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

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Foreword

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Welcome to the latest edition of the CONCAWE *Review*. I hope you will find these articles of interest. Issues such as energy efficiency and air quality are very topical, while REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) remains a key activity and priority for us.

Improving the energy efficiency of refineries has always been important, especially since the 'oil shock' of the 1970s. Although a modern refinery consumes less than 10% of the energy content of the crude oil it processes, this still represents a major operating cost at today's crude oil prices. In fact, energy costs, as a percentage of refinery cash operating costs, have increased significantly over the past 20 years, now representing about 60% for typical refineries. This increase is the result of higher energy prices plus the extra energy consumed to produce today's high quality fuels and to meet the growing demand for lighter products. The first article in this *Review* describes these effects in more detail, shows the progress the industry has already made on energy efficiency, and looks at what more can be done. In addition to the obvious environmental benefits from reducing refinery energy consumption, there are also large financial incentives to further improve efficiency.

In 2010, CONCAWE and its member companies successfully completed the first phase of REACH. CONCAWE was responsible for the common parts of the REACH dossiers for petroleum substances and sulphur, which were then used to complete more than 4,000 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 first phase of REACH was successfully completed, our work on REACH was not over, continuing throughout 2011 and into 2012. 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 the IUCLID (International Uniform Chemical Information Database) system, mean that we need to continue updating the dossiers for future use. We are also receiving licence orders from new market entrants and we are preparing for the next round of registrations for lower volume products in 2013. We expect that CONCAWE's role as a facilitator for the Substance Information Exchange Forum (SIEF) will need to be maintained for quite some time. CONCAWE's recent work and the challenges ahead are described in the second article.

Air quality throughout most of Europe has improved considerably over the past 50 years. Over the same time period, the life expectancy of European citizens has also increased dramatically and better air quality is seen as a contributing factor. The refining industry has made its own significant contributions to air quality improvement, both by reducing refinery emissions and by improving the quality of fuels used in vehicles and other applications. However, as we learn more about the health effects of air pollution, there may be a need for more improvements in air quality. A better understanding of the effects of fine particulate matter (PM) on human health is an important step in determining the most cost-effective means of reducing atmospheric PM. Some ways in which CONCAWE is contributing to this effort are summarised in this *Review*.

For over 40 years, CONCAWE has published an annual analysis of spills from European oil pipelines, covering more than 36,000 km in Europe. An article in this *Review* summarises the latest results. By collaborating through CONCAWE, pipeline operators are able to compare their past performance and identify the main causes of spills. The good news is that the age of the pipeline inventory does not seem to significantly affect its integrity, thanks to improved inspection and maintenance systems. However, third-party interference, mainly through accidents, is now the leading cause of pipeline spills, and the industry is working with others to see how such accidents can be avoided in the future.

This *Review* concludes with results from a recent survey of gasoline and diesel fuels collected from service stations in 17 European countries, with a focus on progress in blending of oxygenated components.

I hope that you enjoy your summer break and this edition of the *Review*, which could be a great addition to your vacation reading!

Contents

Refinery energy systems and efficiency

Refineries have improved their energy efficiency by about 10% over the past 18 years. Here's how they did it!

Oil refineries manufacture a wide range of petroleum products, mainly transport fuels (gasoline, diesel, jet fuel, marine fuels), heating and industrial fuels, and chemical feedstocks. All must meet market requirements in both quantitative and qualitative terms. Crude oils are the main input to refineries and are sometimes supplemented by other natural or semi-processed hydrocarbon mixtures.

Oil refining is an inherently energy-intensive activity, requiring substantial quantities of heat, steam and electricity to operate. This energy is either purchased from outside the refinery or produced on site by consuming a portion of the crude and petroleum products that are produced in the refinery.

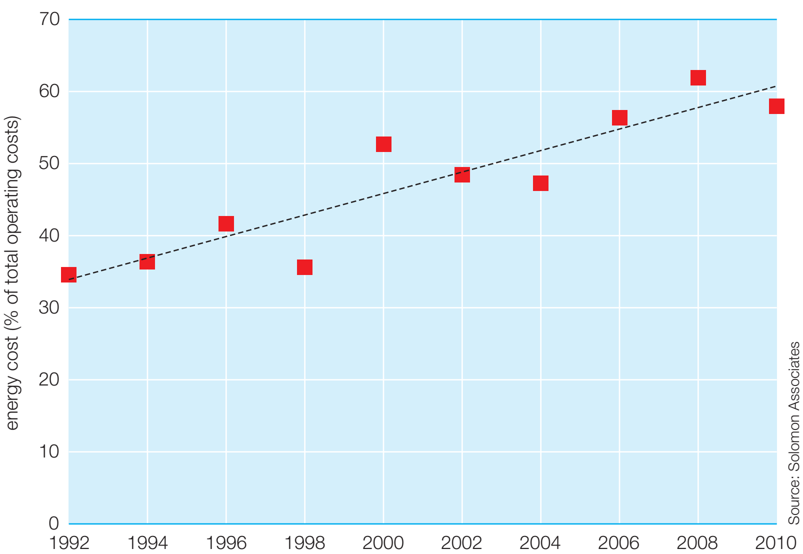
Over time, the energy demand of European refineries has increased for two main reasons:

- Emissions legislation and other performance requirements have resulted in increasing sophistication of the equipment—cars, trucks, heating units, etc.—in which petroleum products are consumed. This has resulted in more stringent specifications for petroleum products, related to safety, performance and pollutant emissions. The most noteworthy example is the very large reduction over the past two decades in the sulphur content of petroleum products and road fuels that has enabled remarkable improvements in vehicle emissions and air quality.
- The market has demanded an ever-increasing proportion of lighter products (such as road- and air-transport fuels) and a decreasing proportion of heavier materials such as heavy fuel oil. As a result, refineries have gradually become more complex, incorporating an array of processes to 'reshape' the supply of refined products to meet the changing market demand, including treating the components of the final products. Unlike many other parts of the world, Europe has developed a large diesel passenger car fleet and a reliance on heavy-duty road transport for freight shipments, resulting in a very high demand for diesel fuel compared to gasoline.

Just like freight transport and airline companies, refiners have long had a strong incentive to improve their energy efficiency. Environmental concerns have reinforced this incentive in recent years, notably the drive to reduce global greenhouse gas emissions. As shown in Figure 1, energy currently accounts for about 60% of the cash operating costs of EU refineries, a proportion that has doubled over the past 20 years due to increasing energy costs and the reasons outlined above.

There are many factors that affect refinery energy consumption and efficiency. These factors, and the complexity of refinery energy systems, are not well understood by those outside the refining industry. For that reason, this article provides an overview of CONCAWE Report 3/12 which addresses these issues and provides data on the various aspects of energy use and energy efficiency improvements achieved by EU refineries over the past 18 years.

