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review

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

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Foreword

Michael Lane,
Secretary General,
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In 2010, CONCAWE and its Member Companies successfully completed the first phase of REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals). CONCAWE was responsible for the common parts of the REACH dossiers for petroleum substances and sulphur, which were then used by our 41 member companies and more than 500 non-member licensees to complete almost 5000 registrations. These registrations represented about 18% of all REACH registrations received by the European Chemicals Agency (ECHA) before the 1 December 2010 deadline.

Although this important phase of REACH has now been completed, much more work is still ahead. The REACH legislation continues to evolve, new guidance is being published by ECHA, and new research studies are constantly being produced. These factors, plus frequent updates to IUCLID (the International Uniform Chemical Information Database), mean that we will need to continue to update our dossiers for future use. We are also receiving licence orders from new market entrants and preparing for the next round of registrations for lower volume products in 2013. We expect that CONCAWE's Substance Information Exchange Forum (SIEF) will need to be maintained for quite some time.

While REACH remains a high priority, other important technical work at CONCAWE has continued. This *Review* begins by highlighting two recent projects from the JEC Consortium, our long-standing collaboration with the Joint Research Centre of the European Commission (JRC) and the European Council for Automotive R&D (EUCAR).

First, JEC's Well-to-Wheels analysis of energy and greenhouse gas (GHG) emissions has been updated, and some new results from Version 3 are previewed here. Another Consortium project, the JEC Biofuels Study, looks at various scenarios for increasing biofuels and other renewables in transport to achieve the 2020 mandates required by major European legislation. This study shows that significant challenges are ahead for both the vehicle and fuel industries in order to meet the EU's legislative expectations by 2020.

As suggested by this study, blending higher levels of ethanol into gasoline is at least one possible means of achieving these future targets. However, when used as a blending component in gasoline, ethanol substantially changes the properties of the final gasoline blend, especially the volatility characteristics. Consequently, in order to better understand these effects, a laboratory blending study was funded by the European Commission to explore the impact of ethanol, from 5% to 25% volume, on the volatility of the final ethanol/gasoline blend.

In March 2011, CONCAWE and two partners, the UK's Energy Institute and Germany's DGMK, co-sponsored a one-day workshop to discuss the problems of microbes and microbial growth in fuel storage tanks. About 160 people attended this workshop to discuss monitoring and mitigation approaches, showing that this topic is of considerable interest to our industry.

For many years, CONCAWE has published an annual analysis of safety statistics for the refining industry and the latest safety results are described in this *Review*. In previous reports, we have focused on personal injury data and, 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 analysis for process safety that will complement our annual safety statistics on personal injuries.

The last article in this *Review* is an interview with Gary Minsavage, CONCAWE's Technical Coordinator for Health Sciences, who recently completed his three-year assignment and returned to ExxonMobil Biomedical Sciences Inc. to continue his corporate career. Gary gives us his perspective on CONCAWE's past, present and future research related to health and petroleum substances. We would also like to thank Gary for his very significant contributions to our health sciences research and REACH registration activities.

With Gary's return to the USA, we are pleased to announce that Ms Arlean Rohde has been selected as CONCAWE's new Technical Coordinator for Health Sciences, and started work in July. Arlean is seconded to CONCAWE from ExxonMobil Chemical Company in Houston, Texas where she has worked as a Regulatory Affairs Coordinator. We are delighted to welcome Arlean and her husband, Bill, to Brussels.

Contents

The JEC Well-to-Wheels Study

The JEC's Well-to-Wheels report has been updated with new results on biofuel production pathways.

In 2000, when the 'JEC' Consortium was formed (see the box on page 7), the first area identified for joint research was the 'cradle-to-grave' comparison of conventional and alternative road fuels and powertrains in Europe. In those early days, 'Well-to-Wheels' (WTW) was a comparatively new concept, requiring new data and new approaches. It was also an excellent starting point for the JEC's scientific and technical studies in areas of common interest.

Thus, the JEC WTW Study was conceived with little expectation that, ten years later, it would still be relevant and providing a scientific benchmark for evaluating future fuel, vehicle and energy options. At the start, the objectives of the JEC study were to:

- assess the WTW energy use and associated greenhouse gas (GHG) emissions for a wide range of automotive fuels and powertrains that were expected to be important to Europe; and
- assess the viability of each of these fuel pathways including best estimates for the associated macro-economic costs.

While the WTW Study integrated results from 'cradle to grave', companion reports separated the WTW results into two discrete steps: 'Well-to-Tank' (WTT) and 'Tank-to-Wheels' (TTW). These reports, taken together, provided a more detailed understanding of how the energy and GHG differed for fuel production steps (the WTT part) and fuel consumption steps in vehicles (the TTW part).

Version 1 of the JEC's WTW Study was published in December 2003 and Version 2 followed in January 2007 with updates to pathways and results. While new TTW results were released in December 2008, the complete Version 3c combining the WTT and WTW parts will be published soon.

This article provides an overview of the WTW studies and a preview of the new or modified results in Version 3c compared to previous versions.

Scope and methodological choices

Figure 1 shows the scope of the JEC WTW Study. Plausible primary energy resources and transport fuels are included as well as vehicle powertrain options such as: internal combustion engines (ICEs) fuelled by liquid fuels, natural gas and hydrogen; various hybrid configurations; and fuel cells (including on-board fuel reformers). Pure battery electric vehicles have not been included in the WTW Study so far and may be addressed in the next revision. The time horizon, which was originally 2010 in earlier versions of the study, has been extended to 2020 for which today's state-of-the-art technologies (both WTT and TTW) are considered to be representative.

Figure 1 Scope of the Well-to-Wheels Study

Primary energy

- crude oil
- coal
- natural gas
- biomass
- wind
- nuclear

Including preliminary views on carbon capture and sequestration

Fuels

- fossil gasoline, diesel and naphtha
- synthetic diesel
- compressed natural gas (CNG) (including biogas)
- liquefied petroleum gas (LPG)
- methyl tertiary-butyl ether (MTBE)/ ethyl tertiary-butyl ether (ETBE)
- hydrogen (compressed/liquid)
- methanol
- dimethyl ether (DME)
- ethanol
- biodiesel including methyl and ethyl esters of fatty acids (FAME/FAEE)

Powertrains

- spark ignition: fossil gasoline, CNG, LPG, ethanol and hydrogen (H_2)
- compression ignition: fossil diesel, DME and biodiesel
- fuel cell
- hybrids: spark ignition; compression ignition; fuel cell
- hybrid fuel cell and on-board fuel reformer

Single vehicle platform: medium-sized EU car

The JEC's WTW reports are available for free download from the website of the European Commission's Joint Research Centre: http://ies.jrc.ec.europa.eu/about-jec

In general, the fuel pathways and underlying data examined in the study are representative of the European situation. There are some exceptions, such as fuels produced from Brazilian sugar cane or from East Asian palm oil.

The way in which energy and GHG emissions relate to co-products is a critical methodological choice in any WTW study. In the JEC study, we calculate credits or debits associated with co-products based on a 'substitution' method which provides the closest representation of 'real life' practice. 'Substitution' means that co-products from fuel production are credited based on the product that they are most likely to replace, for example, pressings from oil seeds can be substituted for soy meal as animal feed. The downside to this approach is that the WTW results will depend on the specifics of the substitution scenario that is considered, and these must be clearly defined.

For biomass-based fuels, it is now well-recognised that the effect of land use change (LUC), both direct and indirect can, in many cases, significantly affect GHG emissions. Considerable work on LUC effects is in progress by many researchers and governments. However, the JEC Consortium is not yet in a position with Version 3c to provide credible estimates of LUC impacts on GHG emissions, so these are not included in the JEC's WTT results at the present time. The focus has been on specific fuel production chains, and LUC effects related to these chains are being considered as one option for future study.

What is new or changed in Version 3c?

Focusing first on the WTT results, several changes and some additions have been made in Version 3c.

Crude oil production

In earlier versions of this study, GHG emissions associated with crude oil production were reported to be 3.3 gCO_2/MJ (with a range of 2.8–3.9). This value was estimated from an average of results provided by the International Oil Companies (IOCs) dating back to the 1990s. An update to this crude oil production figure was needed because GHG emissions reporting was not as well developed a decade ago as it is today. Recent industry statistics from the International Association of Oil & Gas Producers (OGP), and flaring and venting data collected by the National Oceanic and Atmospheric Administration (NOAA), has provided a more relevant basis.

Using these data, a new estimate for the EU average crude oil supply is reported in Version 3c. This new estimate is 4.8 gCO_2/MJ (with a range of 3.6–6.1), an increase of 1.5 gCO_2/MJ compared to earlier results. This addition to the crude oil production step translates into an increase in the total WTW GHG emissions for gasoline and diesel fuel production to 87.6 and 89.2 gCO_2/MJ, respectively, including CO_2 from fuel combustion. Although these appear to be small changes, they are relevant updates, since fossil products provide the baseline against which new processes for biofuels and alternative energies are compared.

Biofuel pathways: modified data and new options

Since the release of Version 2 in 2007, legislative initiatives in the EU and in North America have provided strong incentives for introducing more bio-blending components into transport fuels. This has resulted in new production data from commercial facilities for many existing biofuel pathways as well as the development of entirely new biofuel pathways.

Figures 2 and 3 summarise the new results from the Version 3c report for selected ethanol and biodiesel pathways. These results are expressed as the percentage savings of both fossil energy and GHG emissions compared to conventional fossil gasoline or diesel fuel, as applicable.

These figures highlight the importance of the biomass source or crop that is used to produce the bio-component as well as the accounting mechanism for co-products and residues. For ethanol, plausible domestic pathways for ethanol production span the entire range from 10% to nearly 100% GHG savings compared to conventional fossil gasoline. For many biodiesel pathways, the GHG balance is particularly uncertain because of the contributions from agricultural nitrous oxide emissions, a potent GHG. Using soy as an example, the effect of nitrous oxide emissions is exacerbated by the large yield of soy meal co-product that must be used for other purposes.

