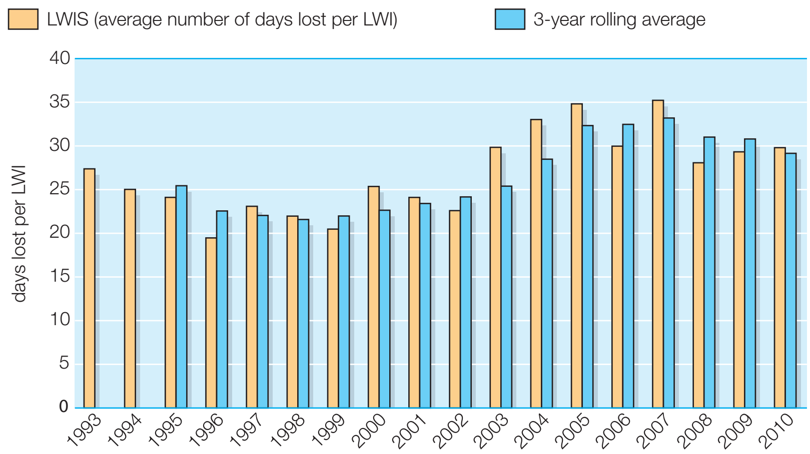
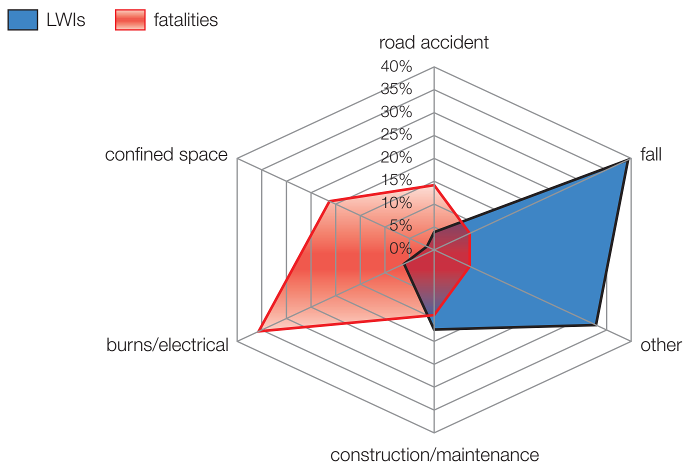


Figure 5 Reported causes on a percentage basis for LWIs and fatalities in 2010



cern and demonstrates that all companies must ensure that their contractor workforce is fully integrated into the company's safety awareness and monitoring systems.

The relationships between the AIF, LWIF and FAR are presented in Figure 3.

Although the number of fatalities per year has an impact on the two curves that are associated with FAR values, the figure shows relatively stable relationships among these indicators over time. Almost half of safety incidents are LWIs and there was approximately one regretted fatality for every 100 LWIs.

Although there have been positive trends in the LWIF and AIF indicators, the LWIS indicator, expressing the average number of days lost per LWI, increased in 2009. LWIS data and the three-year rolling average are shown in Figure 4. Although the LWIS results declined after peaking in 2005, the three-year rolling average still remains above the all-time LWIS average of 25.

Causes of fatalities and LWIs

For the first time in the 2010 survey, CONCAWE also gathered information on the causes of Lost Workday Injuries (LWI) in order to see how closely the LWIs could be related to the causes of fatalities. The LWIs were categorised by the six categories that were previously used to report fatalities. A total of 979 LWIs were reported in 2010 of which 696 (71%) were assigned to one of the 6 agreed categories by the reporting member company.

As can be seen from Figure 5, the percentage data for these LWIs in 2010 show that the distribution of LWI causes is quite different from those that resulted in fatalities.

Because these data are relatively new, there is no basis yet for a robust analysis of trends so CONCAWE will continue to collect these data in future years. It is expected that the results will reveal trends that can be analysed in greater depth, providing valuable data to member companies that can then be used to improve on-the-job safety for employees and contractors.