Figure 1 The energy cost of EU refineries as a percentage of total operating costs



Measuring and comparing refinery energy performance

Energy is required in refineries for heating, reacting, cooling, compressing and transporting hydrocarbon streams, mostly as liquids but also as gases. To achieve high liquid temperatures (higher than about 250°C), fired heaters are used in which liquid or gaseous fuel is burned and the resulting heat is transferred to the liquid process stream. A typical medium-complexity refinery may operate 15–20 process heaters of various sizes. When lower temperatures are sufficient, steam is the more flexible heating medium and is applied in many ways at different pressures and temperatures.

High pressure steam (40–100 bar pressures) can also be used to drive turbines for large rotating machines such as compressors and electricity generating turbines. This may be an attractive alternative to electricity when the steam supply is reliable and abundant.

A key element of energy-efficient refinery design is heat recovery and integration within individual process units, between process units, and with the steam system.

The absolute amount of energy consumed by a refinery is related to, amongst other factors, the refinery's size in terms of crude oil throughput. Another important factor is the refinery's configuration, that is, the combination of different processes used by the refinery. These processes, to a large extent, determine which crude oils can be processed and the type, yield and quality of the different refined products that can be manufactured. The more conversion of heavier streams into lighter products that is carried out, the higher will be the specific energy consumption. This is typically defined as the energy consumed by the refinery to process each tonne of crude oil throughput. A simple refinery performing only distillation and mild hydrotreating may consume 3–4% of the energy content of its crude oil intake. In a complex refinery with many different conversion and upgrading units, 7–8% of the energy content is more typical. A complex refinery will therefore consume more energy than a simple refinery having the same crude oil throughput, but it will also have more capabilities to meet the changing market demand.

Although the concept of energy efficiency is intuitive and easy to grasp, measuring energy efficiency requires that an energy performance metric be established, so that energy efficiency can be tracked over time between different refineries. Because refineries are all different in size, complexity and processing/production capability, simple metrics such as the energy per unit of throughput or per unit of products do not provide an appropriate view on actual efficiency and would actually lead to the wrong conclusions. Indeed, the fact that simple refineries, compared to complex ones, consume a smaller percentage of their energy input is simply a reflection of the different functions these refineries are intended to perform and does not imply that simple refineries perform these functions in a more or less efficient manner.

Over many years, and in cooperation with the refining industry worldwide, Solomon Associates (SA) (http://solomononline.com) have developed an Energy Intensity Index® or EII® which accounts for refinery size and complexity in order to focus explicitly on measuring energy performance. Figure 2 shows the normalised evolution over time of the total energy consumption of a consistent group of EU refineries and of their combined EII®.

As shown by the total energy consumption in this figure, EU refineries have been gradually using more energy as product demand has increased and specifications have become more stringent. While this has occurred, the same refineries have improved their energy efficiency as measured by the EII® by about 10% over the past 18 years. In 2010, this represented annual average savings of about 60,000 tonnes of oil equivalent (toe) per refinery, compared to the 1992 efficiency level, or about 4 million toe/annum for all of the

Figure 2 Energy consumption and efficiency trends for EU refineries

Note: lower EII® values means better refinery efficiency

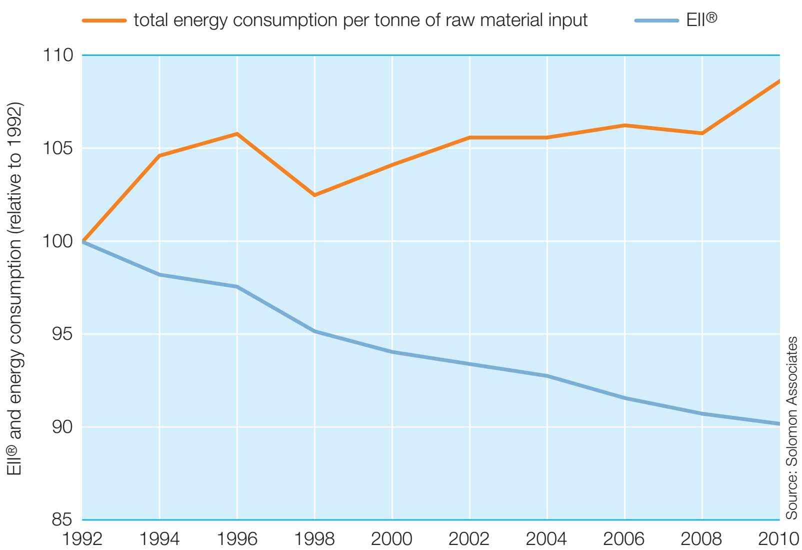
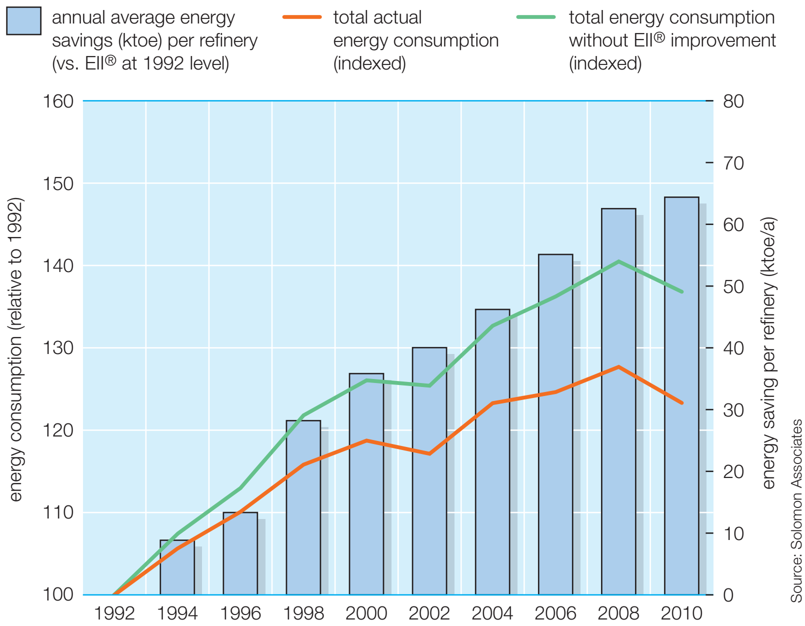


Figure 3 Energy savings from efficiency improvements in EU refineries



EU's 100 refineries (Figure 3). This annual saving is roughly equivalent to the total annual average energy consumption of four large EU refineries.

Where do refineries get their energy?

Refineries traditionally use fuels produced internally from crude oil to generate most of the energy they need. Because there were few alternatives available in the early days of refining, this is partly historical, but it is also a way to usefully consume refinery products that have low market value. A refinery fuel pool will include 'fuel gas' (light hydrocarbons generated as by-products of various processes) and various liquid fuels, often supplemented by imported natural gas. The majority of refineries worldwide, including those in the EU, use a fluidised catalytic cracker (FCC) to convert crude oil to lighter products. The fuel for this energy-intensive process is mostly generated from burning the coke deposited on the recirculating FCC catalyst. Because a relatively large fraction of a refinery's crude oil intake is processed through FCC units, FCC coke represents a significant fraction of refinery fuel. In practice many refineries also exchange energy with industries outside the refinery gate in the form of heat (mostly as steam) and electricity.