Figure 2 New results for selected ethanol pathways

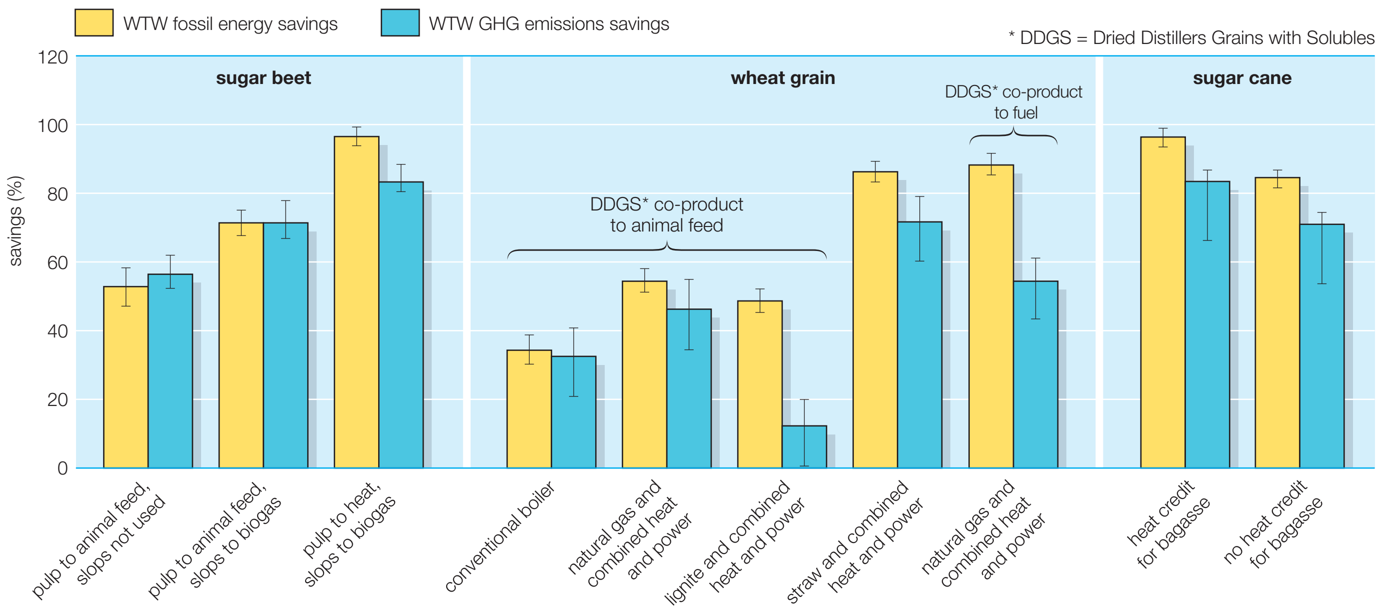
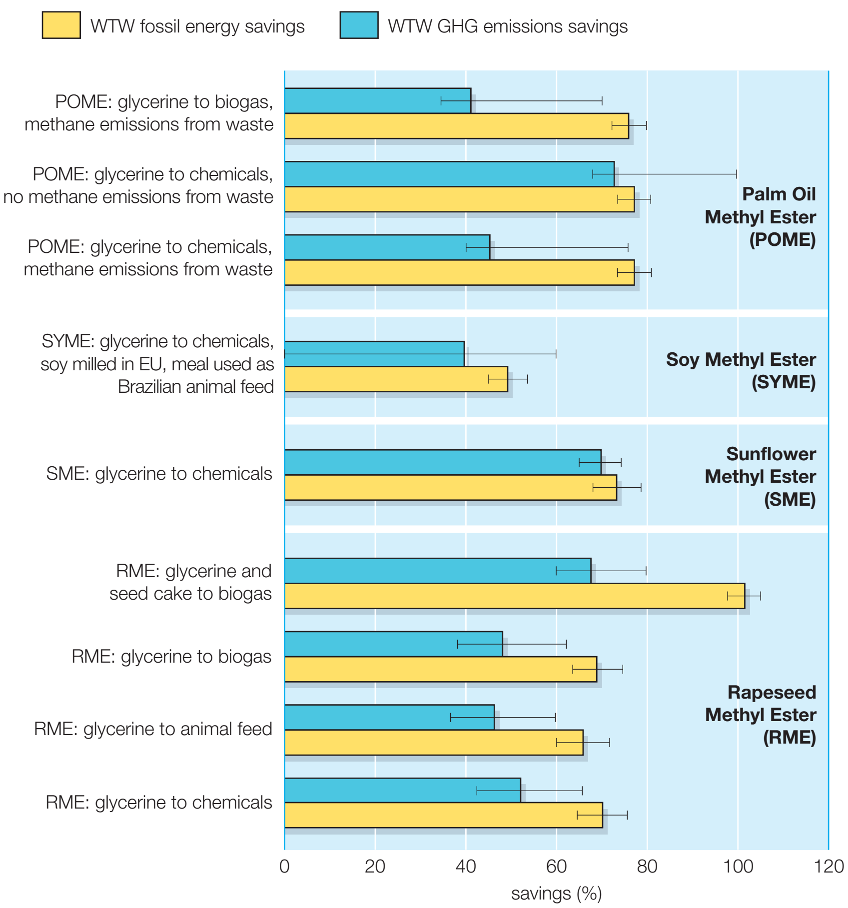


Figure 3 New results for selected biodiesel pathways



Hydrotreated vegetable oil (HVO) processes are an attractive way to produce high-quality hydrocarbons from vegetable and animal oils. For a given vegetable oil, Figure 4 shows that different pathways to produce HVO and biodiesel are very close in terms of their overall GHG savings potential. Two different HVO technologies considered in Version 3c (NExBTL from Neste Oil and a pyrolysis oil technology offered by Honeywell UOP) are essentially equivalent for GHG savings.

Version 3c also includes new data for pathways to produce biogas from dedicated crops rather than from waste material.

Heat and power

Previous versions of the study included electricity production pathways that were then used as inputs to many of the fuel pathways that require electricity in the production process. Continuing this approach, Version 3c now includes heat production pathways, both at domestic and industrial scales, as well as several combined heat and power (CHP) approaches.

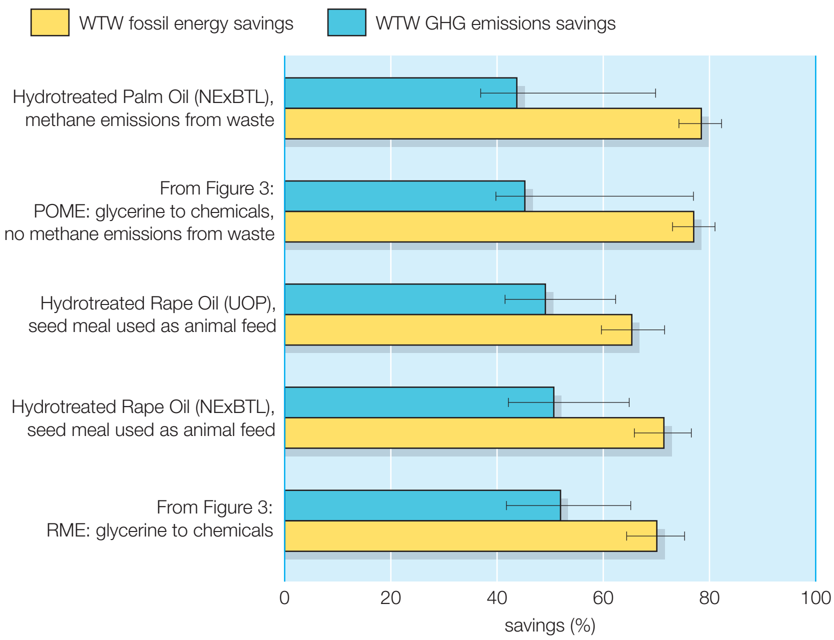
Tank-to-Wheels

For the TTW results, the assumed vehicle performance characteristics have been updated. The primary change is that the gap in engine efficiency between gasoline and diesel ICEs has been extended in time. This reflects a slower than expected narrowing of the efficiency difference between these engine types over the past ten years.

Where next?

Clearly, the WTW approach has proven to be a valuable scientifically-based tool for comparing and contrasting the energy, GHG, and cost performance of different fuel and vehicle options. The speed with which the WTW approach has matured has been dramatic. Both within the JEC Consortium and among the international research community, substantial work is in progress so that important energy and GHG-related decisions can be made more quickly and reliably on a 'well-to-wheels' basis.

Figure 4 Oil seed pathways to FAME and Hydrotreated Vegetable Oil



What is the JEC Consortium?

If you have heard of the 'JEC Consortium' before, it is most likely through work related to the development of the Well-to-Wheels (WTW) methodology and results. Although this is still a central part of the JEC Consortium's work, the scope of its activities has grown considerably over the years.

In 2000, CONCAWE recognised the importance of joining forces with the European Council for Automotive R&D (EUCAR) and the Joint Research Centre (JRC) of the European Commission on topics of common interest. The 'JEC Consortium' formed by these three partners was designed to pursue scientific and technical studies in evolving areas of road transport. A Scientific Advisory Board consisting of senior managers and researchers from all three organisations is responsible for agreeing on the scope of new projects and stewarding the completion of results.

One of the first technical areas identified by the Consortium was the development of scientifically robust tools for comparing different combinations of vehicles and fuels from 'Well-to-Wheels' (WTW), that is, from fuel production to its consumption in vehicles. It was quickly recognised that experimental measurements could not provide all of the answers on the energy requirements and GHG emissions for new vehicle and fuel technologies, and that new approaches would be needed.

The JEC's WTW work has stood the test of time with Version 3c of the WTW Report to be published in 2011, and work already in progress on Version 4. The JEC approach has also been recognised by the European Commission as a 'sound science' way to value different biofuel manufacturing pathways and products, and served in 2009 as an important input into European legislation on renewable and alternative fuel products for energy use.