Abbreviations and terms

AIF	All Injury Frequency
B7	Diesel fuel containing 7% v/v FAME
bbl	Barrel (of oil)
BOB	Blendstock for Oxygenate Blending
CCS	CO_2 Capture and Storage
CEN	European Committee for Standardisation
CEN/TC383	CEN Technical Committee 'Sustainably produced biomass for energy applications'
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DVPE	Dry Vapour Pressure Equivalent
E5	Gasoline containing 5% v/v ethanol
E10	Gasoline containing 10% v/v ethanol
E70	% v/v of gasoline evaporated at 70°C
E100	% v/v of gasoline evaporated at 100°C
EN 16214	European Standard 'Sustainably produced biomass for energy applications'
EN 228	European Standard 'Automotive fuels. Unleaded petrol. Requirements and test methods'
EN 590	European Standard 'Automotive fuels. Diesel. Requirements and test methods'
EGR	Enhanced Gas Recovery
EOR	Enhanced Oil Recovery
ETBE	Ethyl Tertiary-Butyl Ether
EU	European Union
EUCAR	European Council for Automotive R&D
FAME	Fatty Acid Methyl Ester
FAR	Fatal Accident Rate
FCC	Fluid Catalytic Cracker
GHG	Greenhouse Gas
ISO	International Standards Organisation
JRC	Joint Research Centre of the European Commission
kPa	kiloPascal
LOPC	Loss of Primary Containment
LWI	Lost Workday Injury
LWIF	Lost Workday Injury Frequency
LWIS	Lost Workday Injury Severity
mm	Millimetre
MSFD	Marine Strategy Framework Directive
Mt	Million tonnes
NEDC	New European Driving Cycle
N_2	Nitrogen gas
NoMiracle	Novel Methods for Integrated Risk Assessment of CumuLative stressors in Europe
O_2	Oxygen gas
OSPAR	The OSPAR (previously 'Oslo and Paris') Commission for the Protection of the Marine Environment of the North-East Atlantic
pH	Measure of acidity or basicity of an aqueous solution
PSE	Process Safety Event
PSER	Process Safety Event Rate
PSPI	Process Safety Performance Indicator
RAR	Road Accident Rate
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RBMP	River Basin Management Plan
RED	Renewable Energy Directive (2009/28/EC)
v/v	Volume to volume
WEA	Whole Effluent Assessment
WFD	Water Framework Directive

CONCAWE contacts

Secretary General

Michael Lane
Tel: +32-2 566 91 61   Mobile: +32-496 27 37 23
E-mail: michael.lane@concawe.org

Technical Coordinators and Associates

Air quality
Pete Roberts
Tel: +32-2 566 91 71   Mobile: +32-494 52 04 49
E-mail: pete.roberts@concawe.org

Air quality—Research Associate
Lucia Gonzalez
Tel: +32-2 566 91 64   Mobile: +32-490 11 04 71
E-mail: lucia.gonzalez@concawe.org

Fuels quality and emissions
Ken Rose
Tel: +32-2 566 91 69   Mobile: +32-499 97 53 25
E-mail: ken.rose@concawe.org

Health
Arlean Rohde
Tel: +32-2 566 91 63   Mobile: +32-495 26 14 35
E-mail: arlean.rohde@concawe.org

Petroleum products • Risk assessment
Bo Dmytrasz
Tel: +32-2 566 91 65   Mobile: +32-485 54 41 12
E-mail: bo.dmytrasz@concawe.org

Refinery technology
Alan Reid
Tel: +32-2 566 91 67   Mobile: +32-492 72 91 76
E-mail: alan.reid@concawe.org

Water, waste and soil • Safety • Oil pipelines
Klaas den Haan
Tel: +32-2 566 91 83   Mobile: +32-498 19 97 48
E-mail: klaas.denhaan@concawe.org

Office management and support

Finance, Administration & HR Manager
Didier De Vidts
Tel: +32-2 566 91 18   Mobile: +32-474 06 84 66
E-mail: didier.devidts@concawe.org