Over time, however, greater availability of relatively low-cost natural gas, coupled with environmental constraints, has driven a steady decrease in the fraction of liquid fuels consumed in EU refineries, with the proportion decreasing from 23% in 1992 to 13% in 2010.

Refineries require both heat (particularly in the form of medium- to low-temperature steam) and electricity. This is a typical scenario for 'cogeneration' of heat and power and most refineries have applied this in some form for a long time, within the limits imposed by the utilities balance in each refinery. A simple form of cogeneration is to produce steam at a higher pressure than required, then to use the high-pressure steam to drive a turbogenerator before using the steam at a lower pressure to heat process units. In recent years, deregulation of the electricity markets in Europe has enabled the export of surplus electricity to the power grid, and many refineries have installed dedicated combined heat and power (CHP) plants which combine a gas turbine and conventional steam turbogenerator.

In its refinery energy surveys, Solomon Associates uses the term 'cogeneration' to cover all electricity production schemes that also produce useful heat, including CHP. According to this definition, the share of cogeneration in electricity generation in EU refineries has grown from 76% to 92% over the period 1992–2010, while the total cogeneration capacity has increased by 125%. As a result, the average efficiency of electricity generation in EU refineries is substantially higher than the EU average efficiency of electricity production from conventional thermal plants (Figure 4).

However, physical and financial considerations continue to limit the number of opportunities for new, economically viable cogeneration projects. The tariff structure for purchased fuel and exported electricity is of particular importance when making investment decisions about installing cogeneration facilities.

Optimising energy consumption in oil refineries

In oil refineries, as in most other manufacturing industries, energy efficiency cannot be achieved in a day. Good energy performance is the result of innovative engineering, good management of available resources and the careful deployment of refinery investments.

The first step towards achieving good energy performance is to develop and implement a consistent set of organisational measures, systems, procedures and practices dedicated to monitoring, measuring and reducing energy consumption. Such measures are usually known as Energy Management Systems (EMS). The desired structure and attributes of EMS have been described in international standards and legislative documents such as in ISO 50001:2011 and the EU's Energy Efficiency BREF under the Industrial Emissions Directive. All such schemes are based on the 'plan-do-check-act' continuous improvement loop first introduced in generic quality management schemes and standards.

There are also many opportunities to maintain or improve energy efficiency by day-to-day operational measures and good practices. These include process optimisation, heaters and boilers operation and control, heat exchanger monitoring and cleaning programmes, steam system maintenance, housekeeping, state-of-the-art monitoring and control technologies, utilities system optimisation, and reliability programmes.

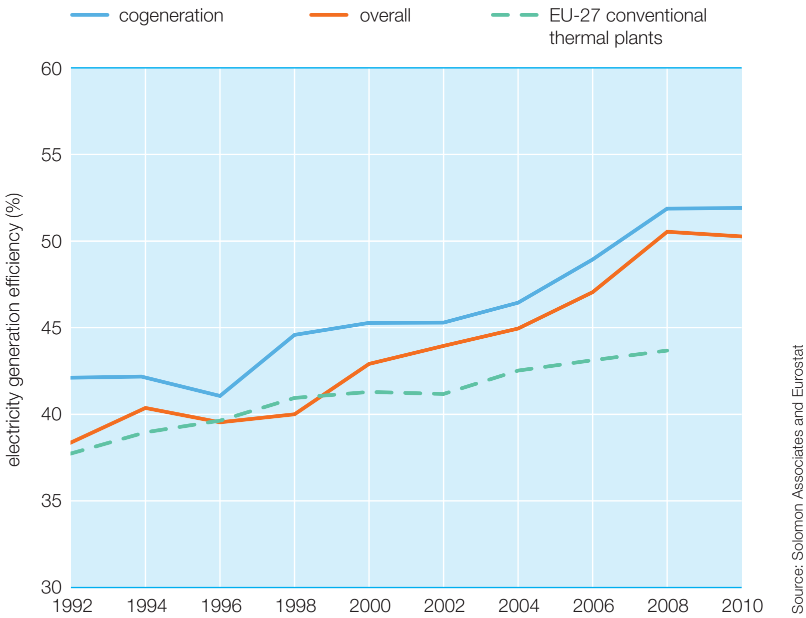
Although much can be achieved by management systems and operational measures, stepwise improvements in energy efficiency tend to require physical changes to the refinery, which in turn also require investments that may be geared to processes in either existing or new plants, or to utilities systems.

In summary

Energy consumption within refineries has always been a major cost element for refiners, currently accounting for about 60% of total cash operating costs. More and more stringent product specifications and steadily increasing demand for lighter refined products require refineries to be increasingly complex with more conversion of heavy residues and more processing of intermediate products. This, in turn, increases the energy demand within the refinery and increases the volume of crude oil that cannot be converted to marketable products. Refiners therefore have a significant incentive to efficiently manage their energy use.

Effective energy management systems and the increased use of cogeneration for electricity production have enabled European refineries to improve their energy efficiency through integrated improvements in refinery operations. Although the incentive is there to achieve further improvements in the future, the challenges are also greater because of the complexity of existing refinery operations and the pressure on efficiency investments in an uncertain economic climate.

Figure 4 Trends in electricity generation efficiency in EU refineries



Note: data for conventional thermal plants were inferred from Eurostat electricity and heat generation data, allocating a standard 90% efficiency to heat production.

REACH: petroleum industry support to registration and compliance

If you thought that the REACH registration process ended in December 2010, think again!

The petroleum industry successfully met the first REACH[1] deadline in December 2010 with the registration of all petroleum substances and sulphur. (See CONCAWE *Review* Vol. 19, No. 1 for details.)

Under the REACH legislation, all registrants of chemical substances are obligated to collaborate with each other through Substance Information Exchange Fora or SIEFs. However, no legal structure or communication mechanism for managing these SIEFs was provided by the REACH legislation or by the Technical Guidance Documents issued by the European Chemicals Agency (ECHA). The only service that ECHA provided was to inform pre-registrants of other pre-registrants for the same substance, then leave it to the participants to organise themselves into SIEFs. This included working out the complicated contractual relationships that must exist between competing businesses under EU competition law.

ECHA's guidance did introduce the concept of a SIEF Formation Facilitator (SFF), a legal entity for facilitating the pre-registration of chemical substances by all registrants. CONCAWE volunteered to act as the SFF for all petroleum substances and sulphur, and expects to continue in this role until 2018, the date of the final registration deadline. CONCAWE's SFF role has already proved its value to member companies by substantially simplifying their involvement in the SIEFs.