Although WTW has been its most visible work product, the JEC Consortium has pursued research in other areas as well. Vehicle studies have focused on evaporative emissions, fuel consumption, and regulated emissions from ethanol/gasoline mixtures. The Consortium also recently published results of the 'JEC Biofuels Study Programme', a project to assess the challenges associated with possible biofuel implementation scenarios to achieve the 2020 targets and objectives of the EU's Renewable Energy and Fuels Quality Directives.

Most importantly, all of the JEC's work is published on the Joint Research Centre's website and is freely available for download, review, and critique by interested researchers and organisations. The Consortium members monitor an email address (infoJEC@jrc.ec.europa.eu) for those who have questions or find technical errors in the published work that should be corrected in future revisions.

The JEC Biofuels Study

Nine biofuel implementation scenarios have been analysed to determine their potential to meet future renewable energy and GHG emissions reduction targets.

The final report of the JEC Biofuels Programme is available for free download at http://ies.jrc.ec.europa.eu/about-jec

Increasing renewable energy in transport

For many years, it has been recognised that energy demand and greenhouse gas (GHG) emissions from the transportation sector are expected to rise over the coming decades, with increasing demand for passenger and freight transport offsetting efficiency gains. In fact, transport is the only European sector in which GHG emissions are increasing rather than decreasing, because energy efficiency measures can be more easily implemented in heavy manufacturing, power generation, building construction and other areas.

In 2009 and 2010, in order to address this trend, the European Union enacted a package of Directives intended to reduce GHG emissions and ensure security of energy supply for the transport sector. These Directives required improvements in the CO_2 emissions performance of passenger vehicles and light-duty vans, as well as an increase in the use of renewable and alternative energies in transport fuels by the end of this decade.

Two of these Directives will have a direct impact on the composition of road fuels over the coming decade and beyond. The Renewable Energy Directive (RED, Directive 2009/28/EC) mandates that 10% renewable energy must be blended into transport fuels by 2020. This energy target translates into more than 14% on a volume basis, assuming that the majority of this obligation will be achieved by blending biofuels into today's service station fuels.

Although advanced biofuel products are being developed that will be manufactured from biomass, e.g. straw and wood, the biofuels that will be available in large volumes by 2020 will either be ethanol fermented from sugars, or esterified vegetable oils and animal fats. Ethanol can be blended today at up to 5% volume in gasoline (E5) while esterified oils, called fatty acid methyl esters (FAME), can be blended at up to 7% volume in diesel fuels (B7)[1]. Smaller volumes of speciality biofuel blends, like E85 or B100, can also be used in specially adapted vehicles. The European Committee for Standardization (CEN) is working to revise the EU-wide fuel standards and increase the allowed blending percentages of biofuels to higher levels.

At the same time, the Fuel Quality Directive (FQD, Directive 2009/30/EC) mandates that fuel suppliers must reduce the GHG emissions of transport fuels by 6% in 2020 compared to 2010 performance. Although efficiency improvements in the fuel manufacturing process will contribute a small amount to meeting this target, the increasing demand for transport fuels, and diesel fuel in particular, means that the majority of this GHG performance improvement must be achieved through biofuel blending. Default values for the GHG performance of different ethanol and FAME manufacturing pathways are included in the FQD.

The 2020 targets have been clearly legislated but the options to reach these targets have not. It has largely been left to Member States and the transport sector to determine these options. Each Member State has now documented how they intend to meet their specific obligations through National Renewable Energy Action Plans (NREAPs), submitted in 2010. These plans vary significantly from one country to the next, depending upon the specifics of the country's transport demands and the availability of alternative energy options for all modes of transport.

The JEC Biofuels Programme

Understanding the achievable options for meeting both the RED and FQD obligations is a complicated task. With different priorities and pace of implementation planned in each Member State, the potential for increasingly uncoordinated changes in fuel blends and vehicle types is considerable. This could lead to fragmentation of the fuel market, making it much more difficult to achieve the 2020 targets.

While the EU Directives were still in draft form, the three partners in the JEC Consortium—the Joint Research Center (JRC) of the European Commission, the European Council for Automotive R&D (EUCAR) and CONCAWE—decided to look closely at this problem. The JEC Biofuels Programme was initiated in early 2008 to examine possible biofuel implementation scenarios for mass market fuels, that could potentially achieve the

[1] Biofuel contents are expressed as a percentage of bio-component in fossil fuel on a volume basis. For example, B7 is 7% v/v fatty acid methyl ester (FAME) in diesel fuel, E5 is 5% v/v ethanol in gasoline, and E85 is 85% v/v ethanol in gasoline.

10% RED target for transport fuels by 2020. Using the scenario results and the FQD's GHG default values for different renewable products, it was also possible to calculate the 2020 GHG emissions reductions associated with different biofuel blending options and volumes.

Nine scenarios were evaluated using reasonable assumptions for the development of the on-road vehicle fleet over the coming decade and the likely penetration of new vehicle technologies, such as plug-in hybrids, electric vehicles, compressed natural gas (CNG) and liquefied petroleum gas (LPG) powered vehicles, etc. A contribution to the RED mandate was also assumed from non-road transport, including inland waterways, rail, aviation and other off-road applications.

Figure 1 Change in energy demand by fuel type in the road transport sector, based on the study's 'Reference Scenario'

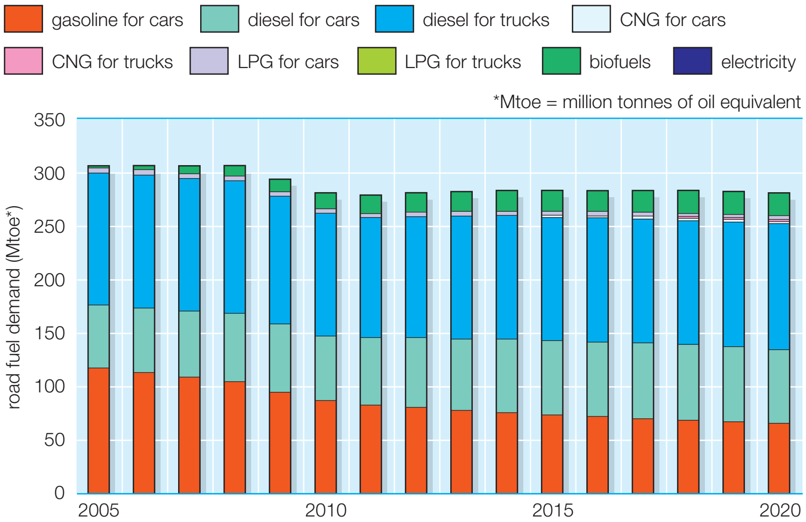


Figure 1: In the study's Reference Scenario, overall gasoline demand will decrease by 24% by 2020, whilst diesel fuel demand increases by 6%. Increasing demand for biofuels, gaseous fuels and, to a smaller extent electricity, is also observed.

The 'Fleet and Fuels' Model

To evaluate these scenarios, the JEC team first needed a handy yet robust modelling tool. The first phase of the study developed and validated a spreadsheet-based simulator called the 'Fleet and Fuels' model. This model is based on historical vehicle fleet data for the EU-27+2 countries (including Norway and Switzerland) and was benchmarked against actual fuel consumption data from the 1990s and 2000s. The model allows independent inputs for seven types of passenger vehicles including flexi-fuel, hybrid electric and battery electric, three classes of commercial vans, and five classes of heavy-duty vehicles and buses. Each vehicle type was described by fixed but adjustable parameters estimating the annual growth rate, typical annual mileage, vehicle fuel efficiency and years of useful life. Fuel alternatives were also considered for each vehicle type.

For service station fuels, two different biofuel levels were allowed for both gasoline and diesel fuels. Fixed percentages of other fuel options were also assumed for E85, CNG, LPG and electricity. Outputs from the model included new vehicle sales, vehicle fleet composition and the projected demand for different fossil fuels, renewable fuels and alternatives.

Figure 1 shows an example in which the energy demand by fuel type is shown from 2005 to 2020. Over this time period and for this 'Reference Scenario', overall gasoline demand is projected to decrease by about 24% while diesel fuel demand increases by about 6%. This increase is due to higher demand from increasingly popular diesel passenger cars and from heavy-duty trucks. Increasing demand for biofuels, gaseous fuels and, to a smaller extent, electricity is also observed. The impact of the 2008–09 economic recession on energy demand is also evident in this figure.

Because the RED counts renewable and alternative energy used in all transport modes, estimating the RED contributions that could be expected from railroads, inland navigation, aviation and other off-road uses was also important. Credible estimates from public sources for non-road transport demand were evaluated so that the RED percentage could be calculated for each scenario using the legislated formula.

The 'Reference Scenario'

With a model of this type, there is no limit to the number of biofuel implementation scenarios that can be tested. In the end, nine scenarios, including the 'Reference Scenario', were selected for more detailed analysis. The Reference Scenario is shown in Figure 2 and represents a baseline scenario relying on the implementation of already-endorsed market fuel standards. As shown in this figure, two gasoline grades are assumed, an E5 'protection grade' for older vehicles and an E10 'main grade' for most vehicles marketed since 2005.