REACH Legal & Administration Advisor
Sophie Bornstein
Tel: +32-2 566 91 68   Mobile: +32-497 26 08 05
E-mail: sophie.bornstein@concawe.org

Documentation/library
Office administration
Annemie Hermans
Tel: +32-2 566 91 80
E-mail: annemie.hermans@concawe.org

Marleen Eggerickx
Tel: +32-2 566 91 76
E-mail: marleen.eggerickx@concawe.org

Sandrine Faucq
Tel: +32-2 566 91 75
E-mail: sandrine.faucq@concawe.org

Anja Mannaerts
Tel: +32-2 566 91 73
E-mail: anja.mannaerts@concawe.org

Barbara Salter
Tel: +32-2 566 91 74
E-mail: barbara.salter@concawe.org

Julie Tornero
Tel: +32-2 566 91 73
E-mail: julie.tornero@concawe.org

CONCAWE publications

Reports published by CONCAWE from 2010 to date

2010

1/10	Sulphur dioxide emissions from oil refineries in Europe (2006)
2/10	Refinery BREF related environmental parameters for aqueous discharges from refineries in Europe
3/10	CONCAWE effluent speciation project
4/10	Performance of European cross-country oil pipelines: Statistical summary of reported spillages in 2008 and since 1971
5/10	Review of dermal effects and uptake of petroleum hydrocarbons
6/10	CONCAWE compilation of selected physico-chemical properties of petroleum substances and sulphur
7/10	European downstream oil industry safety performance. Statistical summary of reported incidents—2009
8/10	Report of a workshop on environment and health: evaluating European air quality research and translating priorities into actions, 19–20 January 2009
9/10	Advanced combustion for low emissions and high efficiency. Part 1: Impact of engine hardware on HCCI combustion
10/10	Advanced combustion for low emissions and high efficiency. Part 2: Impact of fuel properties on HCCI combustion
11/10	Hazard classification and labelling of petroleum substances in the European Economic Area—2010

2011

1/11	Environmental sensitivity assessment of retail filling stations in selected European countries
2/11	Trends in oil discharged with aqueous effluents from oil refineries in Europe—2005 and 2008 survey data
3/11	Performance of European cross-country oil pipelines: Statistical summary of reported spillages in 2009 and since 1971
4/11	A comprehensive review of European epidemiological studies on particulate matter exposure and health
5/11	European downstream oil industry safety performance—statistical summary of reported incidents—2010
6/11	Cost-effectiveness of emissions abatement options in European refineries
7/11	The potential for application of CO_2 capture and storage in EU oil refineries
8/11	Performance of European cross-country oil pipelines: Statistical summary of reported spillages in 2010 and since 1971
9/11	Acute aquatic toxicity of heavy fuel oils: Summary of relevant test data

Joint publications: JRC/EUCAR/CONCAWE Consortium

Well-to-wheels analysis of future automotive fuels and powertrains in the European context, Version 3c (EUR 24952 EN—2011)

EU renewable energy targets in 2020: analysis of scenarios for transport. JEC Biofuels Programme (EUR 24770 EN—2011)

'Paperless' CONCAWE reports

CONCAWE now issues its new research reports electronically and has discontinued the distribution of hard-copy reports. As soon as a new report becomes available, recipients receive a notification by e-mail, thus speeding up the delivery of CONCAWE's reports while at the same time making them more readily accessible for longer-term storage, searching and retrieval. Another way to receive notification of the publication of a new report is by subscribing to the relevant RSS feeds (www.concawe.org/content/default.asp?PageID=636). Adobe PDF files of virtually all current reports, as well as up-to-date catalogues, can be downloaded from CONCAWE's website at: www.concawe.org/content/default.asp?PageID=569.

CONCAWE

Boulevard du Souverain 165, B–1160 Brussels, Belgium

Telephone: +32-2 566 91 60 • Telefax: +32-2 566 91 81

info@concawe.org • www.concawe.org

MIX
Paper from responsible sources
FSC
www.fsc.org
SPECIMEN