As the SFF for petroleum substances, CONCAWE's main responsibilities have been to:

- maintain the integrity of CONCAWE's Risk Assessment reports, including the Chemical Safety Reports;
- protect the intellectual property contained in CONCAWE's REACH registration dossiers that were developed and funded by CONCAWE member companies over many years;
- ensure that access rights are in place for all studies referred to in the registration dossiers;
- ensure communication among all SIEF participants who may be CONCAWE member companies or non-members;
- facilitate submission of the REACH Registration Dossiers to ECHA by SIEF participants;
- streamline the REACH process for all SIEF participants by merging related SIEFs and by forming 'Super SIEFs' covering specific categories of petroleum substances; and
- help all SIEF participants fulfil their legal obligation under the REACH legislation to share relevant data in a fair, objective, transparent and non-discriminatory way.

SIEF activities supervised by the SMCG

Since 2009, CONCAWE's REACH activities have been coordinated by a SIEF Management Coordination Group (SMCG). This group provides oversight for the REACH activities of CONCAWE member companies and the ongoing relationship with non-member companies who are also obligated to register petroleum products. These non-members can include importers and traders who are not eligible for CONCAWE membership under the Association's statutes.

CONCAWE's Secretariat ensures that the SIEFs run smoothly and manages the process of providing SIEF members with access to information under a licensing agreement. This agreement, signed by all SIEF members, includes:

- Licence agreements, essentially a legal framework for the SIEF collaboration, that cover criteria for accessing information and principles for a fair and non-discriminatory sharing of costs. These costs include developing the REACH registration dossiers, updating dossiers, and managing the SIEFs in full compliance with the REACH legislation and with EU competition law.
- A web-based communication platform, called the 'SIEF Communication Tool', that provides SIEF members with timely and relevant information about the substances, the dossiers and their registration under REACH.
- Organisation of the complex but mandatory joint submission of the common parts of the REACH registration dossiers and the continuous update of the dossiers. In 2010, this included the appointment of more than 200 Lead Registrants in charge of submitting common data to ECHA on behalf of all other SIEF registrants.

[1] REACH: Registration, Evaluation, Authorisation and restriction of Chemicals

- A budget for the SIEF management activities covering legal, administrative, information technology, and communication services. These costs were initially fully funded by CONCAWE's member companies and a portion of these costs are being recovered from non-members through the SIEF membership fees.
- A cost model for tracking expenses that were incurred in the preparation and updates of the REACH registration dossiers and for managing the SIEF activities. Importantly, the cost recovery principles needed to be compatible with CONCAWE's non-profit status.

The first REACH registration deadline

More than 4,000 registrations were filed for petroleum substances before the first REACH registration deadline in 2010. This represented almost 18% of all of the registrations that were submitted to ECHA before the first deadline.

These registrations were successfully completed using the registration process set up by CONCAWE in its capacity as SFF. CONCAWE sold licences for more than 1,000 non-member registrations, and provided access to the common parts of the registration dossiers that were prepared by CONCAWE members for 21 different categories of petroleum substances.

According to the REACH principle of 'One Substance, One Registration', all registrants of the same substance should submit their registration dossier jointly through a single 'Lead Registrant'. The Lead Registrant is then responsible for submitting the common parts of the registration dossier on behalf of the other co-registrants and remains the single point of contact with ECHA during the subsequent evaluation of the dossier.

To support the joint submission of these registrations, CONCAWE—in its SFF role—identified more than 200 Lead Registrants, mostly from CONCAWE member companies, who signed Lead Registrant Agreements (LRAs) that defined their unique roles and responsibilities.

Using an on-line approval process, co-registrants were then asked to read and accept the terms of the LRA for each substance that they intended to register. Accepting the LRA enabled them to receive the ECHA 'token' that was required to take part in the joint submission process.

SIEF activities during 2011

Support to CONCAWE member and non-member registrants continued throughout 2011. This included about 120 new licences sold, and another 60 for late registrations and for registrants entering the market after the 2010 registration deadline.

Non-member registrants have also been encouraged to renew their subscriptions to the SIEF Collaboration Service (SCS), coordinated by CONCAWE. This SCS ensures that registrants continue to be informed of REACH and SIEF activities and receive feedback from ECHA about their evaluation of the submitted registration dossiers. This is important because all REACH registrants have a legal obligation to update their dossiers with any new information about the registered substances or their own activities that occurred after the initial registration in 2010.

About 96% of 2010 registrants renewed their subscription for 2011 and a similar number is expected to do so in 2012. A key part of an SCS subscription is access to the CONCAWE SIEF Communication Tool, re-launched in 2011 as *SIEF.space*. This tool was revamped in response to SIEF members' feedback about functionalities and access to information. *SIEF.space* now provides a more streamlined and user-friendly interface for access to dossiers and tokens, as well as valuable CONCAWE guidance and other information on dossier preparation and submission.

Preparation for the next registration deadline in May 2013

Although some may have thought that REACH was finished after the first registration deadline in 2010, this is far from the case. Lower tonnage substances, those between 100 and 1000 tonnes per year, must be registered next by 30 May 2013. Although the REACH data requirements are less extensive for these substances compared to the 2010 registrations, CONCAWE will continue to provide all SIEF members with complete registration dossiers containing all the information related to these lower tonnage petroleum substances. Fortunately, the number of substances to be registered in 2013 is expected to be much smaller, only about 10% of the 4,000 petroleum product registrations completed in 2010.

All pre-registrants have now been contacted and asked to communicate their intentions regarding the REACH deadlines in 2013 and 2018. Only about 10% of these pre-registrants have responded so far. The remainder are urged to do so, so that CONCAWE can better define the level of SIEF support that will be required in the coming years.

CONCAWE members can download the registration dossiers for 2013 registrations directly from *SIEF.space*. Accepting the terms of the licensing agreement also provides them with the special token that enables them to take part in joint submissions with other registrants.

Non-members will receive links to a special web page where they will be able to purchase licences. The licence fee will remain at the same level as in 2010, except where the underlying dossier has been updated since then. As was the case in 2010, 2013 dossier licences are being sold solely to achieve a fair recovery of the costs already incurred by CONCAWE for preparing the registration dossiers based on research completed previously.

Registrants will also receive extensive information and guidance via *SIEF.space*, and the SIEF team will continue to provide assistance and answer questions about licensing, registration, joint submissions, cost sharing and, of course, ECHA's evaluation of the registration dossiers already submitted.

Evaluation of registration dossiers and updates

REACH requires registrants who have already submitted a dossier to update their registration without undue delay with any new information about the substance or registrant. CONCAWE has developed a dossier update programme which ensures that dossiers revised with new information in the common parts of the dossier remain compliant with any new guidance published by ECHA since 2010. This also ensures compliance with any updates to ECHA's software system.