Figure 2 Assumed change in gasoline and diesel biofuel blends in the study's 'Reference Scenario'

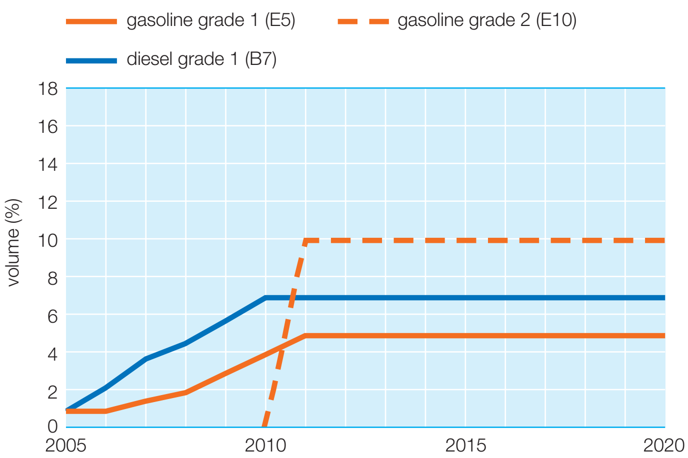


Figure 3 Ethanol and FAME required in 2005 and 2020 to meet the 'Reference Scenario' using E5, E10 and B7 blends

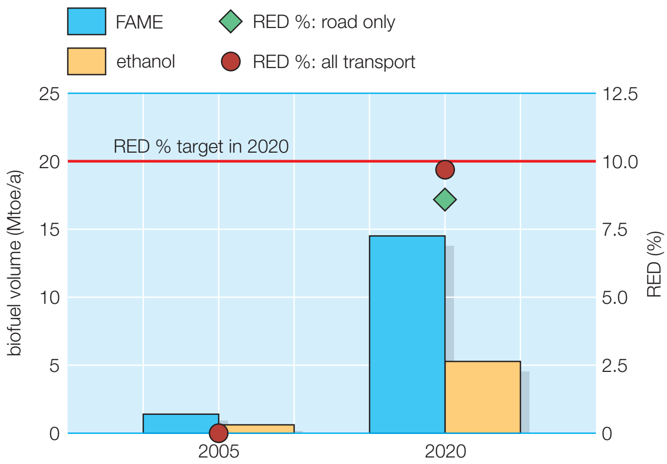


Figure 3: The study's Reference Scenario, which includes a reasonable contribution from non-road transport modes, falls short of the 10% RED target for renewable energy in transport by 2020.

Only one diesel grade was assumed, a B7 grade that can be used in all passenger and heavy-duty diesel vehicles. A contribution for E85 demand from flexi-fuel vehicles was included as well as assumptions for the development of alternatively-powered vehicles including hybrid and battery electrics and vehicles operating on gaseous fuels.

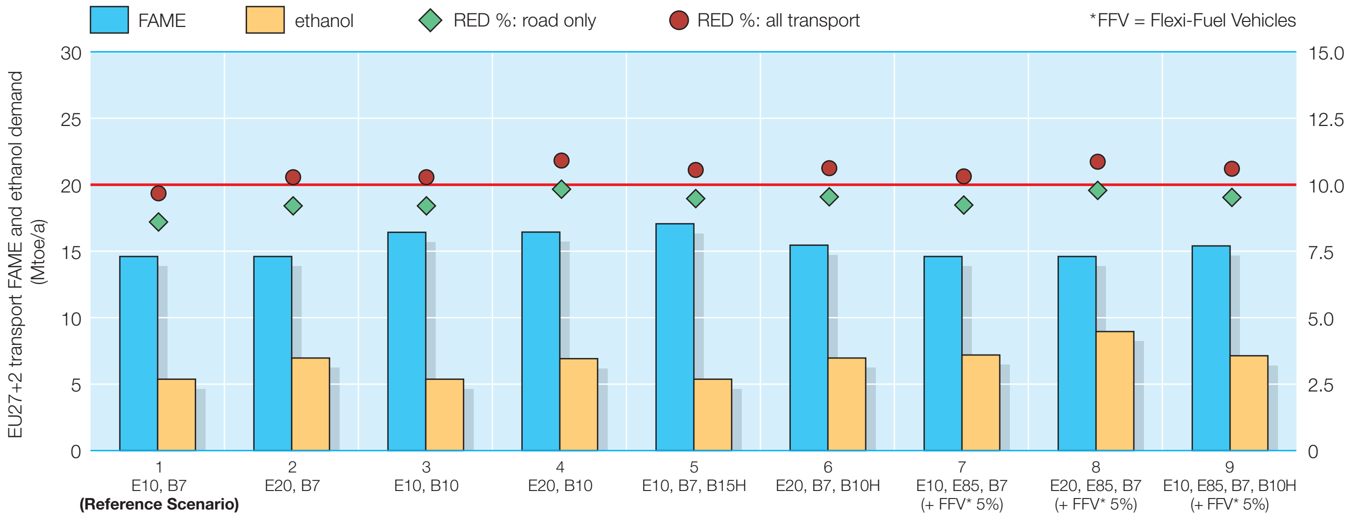
With these vehicle types and fuel grades, the model was then used to estimate the biofuel demand volumes and their overall contribution to the RED mandate. Figure 3 shows that this Reference Scenario would require about 15 Mtoe/a of FAME for diesel blending and about 5 Mtoe/a of ethanol for gasoline blending in 2020. The RED percentage from road use only is about 8.6%, with an additional 1% contribution from non-road transport modes. Thus, the Reference Scenario is projected to fall short of the 10% RED mandate, despite using particularly optimistic assumptions about the pace of advanced biofuel implementation, the number of vehicles compatible with higher biofuel levels, and the willingness of customers to select the fuel grades containing higher biofuel contents. Significant questions related to implementation costs, implications for refining and the fuel supply and distribution system, and the availability and certification of sustainable biofuels have not been addressed so far.

Beyond the Reference Scenario

Eight other 'technically feasible' scenarios were also analysed, based on higher biofuel contents, multiple grades, increasing shares of compatible vehicles in the fleet, and customers' willingness to choose the right fuel for their vehicle. As shown in Figure 4, an evaluation of these eight scenarios shows that the 10% RED target can perhaps be reached using higher biofuel blends, such as E20, B15 for compatible vehicles, or a larger market share for E85. Importantly, the 1% RED contribution from non-road transport is essential in order to meet the RED mandate. Without this contribution, the RED percentage only approaches the 10% mandate using optimistic assumptions about the pace of biofuel implementation and the availability of compatible vehicles.

None of the selected scenarios, however, achieves the minimum 6% GHG reduction target mandated in the FQD, without significant improvements in the GHG reduction performance of readily available biofuels over the next 10 years compared to the legislated GHG default values. The study estimated that the average GHG reduction performance for all biofuels assumed in these scenarios would need to be better than 63% in order to meet the FQD mandate—a value much higher than that included in the FQD legislation. Potential complications due to implementation costs, indirect land use change, and sustainability certification of biofuel production have not been considered in this study.

Figure 4 The demand in 2020 for FAME and ethanol for nine different biofuel implementation scenarios. The projected contributions to the RED % are also shown for road use only and for all transport modes.



An additional part of the study was an assessment of the assumptions used in the modelling work. Because there are many variables for vehicles and fuels, understanding how sensitive the estimated RED percentage might be to these variables was also evaluated. A sensitivity analysis was undertaken which showed that the use of FAME blends higher than B10, the pace of development of advanced biofuels, the E85 demand from flexi-fuel vehicles, and the use of renewable electricity in rail transport were especially important.

Customer acceptance for fuelling their compatible vehicles with higher biofuel levels is also critical in order to reach the RED mandate and to approach the FQD GHG reduction target. For example, the study assumes that all flexi-fuel vehicles will be fuelled with E85 for at least 90% of their distance travelled and that consumers will always choose the highest available biofuel grade that is compatible with their vehicle. Slower introduction of higher biofuel blends and compatible vehicles would have a substantial negative impact on reaching the RED mandate and GHG reduction from the transport sector.

Additional considerations

This study did not assess the viability, costs, logistics or the impact on the supply chain and vehicle industry of the different demand scenarios. Additional work would be needed to determine the technical and commercial readiness of any one scenario. Realising any one of these 'technically feasible' scenarios will depend on a combination of factors, the associated costs, the timelines and coordination of decisions across the EU, and demand trends at the global level.

The suitability of a biofuel scenario will depend on the specific national needs. It is important, however, that harmonization proceeds in a coordinated way to avoid market fragmentation for both vehicles and fuels. The compatibility between fuel blends and vehicles will control the pace of introduction, and it will be important to avoid a proliferation of nationally-adapted solutions. Multi-stakeholder coordination and timely decisions will be essential in order to approach the 2020 targets.

The JEC Biofuels Study recognises that much more technical work is needed to ensure the feasibility of any one scenario. The compatibility of different biofuel types with road and non-road vehicles is not yet proven, and the evaluation process to ensure compatibility will require time, testing and investment. For this reason, these questions need to be addressed using a coordinated European approach and with the input of all stakeholders.

Figure 4: The nine scenarios evaluated in the study show that it may be possible to meet the RED % target but that renewable energy in non-road transport modes and the coordinated implementation of higher biofuel blends will be essential.

Microbes in the system

A workshop co-sponsored by CONCAWE, the UK's Energy Institute and Germany's DGMK looks at the problem of microbial growth in fuel supply and distribution systems.

'Microbe' is an overly general term for a wide range of bacteria, fungi and yeasts that are frequently found in air and water, and are capable of building themselves a comfortable home in fuel supply storage tanks and distribution systems. These micron-sized cells (much smaller than the diameter of a human hair) readily multiply to form organised microbial communities in the presence of water, trace elements required for cell growth, and a suitable food source such as biodiesel or aviation fuel. Once growth has started, these communities can rapidly form microbial mats or 'biofilms' that can coat tank walls, plug fuel supply filters, and even lead to the corrosion of tanks and other metal parts. Fortunately, in-line filters at service station pumps are effective at removing microbes from the fuel during the dispensing process. However, frequently blocked fuel filters often provide an early warning that microbial growth may be flourishing in storage tanks.

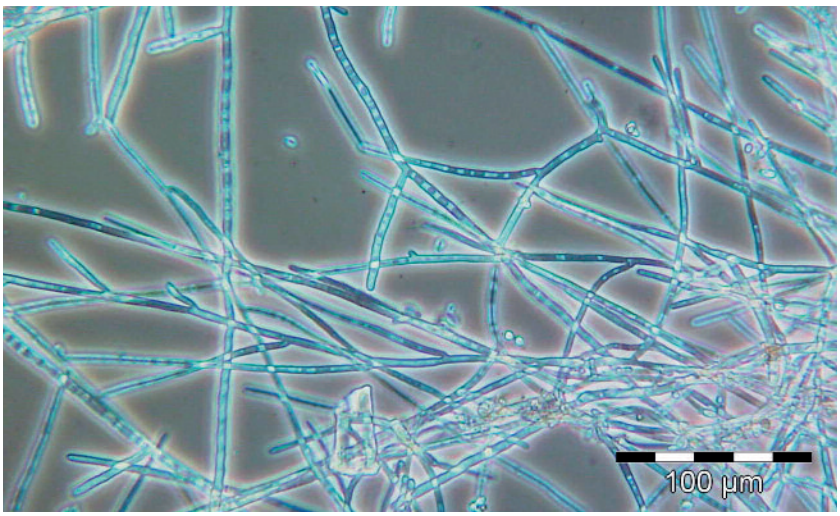
Dealing with microbial growth problems can have a significant and disruptive impact on day-to-day fuel supply operations. It is an urgent concern for those responsible for distributing high quality transport fuels to the marketplace. For this reason, about 160 experts recently came together in Brussels for a one-day workshop on microbial growth in fuel supply and distribution systems, in order to share experiences and possible solutions. The workshop, held on 16 March, was co-organised by CONCAWE and two partner organisations—the Microbiology Committee of the Energy Institute (EI) and DGMK (the German society for petroleum and coal science and technology, located in Hamburg). Workshop participants included: those responsible for fuel logistics operations in pipelines, terminals and service stations; microbiologists familiar with the fundamentals of microbial growth; manufacturers of measurement equipment and mitigation solutions; and others with an interest in the impact of biofilms on fuel products, equipment operations and vehicles.

The workshop had four objectives, which were to: understand how microbial growth problems occur in the first place; share best practices on how to measure their presence and mitigate their effects; identify areas for future research; and network with others who are interested in the same issues. To address the last objective, the workshop included a commercial exhibition that allowed attendees to meet and exchange business cards with suppliers of measurement test kits, and with experts in tank cleaning and biocide treatments.

The workshop covered five important questions: What is the industry experience? What environmental conditions can contribute to microbial growth problems? How are these problems routinely measured and monitored? How can microbial growth problems be mitigated? What additional research is needed in order to understand and deal with these problems?

These micron-sized cells can multiply to form organised microbial communities in the presence of water, trace elements required for cell growth, and a suitable food source such as biodiesel.

Figure 1 Microscopic photo of one type of micro-organism found in a fuel storage tank



Although microbe problems have been known for many decades, increasing fatty acid methyl esters (FAME—derived from vegetable and animal oils) in diesel fuels while decreasing the concentration of residual sulphur- and nitrogen-containing molecules have generally favoured more microbial growth. More FAME in the fuel increases the food and nutrient supply, while lower sulphur and nitrogen molecules may deplete potential microbial poisons. While some microbes are genetically engineered to grow well in oxygenated environments, others are quite content in oxygen-free or anaerobic environments, so understanding the specific needs of common microbes is important to routinely mitigating their growth in fuel supply and distribution systems.

Taking action

Water is the key, however—without water, growing and sustaining a microbial community is very difficult. For this reason, routine monitoring of storage tanks, using test kits that are sensitive to microbes, helps spot problems early enough so that remedial treatments can be avoided or can be put into action quickly if needed. Although aggressive biocide treatments are sometimes needed to mitigate microbial blooms, good housekeeping, especially draining storage tanks of residual water layers, is an essential control strategy. This means that a routine maintenance and remediation action plan must be in place before problems occur, and is an increasingly important quality control tool for terminal and service station operators.

Unfortunately, microbe problems are sometimes not spotted early enough and a broad-spectrum biocide from a speciality chemical company may be needed as well as an expert in biocide application and tank remediation. Although these approaches can be effective, over-using biocide treatments runs the risk that microbes can eventually adapt to today's chemical treatments, leading to the need for new and ever more aggressive options. More research was identified at the workshop to keep ahead of these problems, including obtaining more complete and detailed information on different microbial types that are found in fuel systems, faster and more specific monitoring kits and more targeted biocide treatments.

The workshop presentations are available on the 'Events' page of the CONCAWE website. The three organisations that hosted the workshop are planning to issue a full report on the proceedings later this year. The EI's Microbiology Committee is also currently working on new guidelines for managing microbial growth problems in fuel supply and distribution systems, which will be published soon—for more information see www.energyinst.org/microbiology-bulletin.

Figure 2 A typical biofilm that can be found in an affected fuel supply system

Once growth has started, microbial communities can rapidly form mats or 'biofilms' that can coat tank walls, plug fuel supply filters, and even lead to the corrosion of tanks and other metal parts.

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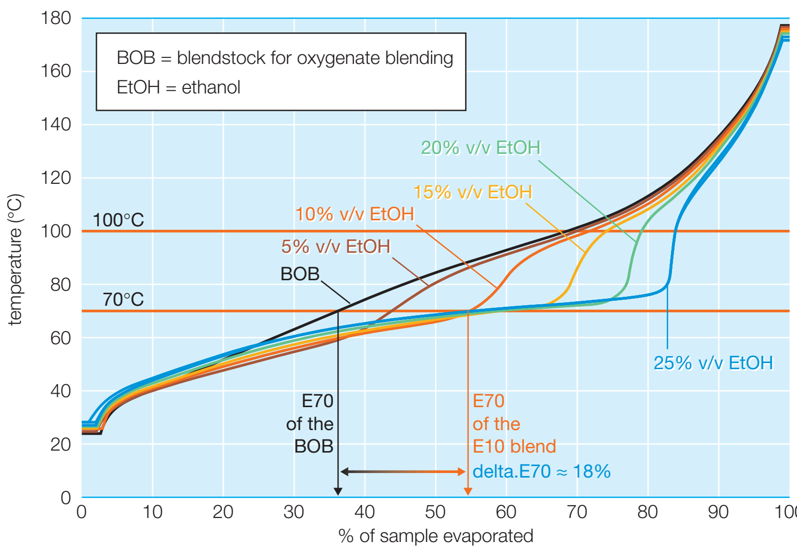
Understanding the volatility of ethanol/gasoline blends

A laboratory study probes complex blending behaviour by observing the impact of ethanol content on the distillation properties of gasoline blends.

The EU's Renewable Energy Directive (RED, 2009/28/EC) mandates that 10% of transport fuels on an energy basis must be derived from sustainably produced, renewable sources by 2020. As also required by the RED, each Member State must evaluate how they intend to reach their individual mandate based on their unique combination of energy resources and transport demands. The results of these evaluations have been published in each country's National Renewable Energy Action Plan (NREAP). In general, the NREAPs anticipate that conventional bio-components, such as ethanol from sugar fermentation and fatty acid methyl esters (FAME) esterified from natural oils, will largely be used to meet the 2020 mandates because of the slower pace of development of more advanced bio-components. Although today's EU-wide specifications allow up to 5% v/v ethanol in gasoline (E5) and up to 7% v/v FAME in diesel fuel (B7), work is progressing in the European Committee for Standardization (CEN) to increase these blending limits.

Both ethanol and ethers, such as ethyl tertiary-butyl ether (ETBE) or methyl tertiary-butyl ether (MTBE) will be used to increase the oxygenate fraction in gasoline fuels. Because of its special properties, however, ethanol imparts especially large property changes when it is blended at low concentrations into gasoline. 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) are two important specification parameters for gasoline because these values are known to have an effect on the driveability performance and 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 in gasoline 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 specification value allowed for market fuels, the volatility of the BOB must be lowered by adjusting the composition of the BOB. This 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.

CONCAWE evaluated the published literature associated with this effect, as well as the impact of volatility changes on vehicle performance (see CONCAWE Report 8/09). The results of this review showed that the analytical data on different ethanol/gasoline blends are limited, especially for ethanol concentrations at 10% v/v and higher. The lack of enough reliable data and predictive models for the effect of ethanol on the blend's volatility makes it difficult to anticipate what properties should be controlled to ensure that ethanol/gasoline blends are always on-specification and cost-effectively manufactured.

To develop these data and explore these effects, CONCAWE and Shell Global Solutions UK formed a consortium in 2009–2010. This project was called the 'Bioethanol/Petrol: 5-25 Study' or BEP525 and was supported by the European Commission. The objectives of the study were straightforward: to vary the composition and properties of the gasoline BOB over a wide range allowed by the CEN EN228 gasoline specification, and quantitatively measure the effect of different ethanol concentrations on the distillation curve of the blend.

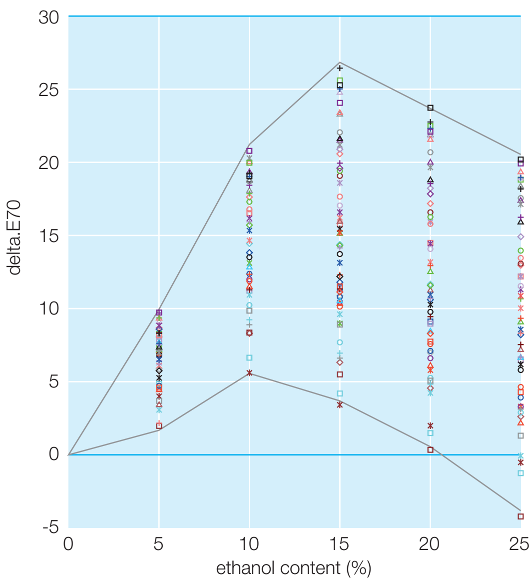
For this study, 60 different gasoline BOBs were blended from typical refinery streams spanning a wide range in hydrocarbon composition and initial volatility. Five different ethanol/gasoline blends, from 5 to 25% v/v ethanol, were made from each BOB, and the properties of the resulting blends were re-measured using a variety of analytical techniques. Both ETBE and MTBE were also included in the blending matrix in order to reproduce realistic marketplace fuels.

The results are shown in Figure 2, where each point at a given ethanol content represents one of the 60 BOB samples specially blended for the study. The figure shows the delta.E70 of each ethanol/gasoline blend, which is the E70 of the ethanol blend minus the E70 of the gasoline BOB, plotted versus the ethanol content of the blend. Clearly, the impact of ethanol on the blend's distillation is substantial, as was shown for just one example in Figure 1. At 10% v/v ethanol, the increase in delta.E70 for the ethanol/gasoline blends ranges from 5 to 21% and the effect is even larger at higher ethanol contents.