This programme will also address updates to the dossiers that may be required in response to evaluation feedback that is expected after ECHA has completed the first dossier reviews. Registrants were encouraged, in ECHA's 2011 report on dossier evaluations, to update already submitted dossiers before ECHA starts their evaluation so that the dossiers are in line with any new recommendations. CONCAWE intends to ensure compliance of its registration dossiers by grouping updates into several releases throughout 2012.

The first major update of CONCAWE's dossiers took place in February 2012, covering three substance categories. All co-registrants have been informed of the content of these updates as well as the implication of any changes and the importance of extending their co-registrant licences to ensure continued access to the updated dossiers. Lead Registrants have also been asked to update their registrations and confirm their successful submission to CONCAWE. Information is always shared on *SIEF.space*, the central information repository for Petroleum Substances SIEFs.

More questions?

Current or future registrants can contact CONCAWE's SIEF Team at one of the contact e-mails below depending on the nature of their question:

- Licence@super-sief.eu for questions related to licence agreements.
- LR@super-sief.eu for questions related to the joint submission of their registration.
- Info@super-sief.eu for questions related to the technical content of the dossier prepared by CONCAWE or the category approach.
- Admin@super-sief.eu for questions on the licences ordering process and payment of licence fees.
- Siefspace@super-sief.eu for questions regarding the SIEF Communication Tool.

Reducing the concentration of fine particulates in ambient air

Three factors are discussed that should be considered for a robust air quality policy.

From many health and epidemiological studies, it is generally accepted that exposure to fine particulate matter (PM) is harmful to human health and that actions should be taken to reduce the concentration of PM in air.

Atmospheric PM is a complicated mixture of particles from different origins, arising both from natural sources and from human activity (anthropogenic PM). The PM mixture changes over time as sources change and as mitigation measures are implemented in response to new regulations. Epidemiological studies that provided the statistical evidence related to health effects did not and, in fact, could not account for changes in PM composition. Thus, the PM concentration in air is the controlling parameter and reducing the overall PM concentration is the air quality policy target. Putting controls on PM sources, both for directly emitted or primary PM and for materials that react in the atmosphere to form secondary PM, will change the composition of PM. If different components of PM have different degrees of harmful effect, then it is important to assess how different reduction strategies that simply reduce the PM mass concentration will perform.

Health impacts of PM

The Clean Air for Europe (CAFE) programme (2001–2005) was the first European policy study to conclude that reducing concentrations of PM would improve human health. The resulting 2005 Thematic Strategy on Air Pollution (TSAP) set as one of its objectives the aim of reducing the calculated 'Years of Life Lost' (YOLL) in the European population due to exposure to $PM_{2.5}$[1] by 47% in 2020 compared to 2000.

The CAFE programme assumed that a life-long exposure to an annual $PM_{2.5}$ concentration of 10 $\mu g/m^3$ would increase the mortality risk by 6%. This mortality risk is based on a 2007 UK study[2] but is similar to values reported by the US Science Advisory Board, the World Health Organization and others. To put this figure in context, starting with the risk profile of a 2005 UK population, a 10 $\mu g/m^3$ reduction in PM would be expected to increase life expectancy by 7.5 months.

The monetary value that is placed on the estimated reduction in mortality risk is called the 'Value of a Life Year' (VOLY) and is used in EU air quality policy to compare health benefits with the costs of mitigating airborne PM using different mitigation measures. Because the VOLY is a large number and is multiplied by the YOLL for the whole EU population, the perceived value of mitigating $PM_{2.5}$ is very high when examining different options for improving ambient air quality.

Of course, many factors other than PM levels affect mortality risk, such as access to health care. In fact, dramatic reductions in mortality risk have occurred over the past 40+ years from improved socio-economic conditions and other measures implemented to improve human

[1] $PM_{2.5}$ is particulate matter with diameter of 2.5 micrometres or less.

[2] UK Committee on Medical Effects of Air Pollution (COMEAP, 2007).

What are 'Years of Life Lost' and how are they estimated?

An actuarial life-table is typically used to describe the evolution of 100,000 people, called a 'cohort', from birth to death. For example, if the life expectancy is 70 years at birth, then this cohort of 100,000 people contains 70 x 100,000 or 7,000,000 life-years. If the life expectancy at birth is instead 70 years plus one month, then a cohort of 100,000 people would contain 7,008,333 life-years.

There are, of course, many health and environmental factors that can be expected to increase life expectancy, not just a reduction in PM emissions. However, if we assume that a reduction in PM exposure reduces the mortality risk and increases the life expectancy at birth by just one month, then we can attribute these additional life-years solely to the benefits of PM reduction.

Therefore, in theory, a hypothetical cohort of 100,000 people could 'lose' 8,333 years of additional life if they were born into a world where mitigation measures had not been put in place to reduce airborne PM levels. This hypothetical 'loss' is called the 'Years of Life Lost' or YOLL.

Of course, the robustness of these estimates cannot be tested because it is not possible (or ethical) to expose two actual populations of people to different ambient PM concentrations without changing any other factors that affect life expectancy. For this reason, YOLL, when used in an air quality context, is a hypothetical estimate based on assumptions regarding human exposure to air pollutants, such as PM.

health. Since 1960, life expectancy has increased at a rate of approximately 2.5 months per year, a total increase over this period of more than 10 years.

PM reductions that can be realistically achieved by the most cost-effective measures are found to have a value of about 2–3 months over a 10-year time frame, that is, a life expectancy improvement of only about 10% compared to the normal variation that has been observed since 1960. For this reason, it is very difficult to quantify the actual improvement to a population's life expectancy from air quality improvements alone.

Robustness of policy assumptions

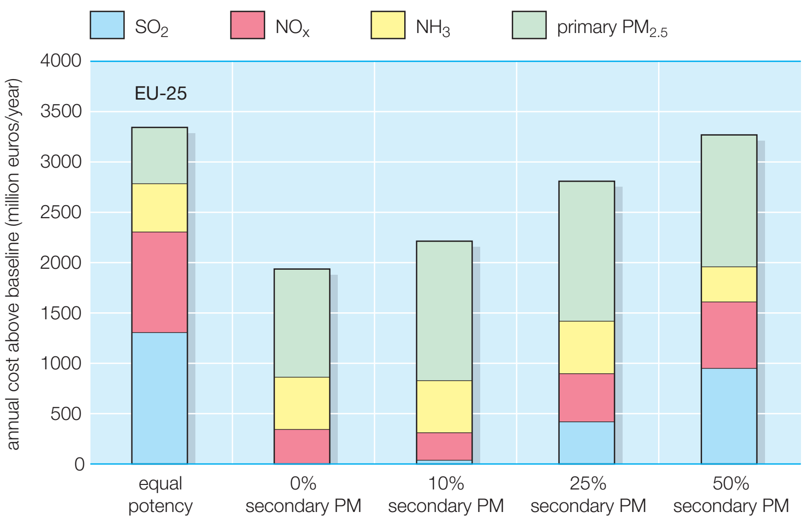
The effect of particle composition

In developing the TSAP, it was assumed that all particles are equally harmful to human health so that all measures to reduce PM concentrations are equally effective. We can examine what the effect might be if particles from some sources are more 'potent' and others less 'potent' in their effect on human health.