In addition to the distillation behaviour of ethanol/gasoline blends, the study also evaluated changes in vapour pressure, the impact of small amounts of water on the blend's volatility and the molecular composition of the final blends. Predictive models for distillation properties were also developed based on regression techniques.

Because of the dramatic effects of ethanol on gasoline distillation, some refineries that typically manufacture BOBs having higher distillation properties can be expected to experience difficulties meeting the current volatility specification limits for 10% v/v ethanol/gasoline blends. For this reason, the responsible CEN Working Group is considering a CONCAWE proposal to relax the maximum volatility limits for 10% ethanol/gasoline blends. At the same time, two major vehicle test programmes, one by CONCAWE and one by the European auto industry, are in progress to investigate whether this relaxation will introduce any new emissions or driveability performance problems for current and future vehicles. Results from these studies are

Figure 2 Change in E70 distillation property with increasing ethanol content



The impact of ethanol on the blend's distillation is substantial; at 10% v/v ethanol, the increase in delta.E70 for the ethanol/gasoline blends ranges from 5% to 21% and is even greater at higher ethanol contents.

expected to be completed in time to inform CEN's technical discussions on E10 gasoline blends.

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 future aspirations of the RED and the NREAPs.

The European Commission's financial support of the BEP525 Study is greatly appreciated (TREN/D2/454-2008-SI.2.522.698). The study report, data and models are available for free download from the European Commission (http://ec.europa.eu/energy/renewables/studies/biofuels_en.htm) or CONCAWE (www.concawe.org) websites.

Downstream oil industry safety statistics

The 2009 safety statistics report focuses on personal injuries and process safety incidents for the European refining industry.

The importance of a modern and effective safety management system is widely recognised by the oil industry. Because the collection and analysis of incident data are essential elements of these systems, CONCAWE has been compiling statistical safety data for the European downstream oil industry since 1993. The purpose of this activity is twofold:

1. To provide CONCAWE's member companies with a benchmark against which to compare their own performance; this provides information against which they can evaluate the efficacy of their management systems, identify shortcomings and take corrective action.
2. To demonstrate that the responsible management of safety in the downstream oil industry results in a lower level of accidents, despite the hazards intrinsic to its operations.

The 2009 annual safety report was published in 2010 (CONCAWE report 7/10) and is available on CONCAWE's website. In addition to the 2009 results, the report also includes a full historical perspective from 1993, as well as comparative figures from other industry sectors. Data were submitted by 33 CONCAWE member companies, accounting for more than 97% of the refining capacity of the EU-27 and European Free Trade Association Member States.

In line with previous reports, the safety 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 indicators are:

- Number of fatalities;
- Fatal Accident Rate (FAR) per 100 million hours worked;
- All Injury Frequency (AIF);
- Lost Workday Injury Frequency (LWIF);
- Lost Workday Injury Severity (LWIS); and
- Road Accident Rate (RAR) per million km travelled.

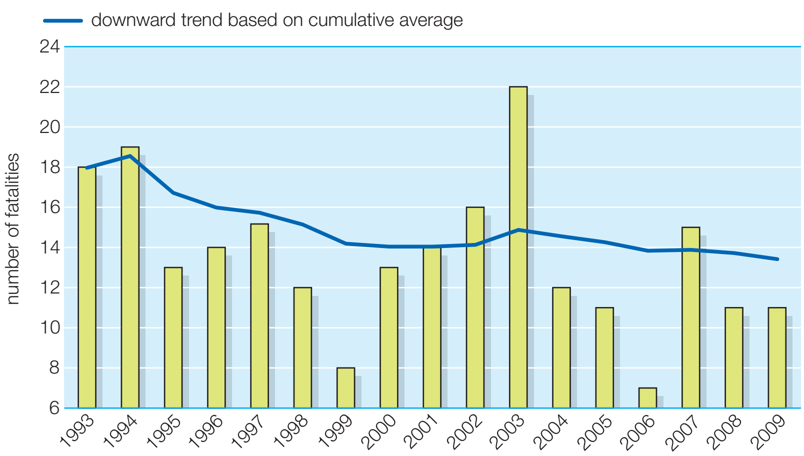
The statistics relate to companies' own employees, as well as to contractors, and are split between 'manufacturing' (i.e. mostly refineries) and 'marketing' (i.e. distribution and retail). The performance indicator results are of greatest interest in the form of historical trends because they provide guidance to safety management efforts for continuous improvement. Figure 1, for example, shows the declining trend in the number of fatalities while Figure 2 shows the evolution of the three-year rolling average for the four main indicators, FAR, AIF, LWIF and RAR.

These indicator trends show a steady performance improvement over the past 16 years with a slow but constant reduction of LWIF, which has remained below 3.0 for the fifth consecutive year. The figures suggest that AIF peaked around 1996–97 but this could be due to incomplete AIF reporting in the early years when this indicator was not formally used in all companies. The trend is definitely on a downward slope, however, and AIF figures have improved for all categories.

Regrettably, 11 fatalities were again reported in 2009. This number is higher than the 2006 result, which was the best over the 16 year period. Following a steady downward trend in the 1990s, fatality numbers began to increase in the first years of the last decade, peaking in 2003. This unfavourable trend appears to have stabilised since 2004, with the three-year rolling average for FAR remaining at around two for the past three years.

Of the 2009 fatalities, three were due to road accidents, three were due to one confined space entry incident, and two were caused by falls from height. For the remaining three fatalities, one resulted from hazards directly associated with maintenance and construction activities, one was caused by burning/electrocution, and one was classified as the result of other industrial activities.

Figure 1 Number of reported fatalities since 1993



The principal causes of fatalities over the past five-year period continue to be road accidents (~40%) and incidents during construction/maintenance activities (~45%). For the entire period over which CONCAWE has been gathering these statistics, these two causes of fatalities have contributed 45% and 35% respectively. The third major cause of fatalities (12%) is 'burns, explosions and electrocution'.

The relationship between the AIF, LWIF and FAR is presented in Figure 3. Although the number of fatalities per year biased the curves associated with the FAR values, the figure does show relatively stable relationships among these indicators over time. Almost half of incidents are Lost Workday Injuries (LWIs) and, regrettably, there was approximately one fatality for every 100 LWIs.

In spite of the positive trends in LWIF and AIF, the LWIS severity indicator, that expresses the average number of days lost per LWI, increased in 2009. The LWIS results and the three-year rolling average are presented in Figure 4. Although the LWIS results declined after the peak in 2005, the three-year rolling average of this severity indicator still remains above the all-time LWIS average of 25.

When combined with the apparent stability in the number of fatalities, the LWIS results may indicate that the nature and impact of incidents is not decreasing similarly. Hence, although the overall safety performance in the industry is improving with respect to incident frequencies and absolute number of incidents (see also the 2007 and 2008 reports), there is little improvement in the impact of incidents that do occur.

This observation has triggered a discussion within CONCAWE's safety group as to whether the performance indicators that are currently used are sufficient or whether they should be extended. CONCAWE experts have concluded that the observations described above warrant a closer look into the types and causes of the incidents that continue to occur. For example, many companies now routinely monitor performance indicators related to process safety, which may be one major factor.

In recognition of this trend, CONCAWE, starting in 2010, decided to extend the key performance indicators that it monitors by adding a Process Safety Performance Indicator (PSPI). The selected PSPI incorporates the lagging Tier 1 and Tier 2 reporting elements (i.e. loss of primary containment events of greater and lesser consequence, respectively). These have been defined by the American Petroleum Institute (API) in the ANSI/API Recommended Practice 754, *Process Safety Performance Indicators for the Refining and Petrochemical Industries* (www.api.org/Standards/new/api-rp-754.cfm).

Figure 2 Three-year rolling averages for personal incident statistics relating to the European downstream oil industry

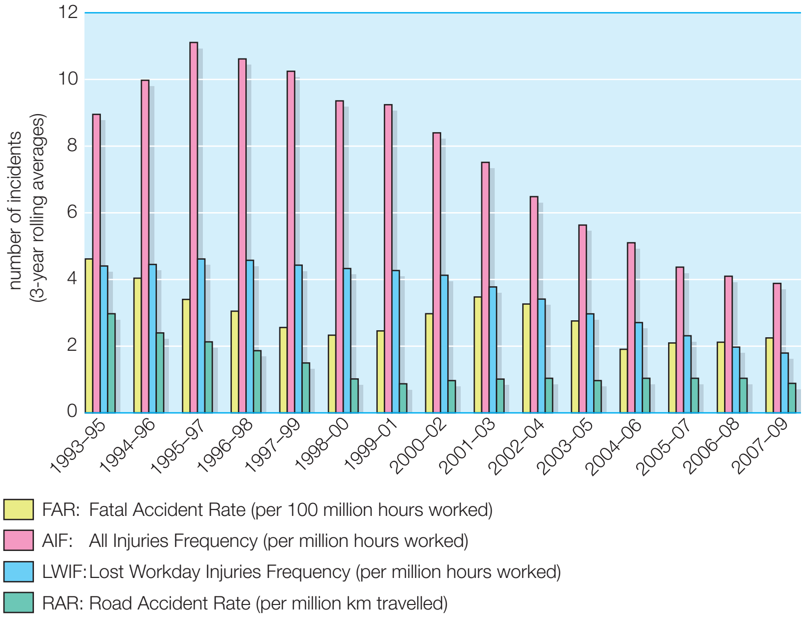


Figure 3 Incident and fatalities frequencies relationships for the European downstream oil industry

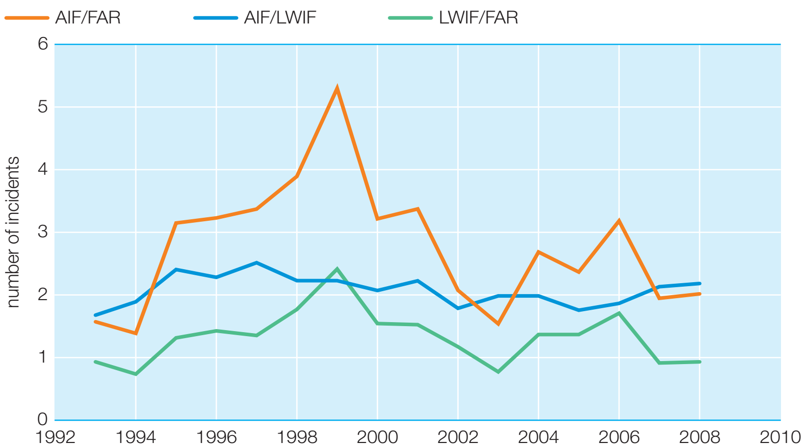


Figure 4 Lost Workday Injury Severity (LWIS) from 1994–2009 and the three-year rolling average in the European downstream oil industry

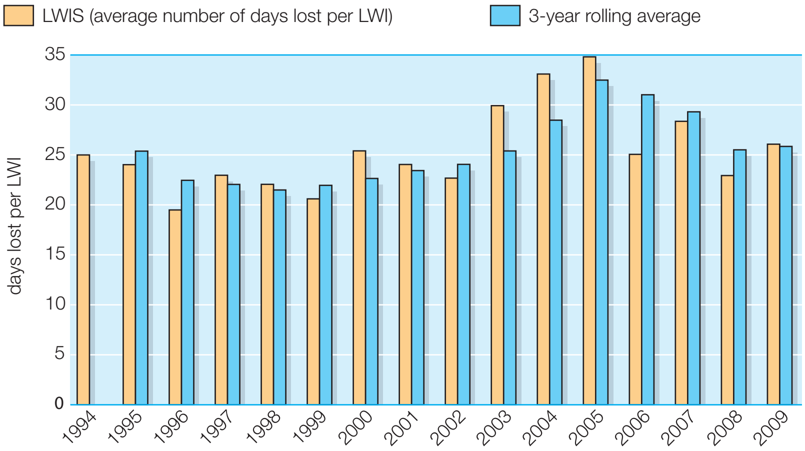
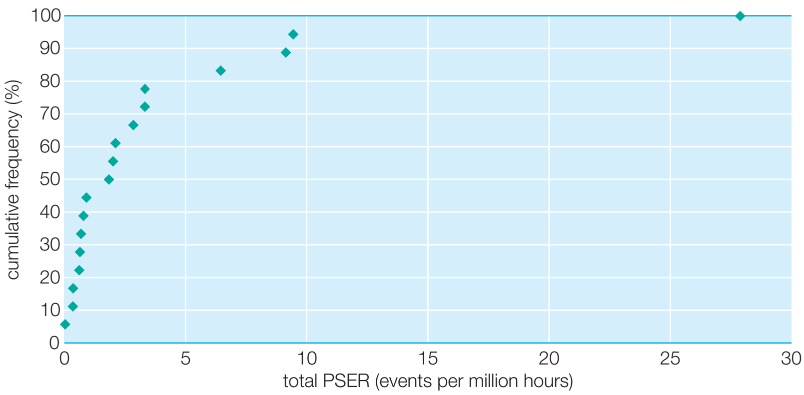


Table 1 Results of the 2009 PSPI data gathering

	Manufacturing	Marketing	Both sectors
Companies			
Total	33	33	33
Process safety reporting	18	7	7
% reporting	55%	21%	21%
Hours worked (Mh)			
Totals	242.4	303.1	545.5
Process safety reporting	143.8 (99.8)[a]	50.2	194
% reporting	59% (41%)[a]	17%	36%
Tier 1 PSE: *No. of PSEs*	156	22	178
Tier 2 PSE: *No. of PSEs*	430	196	626
Tier 1 PSER: *PSE/Mh reported*	1.09	0.44	0.92
Tier 2 PSER: *PSE/Mh reported*	4.31	3.90	3.23
Total PSER: *PSE/Mh reported*	4.08	4.34	4.14

[a] Figures in brackets are the hours reported by the companies that provided Tier 2 Process Safety Events (PSEs)

Figure 5 Cumulative frequency for manufacturing PSER



The PSPI indicator was selected because it was considered to be applicable to our industry and is already in use by many member companies. Furthermore, it will enable a comparison on a regional scale within our industry. CONCAWE has therefore requested that all member companies begin gathering PSPI information in 2010. To gain preliminary insight into this PSPI reporting, the 2009 safety performance questionnaire was also extended with a request for PSPI data; 18 member companies responded by providing these data in their annual report for analysis. The results of the PSPI data gathering in 2009 are provided in Table 1.

In Figure 5, the cumulative frequency for the Process Safety Event Rate (PSER) is shown for manufacturing sites only where the PSER data were considered to be sufficiently robust to warrant such an analysis. These first results are encouraging because they show that Process Safety Management is already well integrated into our industry's procedures and that companies are ready to share their PSPI data with CONCAWE.

CONCAWE expects that more member companies will provide this information in the coming years. It will then be possible to develop a robust PSPI database for performance reporting and trend analysis for the European refining and distribution industry. This is expected to provide data that can be used to support the positive evolution of responsible safety management in the oil industry, including Process Safety.

Interview with CONCAWE's Technical Coordinator for Health Sciences

Gary Minsavage provides his perspective on CONCAWE's research and the importance of health sciences for our industry.

Gary Minsavage became CONCAWE's Technical Coordinator for Health Sciences in 2008 and returned in early May to his home company, ExxonMobil Biomedical Sciences, Inc. The CONCAWE *Review* departs from its usual format to interview Gary on his Brussels assignment and his return to the United States.

Q: Gary, what did you enjoy most about your Brussels assignment?

A: *I enjoyed the wide range of interesting projects and especially contacts with the technical experts I had the pleasure of working with for three years. This was an outstanding opportunity to use my knowledge as a health scientist on problems of critical importance to the European refining industry. I suppose I should say something about the pizza, Belgian beer and chocolates, and although they are very good, there is no doubt that raising our young daughter in Brussels and the birth of our second 'Belgian' daughter were very special events for my wife and me during our Brussels stay.*

Q: Why is CONCAWE doing research in the health sciences area?

A: *When CONCAWE was formed in 1963, its charter anticipated that research would focus on 'environment, **health**, and safety in refining and distribution'. In the early years, many of the health sciences that we rely on today were still being developed so the focus of work was mostly aimed at the occupational health of refinery workers, including toxicology studies and surveys of occupational exposures to hazardous substances. This work provided opportunities for CONCAWE to work with key international organisations within the United Nations and with European institutions involved in environmental and occupational health.*

Over the past decade, EU legislation has increasingly focused on environmental impacts on public health and CONCAWE has contributed research in several areas, especially in air quality through the CAFE (Clean Air for Europe) programme and, more recently, through the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals—EC Regulation No. 1907/2006) programme. CONCAWE has developed a strong 'Health Management Group' to address these EU initiatives, with member company experts in occupational hygiene, exposure science, toxicology, epidemiology and other areas.

Today, a thorough understanding of the potential health effects associated with the production, distribution and use of petroleum substances is still the main focus of CONCAWE's health programme. Health sciences are harnessed to address these issues including the management of health and safety at work, the effects of air pollution on public health, and consumer safety related to the use of petroleum products. Our health programme also relies on leveraged projects and expert contractors in order to complement expertise from our member companies.

Q: What do these different areas of health science contribute to your research?

A: *This is an important question so I would like to provide a few fundamentals on the major health sciences areas that we rely on:*

- ***Occupational hygiene** includes the recognition, evaluation, and control of environmental stressors on human health which, in a work setting, could result in worker injury, illness or physical impairment. For our industry, this includes effects on the well-being of workers and on members of the public due to the manufacturing or environmental exposure to petroleum products.*
- ***Exposure science** identifies and characterises 'real world' contacts with toxic materials and their uptake in the human body causing acute or chronic health effects. Exposure studies are vital for preventing incidents and ensure that accountable and cost-effective policies result from a thorough understanding of exposure profiles in the population.*
- ***Toxicology** is the study of adverse effects on human health, for example the potential impact on people exposed to gasoline vapours.*
- ***Epidemiology** is the study of complex patterns of human health, illness and associated factors in the population. Statistics are very important in this area, for example to assess the risk that workers involved in the manufacturing or distribution of a petroleum product could develop a specific illness.*

- ***Occupational medicine*** *ensures that the best available health advice is provided to organisations and individuals so that the highest standards of occupational health and safety can be achieved and maintained. An example here might be providing first aid advice to emergency responders to accidental gasoline spills.*

Q: Why is an understanding of the health effects associated with the manufacture, distribution and use of petroleum substances still important today?

A: *You will not be surprised to hear that many petroleum substances are classified as hazardous to human health. For example, fuels, including gas oils, gasolines, kerosines and heavy fuel oils, represent the largest production volume for our industry and are classified as hazardous to human health with classifications ranging from skin irritants to carcinogens.*

Understanding the uses, hazards, exposures and therefore risks to human health ensures that appropriate measures can be developed that enable the safe use of these substances. Achieving this outcome requires all of the areas of expertise that I mentioned previously. In addition, the development of advanced analytical techniques and genetic analysis are changing the way we study and understand human health effects. These approaches are important today for assessing the impact on human health from exposure to bitumen, benzene, particulates and ozone, for example. Importantly, regulatory-based health risk assessments have evolved, and will continue to do so (e.g. REACH).

Q: What was CONCAWE's goal in the REACH process?

A: *REACH replaced a number of directives regulating existing chemicals and the introduction of new substances to the market. The core part of REACH is the registration of chemical substances with risk assessments related to human health and environmental impacts. Since the majority of petroleum substances met the REACH criteria for registration, our products could not be manufactured or imported after 2010 if they had not been successfully registered. In essence, successfully completing the risk assessments and REACH registration process provided a 'licence to operate' for petroleum substances and, without this 'licence', refining and importing operations could theoretically have been stopped. Fortunately, such drastic measures were not needed because CONCAWE's parts of the REACH dossiers and registrations by manufacturers/importers were completed on schedule. In the end, the European refining industry accounted for approximately 18% of all REACH registrations that were submitted to the European Chemicals Agency (ECHA) by the December 2010 deadline. ECHA is the EU agency responsible for managing the technical and administrative parts of the REACH system.*

Q: What did the preparation of a REACH dossier actually involve?