Figure 1: The bars show the additional cost above baseline for the EU-25 based on assumptions about the relative potency of primary and secondary PM.

As an example, Figure 1 shows what would happen to a control strategy if the inorganic secondary particles, ammonium sulphate and nitrate formed in the atmosphere, were less potent than the primary particles emitted from combustion processes. Controls on SO_2, NO_x and NH_3 are needed to reduce secondary particles, while controls on smoke emissions are needed to reduce primary particles. In this example, the cost of meeting all of the TSAP environmental objectives are calculated, not just the cost of reducing the year 2000 YOLL by 47% in 2020. The bars show the additional cost for the EU-25 (in millions of euros) above the baseline cost of currently agreed legislation, based on assumptions about the relative potency of primary and secondary PM.

Figure 1 Additional cost above baseline to meet the same TSAP objectives for different assumptions about the relative potency of primary and secondary PM



The left-most bar shows the current TSAP approach where all PM, both primary and secondary, are assumed to be equally potent in their effect on human health. The costs of mitigation measures for controlling SO_2, NO_x, NH_3 and primary $PM_{2.5}$ are shown in terms of their annual cost to implement.

The second bar represents an extreme case where all harmful particle effects are assigned to primary $PM_{2.5}$. The overall cost of mitigation measures is markedly lower. All costs for controlling SO_2 are essentially avoided, NO_x control costs are lower and NH_3 costs are similar. The total cost for controlling primary $PM_{2.5}$ has more than doubled however.

This calculation meets the EU targets for reducing acidification and eutrophication which require reductions in NO_x and NH_3. The contribution of SO_2 to acidification in Europe is now very small as a result of the historical reductions in these emissions.

The remaining three bars in Figure 1 show the effect of re-introducing harmful effects from secondary particles at different levels, from 10% to 25% to 50%. The risk factor for the whole PM mixture is kept constant so there is a compensating reduction in the potency of primary particles compared to the second case. Controls on SO_2 emerge once again as an important mitigating factor as the assumed potency of secondary particles increases. The overall cost of measures also increases.

The effect of sectoral contributions

For emissions reporting purposes, activities are commonly grouped into sectors according to the SNAP (Selected Nomenclature for sources of Air Pollution) convention. Sector 1 is large combustion sources, Sector 2 is non-industrial combustion including domestic sources, Sector 3 is industrial combustion (including oil refineries), Sector 4 is process industries, Sector 7 is on-road vehicles, and Sector 8 is non-road machinery and transport. Sectors 5 and 6 are not shown.

We can consider how best to describe emissions from different sectors when assessing air quality policy. The Integrated Assessment Modelling (IAM) methodology has been used in Europe to evaluate the costs associated with reducing emissions from different sectors. The IAM assesses the effect on emissions concentrations by modelling these reductions in national emissions. This methodology is a good approach for those sectors that are more or less evenly distributed across the country. A fully sectoral modelling approach, however, should represent the geographic distribution of emissions from different sectors and not just their total emissions.

In a previous study[3], a sectoral approach was tested to see if it would give similar or better results when compared to an approach based only on national emissions limits. The relationship between changes in emissions from different sectors on pollutant concentrations was calculated, accounting for the geographic distribution of sector emissions. An important aspect, from a health

[3] *EURODELTA: Evaluation of a sectoral Approach to Integrated Assessment Modelling—Second report*

Figure 2 Results of a sectoral study on $PM_{2.5}$ control scenarios for some European countries

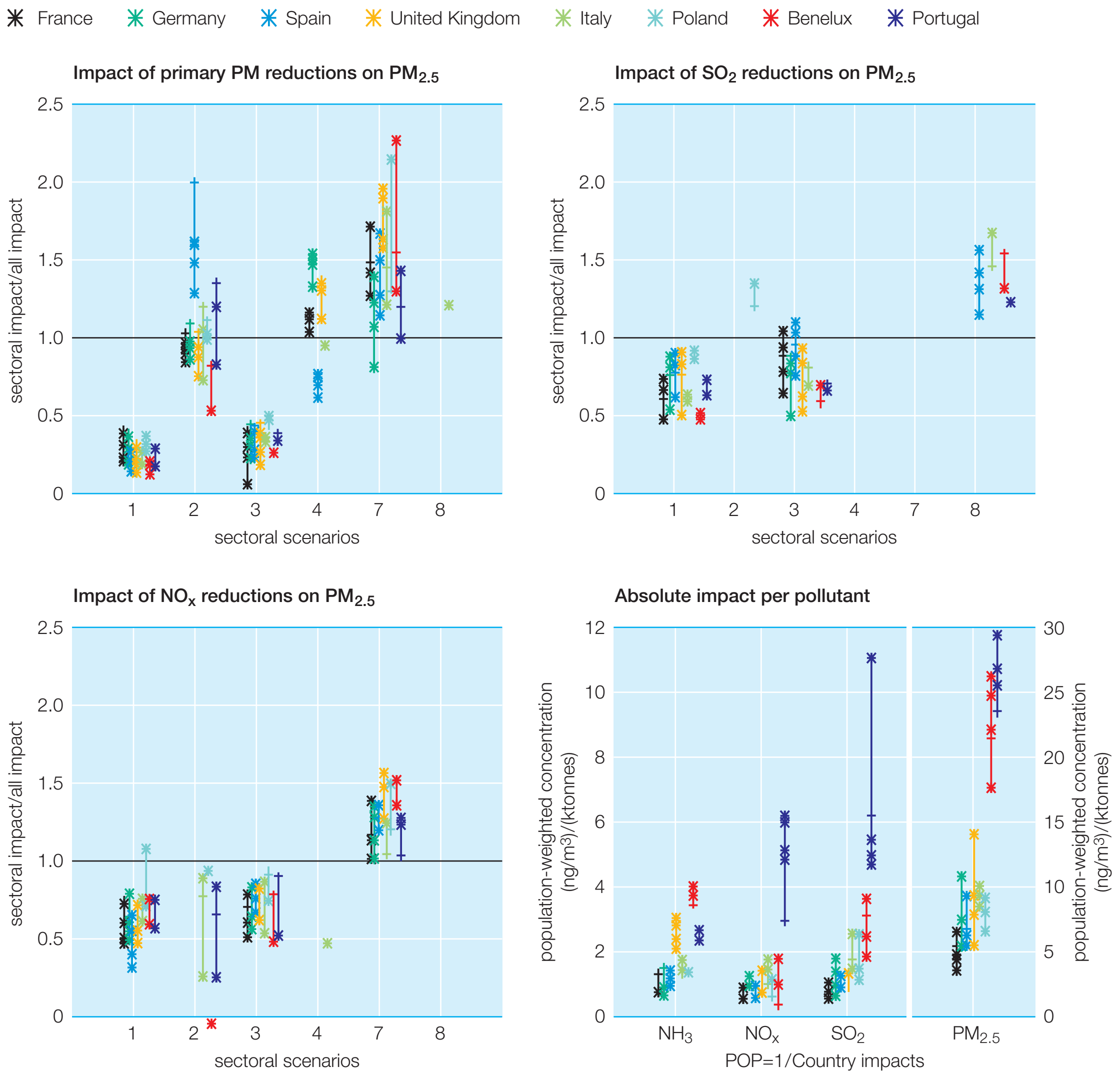


Figure 2: Results from the EURODELTA[3] study show that reducing industrial emissions (Sectors 1 and 3) is generally much less effective than would be expected using the national emissions limit approach. This is an important finding because a relatively high weighting is placed on controlling industrial emissions as part of the Integrated Assessment Methodology process.

assessment viewpoint, is that emissions from sectors that are close to population centres may have a greater effect on human health than those that are farther away.