A: *Petroleum substances, except for sulphur and some petroleum gases, are recognised by REACH as 'substances of unknown or variable composition, complex reaction products or biological materials' (UVCBs). The complex and variable nature of UVCBs makes it challenging to assess their intrinsic hazardous properties and associated risks. For this reason, CONCAWE first had to develop methodologies including read-across, trend analysis, data sharing and toxicity-prediction approaches, that would help us to complete the required assessments. Although there had been a lot of previous work, some data gaps were identified, especially associated with reprotoxicity testing because this area has not historically been a focus of regulation.*

To address the REACH requirements, CONCAWE's toxicologists developed a consistent approach to hazard assessment for all petroleum categories and substances. We also developed REACH-required 'derived no-effect levels' (DNELs) for petroleum substances based on available data. This obviously relied heavily on CONCAWE's data from decades of previous research. Health hazard assessments and DNEL recommendations were based on an extensive database on petroleum substances, and the toxicology team developed the final hazard classifications and recommendations needed for the REACH dossiers (see CONCAWE Report 11/10). To the extent that guidance was available from ECHA, the approaches we developed were aligned with their guidance.

CONCAWE's team of occupational hygienists and exposure scientists also simplified exposure scenarios and developed an approach to consolidate different uses of petroleum substances. To do this, the team used exposure data and models for the hundreds of different potential uses for petroleum substances identified through the REACH process. Many of these approaches were also used by other industry sectors to complete their own REACH dossiers. This was a substantial effort, estimated to be thirty to forty person-years of work by our toxicologists, occupational hygienists and exposure scientists.

Q: That does sound like a lot of work!

A: *It was a mammoth task, certainly the largest single project that has ever been completed by CONCAWE. Our health sciences teams contributed significantly to the REACH process in terms of technical input, breadth of information and sheer people-power—what we call 'sweat equity'.*

Let me give you an example. CONCAWE ultimately prepared 22 different REACH dossiers covering 576 petroleum substances grouped into 'categories'. If we were to look at just one of these dossiers submitted to ECHA in 2010, say for 'low boiling point naphthas (gasolines)', the dossier had a number of different required parts.

The core of the REACH dossier, the Chemical Safety Report (CSR), was about 600 pages for the gasoline dossier and summarised an even more detailed assessment contained in the IUCLID (International Uniform Chemical Information Database) data file, also required by REACH. About half of each CSR was devoted to health hazard assessments and exposure scenarios that were themselves based on literally hundreds of previously completed research studies. These studies could often run into several hundred pages and each study required review, assessment and entry into IUCLID. The rest of the CSR included information on classification and labelling, physico-chemical information, environmental hazard assessment, and risk characterisation.

In a post-REACH registration world, this detailed information will be communicated between producers and purchasers by means of a new extended Safety Data Sheet (SDS). Creating the extended SDS is the responsibility of each producer but the information that it contains must be consistent with the CSR developed by CONCAWE.

Before REACH, an SDS was about 8 pages long. After REACH, an extended SDS can be as long as 100 pages if the producer is selling into markets involving all of the uses that were assessed in the CSR.

Q: What do you think was the benefit of all this work?

A: *For the petroleum substances (excluding petroleum gases) that were finally registered by CONCAWE member companies and importers, 90% are classified as hazardous to human health to some degree, ranging from skin irritants to carcinogens. It is important to say that CONCAWE's historical hazard recommendations regarding the safe handling and use of petroleum products were not significantly changed by the REACH assessment process. We believe that this reflects well on our industry's past commitment to risk assessment and the development of safe use advice.*

Still, as painful as the process was, it must be said that our industry and its supply chain have benefited from the REACH process. Through REACH, we have (1) assessed an extensive database of health-related information, (2) gained a more complete understanding of how petroleum substances are used and not used, (3) applied a thorough and systematic approach to risk characterisation, and (4) developed common approaches to minimise risk associated with petroleum substances and their uses.

Q: Does this mean that REACH work is now completely finished?

A: *Although the common parts of the REACH dossiers have been submitted, we believe that REACH will continue to be an integral part of CONCAWE's work on health and petroleum products for a long time, probably at least until 2018. The REACH dossiers will be kept up to date, new ECHA Guidance will be addressed, queries from Member States will be answered, and new data from our industry and other sources will be added. In the meantime, we are developing technical methodologies and engaging with other stakeholders to clarify the hazards and risk assessments for UVCB substances.*

Q: Clearly REACH was a major activity for you and for CONCAWE during your assignment. Did other work in health sciences take a back seat?

A: *Fortunately, no.*

While our health experts were occupied with REACH, we still found time for a significant research programme on health and petroleum substances. Many of these projects were leveraged through multi-sponsor, multi-year projects being carried out by others. For example, we have projects under way with academic, private and national technical organisations including the University of Utrecht, Fraunhofer's Institute for Toxicology and Experimental Medicine, the Boston-based Health Effects Institute, VITO (at the Flemish Institute in Belgium), and RIVM in The Netherlands.

From 2008 to 2011, CONCAWE either sponsored or co-sponsored health sciences projects that resulted in 13 major publications. Six were published in peer-reviewed journals while seven were or will be published as CONCAWE reports[1]. These reports focused on important health-related issues: the contribution of diesel exhaust exposure to lung cancer risk in workers; an assessment of the relationship between benzene exposure and Non-Hodgkin's Lymphoma (NHL); a health assessment of refinery and maintenance activities associated with the use of heavy fuel oils; and an assessment of carcinogenic risk to asphalt workers exposed to bitumen fumes.

Health effects due to benzene exposure have been studied for more than 50 years. Key questions remain, however, regarding the lymphohematopoietic (LH) cancer subtypes that may be induced by low-level exposure to benzene. CONCAWE is coordinating work with the US API, CEFIC Aromatic Producers Association, and the Canadian Petroleum Products Institute that will be one of the most technically advanced and thorough studies assessing the relationship between benzene exposure and specific disease types and subtypes. This multi-year, multi-investigator study, known as the 'Benzene Pooled Analysis', will update, then combine or 'pool' existing benzene case-control studies to produce a robust database on disease states and benzene exposures. These data are expected to affect updates to Occupational Exposure Limits (OELs) and Environmental Quality Standards (EQS) under the Water Framework Directive.

We are also engaged in critical reviews of the health impact of air pollution, especially related to industry operations and the use of petroleum substances. Where possible, we leverage our activities with other organizations to fill key knowledge gaps that will be important for the 2013 Air Quality Directive Review.

Q: Where will CONCAWE's health sciences be going in the future?

A: *The success of CONCAWE's health sciences activities began with a focus on effective approaches for occupational health management and moved on to address broader environmental and human health issues. These included product safety and chemical risk assessment (e.g. REACH), vehicle emissions regulations, and ambient air quality standards. In these areas, many underlying scientific questions are still unresolved and new issues continue to emerge. CONCAWE's role is to work with scientific collaborators, regulators and other stakeholders to complete needed research to address these questions. To do this, we will continue to commission high-quality reviews and research from our own budget.*

Fortunately, my replacement has already been named so the work in this area will continue with very little interruption. Arlean Rohde, seconded from ExxonMobil Chemical Company, arrived in Brussels this summer and the handover process is already under way.

Q: So, what *did* you enjoy most about your Brussels assignment?

A: *Exploring the parks and forest with my family was very enjoyable. Riding my bike to work was also great … and necessary to counteract the effects of the wonderful pizza, Belgian beer and chocolates!*

[1] See CONCAWE Reports 5/08, 5/09, 5/10, 8/10 and 4/11, available on the CONCAWE website (www.concawe.org)

Abbreviations and terms

AIF	All Injury Frequency
BOB	Blendstock for Oxygenate Blending
CAFE	Clean Air For Europe
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CSR	Chemical Safety Report
DDGS	Dried Distillers Grains with Solubles
DME	Dimethyl Ether
E70	%v/v of gasoline evaporated at 70°C
E100	%v/v of gasoline evaporated at 100°C
ECHA	European Chemicals Agency
EQS	Environmental Quality Standards
ETBE	Ethyl Tertiary-Butyl Ether
EUCAR	European Council for Automotive R&D
FAEE	Fatty Acid Ethyl Ester
FAME	Fatty Acid Methyl Ester
FAR	Fatal Accident Rate
FFV	Flexi-Fuel Vehicle
FQD	Fuel Quality Directive (2009/30/EC)
GHG	Greenhouse Gas
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IOC	International Oil Companies
IUCLID	International Uniform Chemical Information Database
JEC	JRC, EUCAR, CONCAWE consortium
JRC	Joint Research Centre of the European Commission
LH	Lymphohematopoietic
LPG	Liquefied Petroleum Gas
LUC	Land Use Change
LWI	Lost Workday Injury
LWIF	Lost Workday Injury Frequency
LWIS	Lost Workday Injury Severity
MTBE	Methyl Tertiary Butyl Ether
NExBTL	NExt generation Biomass To Liquid (renewable fuel produced by Neste Oil)
NHL	Non-Hodgkin's Lymphoma
NOAA	National Oceanic and Atmospheric Administration
NREAP	National Renewable Energy Action Plan
OEL	Occupational Exposure Limits
OGP	International Association of Oil & Gas Producers
POME	Palm Oil Methyl Ester
PSER	Process Safety Event Rate
PSPI	Process Safety Performance Indicators
R&D	Research and Development
RAR	Road Accident Rate
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive (2009/28/EC)
RME	Rapeseed Methyl Ester
SDS	Safety Data Sheet
SIEF	Substance Information Exchange Forum
SME	Sunflower Methyl Ester
SYME	Soy Methyl Ester
TTW	Tank-to-Wheels
UVCB	Substance of Unknown or Variable Composition, Complex Reaction Product or Biological Material
WTT	Well-to-Tank
WTW	Well-to-Wheels

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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
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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
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