Results from this study are shown in Figure 2 for different European countries. Looking first at the upper left-hand box, the vertical axis shows the effectiveness of a targeted reduction in $PM_{2.5}$ from a particular sector compared to a reduction in the national emissions limit from all sectors. Points above the 1.0 line mean that an emissions reduction from a particular sector is expected to produce a greater reduction in $PM_{2.5}$ exposure compared to a reduction in the national limit for $PM_{2.5}$ emissions. Consequently, greater reductions in airborne PM could be expected by targeting mitigation measures on specific sectoral emissions. The other boxes show the impact of reductions in SO_2 and NO_x on $PM_{2.5}$ as well as the absolute impact for reductions in each pollutant.

The results show that reducing primary $PM_{2.5}$ from industrial emissions (Sectors 1 and 3) is generally much less effective than would be expected by using the national emissions approach. This is an important finding because it means that the IAM over-emphasises the importance of industrial sources for PM. It also means that targets for $PM_{2.5}$ reductions may not be met if they rely on industrial control measures. It is clearly important that mitigation measures are applied to the most appropriate emissions sources if policy measures are to be successful in achieving the air quality and human health objectives.

The effect of air quality policy on climate cooling

Emissions of carbonaceous particles (black carbon) are known to have a climate warming effect, both as an aerosol and through the effect of PM deposits on snow surfaces. Emissions of SO_2, however, have a strong cooling effect through the formation of sulphate particles. It is now clearly understood that the significant reduction in sulphur emissions achieved over the past 30 years to help reduce acidification in Northern Europe has also removed a substantial climate cooling effect.

While continued reductions in SO_2 emissions based on the current IAM methodology are mainly driven by the effect of PM on human health, the corresponding beneficial effects of sulphate emissions on climate cooling have not been adequately evaluated. If the two effects mentioned in the previous sections are combined—differences in potency of PM components and the lack of effective controls on sectoral emissions—then current mitigation options required by the IAM could be ineffective, costly, and counterproductive from a climate warming and cooling perspective.

Conclusion

There is no question that improving air quality and reducing the impact of air pollutants, such as PM, on human health is an important objective. Mitigation measures, however, should be evaluated fairly, based on their cost-effectiveness for achieving the desired air quality improvements. Otherwise, there is considerable potential that investments will be made to reduce emissions, but that these will not in fact achieve the desired improvements in air quality or human health.

As demonstrated here, there are two serious sensitivities that should be accounted for when designing air quality policy. Individually, they challenge the effectiveness of mitigation measures that can be expected based on the current modelling approach. If these two factors act together, then current policy measures are very likely to under-perform against their expected targets and there may well be consequential and adverse impacts for climate. These aspects should be explored in greater detail to evaluate the robustness of proposed policy measures. More importantly, the IAM used for modelling European air quality policy should be updated to take these effects into account.

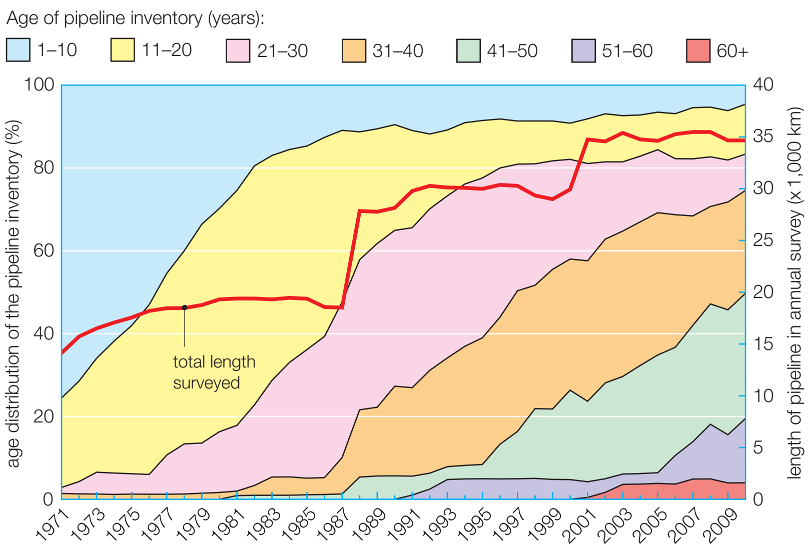
Europe's oil pipelines: 40 years of results

CONCAWE reports on the performance of Europe's oil pipelines

The Oil Pipelines Management Group (OPMG) is one of CONCAWE's oldest, having been in existence since the early 1970s. OPMG is open to all European oil pipeline operators and provides a unique forum for exchanging experience on non-competitive aspects of pipeline operations, mainly in the areas of safety, security and environmental protection. OPMG also facilitates sharing of non-confidential information on incidents and near misses, and maintains close contact with operators of other pipelines (gas and chemicals) through their trade associations.

Regulations affecting pipelines may be developed at national, EU or international levels. OPMG tracks these developments and represents the industry in discussions with regulating authorities in order to ensure that the safety and environmental record of the EU pipeline network is well understood. This was done recently in discussions on the possible inclusion of pipelines in the update of the Seveso II Directive. Every four years, OPMG also organises the CONCAWE Oil Pipeline Operators Experience Exchange (COPEX) Seminar to review the state of the EU oil pipeline network. Highlights of the 2010 COPEX Seminar were reported in CONCAWE *Review* Vol. 19, No. 1 and the presentations are available on the CONCAWE website.

Figure 1 The average age of the European pipeline inventory, 1971–2010



Surveying the oil pipeline inventory

The most significant OPMG activity, however, is the annual survey of pipeline spillage incidents. CONCAWE's survey database lists 478 spillage incidents covering more than 40 years from 1971 to 2010. OPMG's report on the annual survey (Report 8/11) provides details of the spills that occurred in 2010 and a historical analysis of the EU's pipeline inventory and performance since 1971.

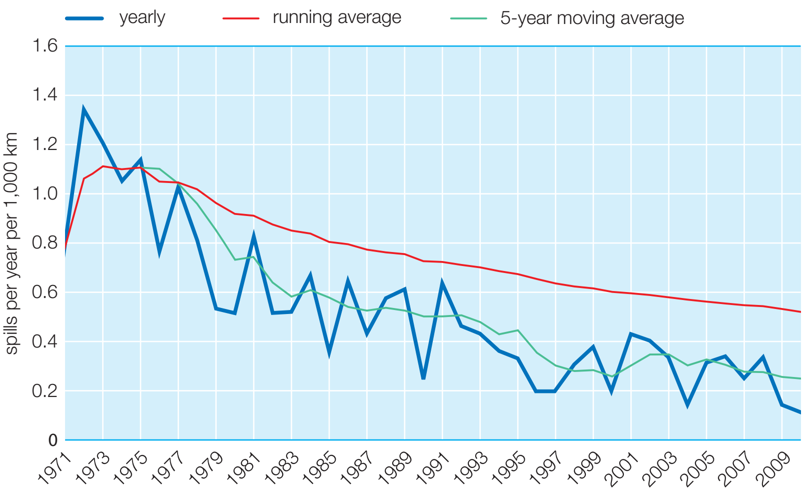
To complete the annual survey, CONCAWE contacts all 78 oil pipeline operators across Europe who are responsible for the safe operation of more than 36,000 km of so-called 'cross-country' pipelines. In this definition, pipelines to off-shore locations are excluded but short underwater sections in rivers and estuaries are included. The survey originally covered pipelines operated by oil companies in Western Europe, but has broadened over the years. Most of the military (or ex-military) pipelines joined the survey in the late 1980s, followed about 10 years ago by a number of Eastern European operators. The current inventory now represents the majority of pipelines in Europe, with the exception of the military or ex-military lines in Italy, Greece, Norway and Portugal and the state-owned lines in Poland and Romania.

For the 2010 survey, 69 operators responded, representing a total inventory of 34,645 km. Taken together, these pipelines transport about 800 million m^3 of material every year, about 2/3 crude oil and 1/3 refined products, which is more than the total annual EU refinery throughput. The majority of these pipelines were installed in the 1960s and 1970s so the average age of the pipeline inventory has been steadily increasing over time (Figure 1).

Pipeline spillage volumes

The total number of pipeline spills per year has slowly decreased with each survey, while the spillage frequency shows an even stronger downward trend (Figure 2). Although there are large variations from year to year, the total volume spilled each year has remained constant at around 2,000 m^3/annum, even though the total length of pipelines surveyed has increased over the years. On average, about 60% of the spilled oil is recovered. This figure has also improved over the past 10 years, and is now at about 80% recovery in the most recent surveys,

Figure 2 EU cross-country oil pipelines spillage frequency



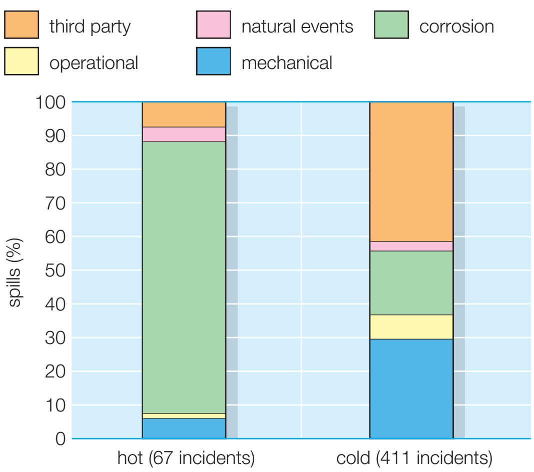
although it is too early to know whether this is a statistically significant trend.

Causes of pipeline spills

The causes of spills are analysed according to five main categories: mechanical, operational, corrosion, natural events and third-party interference, and their distribution is shown in Figure 3, for both 'hot' and 'cold' pipelines.

'Hot' pipelines represent less than 1% of the total inventory today but account historically for 14% of the total reported spillage incidents. These pipelines, a small and decreasing part of the inventory, consist of insulated pipelines transporting heated products, mainly heavy fuel oil. The majority of these have been phased out over the years because of external corrosion problems.

Figure 3 Causes of pipeline spills



For the larger fraction of 'cold' pipelines, the most common causes of spillage are third-party interference, mechanical failure and corrosion. The long-term trend has improved over time for these three categories, as it has for all spills taken together.

Third-party interference is the main cause of spillage incidents for 'cold' pipelines and is considered by operators as the main threat to the integrity of pipeline operations. A small fraction of these spills are the result of malicious or criminal activities, but the majority are accidental and mostly related to farming and excavation. The pipeline industry is actively working with land owners, contractors, national authorities and regulators to devise new ways of reducing the occurrence of these accidents.

Mechanical failures can result from many causes related to design and materials, as well as from construction defects. An in-depth analysis of the 34 mechanical failures reported in the past 10 years has shown that only about 10% of these could be linked to fatigue-related failures. This suggests that the observed increase is not necessarily linked to the age of the pipeline inventory.

Although corrosion failures also occur in 'cold' pipelines, the long-term trend is downward for this failure mode, suggesting that corrosion problems are under control in spite of the aging of the pipeline inventory.

How important is the pipeline's age?

As shown in Figure 1, the median age of the EU's oil pipeline is about 40 years with a small percentage more than 60 years old. Although the pipeline's age is a possible cause for spills, CONCAWE's analysis does not suggest that the pipeline's age is an important factor. Pipeline operators have adopted modern management systems covering operational maintenance and inspection, and the now routine use of sophisticated in-line and external inspection techniques provides early detection of structural problems, triggering action before a spill can occur.

CONCAWE's market fuel survey: assessing progress in biofuel blending

Evaluating oxygenate concentrations in service station fuels from 17 European countries

The use of bio-derived blending components in transport fuels is increasing around the world as a result of legislative initiatives to reduce transport greenhouse gas (GHG) emissions, improve energy security and support agriculture. Within the European Union, the Renewable Energy Directive (2009/28/EC) requires that transport fuels must contain at least 10% energy content of renewable products by 2020. This energy target will largely be achieved by blending sustainably-produced biofuels into today's market fuels.

Meeting this overall European target is the responsibility of each Member State and each country has already reported their approach through National Renewable Energy Action Plans (NREAPs) published in 2010. These plans vary significantly from one country to the next depending upon the specifics of the country's transport demands, agricultural production and the availability of alternative energy options that can also be used to meet the renewable energy mandate.

The renewable bio-components that will be available in large enough volumes by 2020 to meet the demand are likely to be bio-ethanol produced from sugar fermentation, ethers manufactured from bio-ethanol and bio-methanol, and esters and hydrocarbons produced from vegetable oils and animal fats. Although some progress is being made on more advanced bio-components derived from biomass, like straw and wood, these products are not expected to contribute substantially to meeting the EU renewable fuel mandate before 2020.

Today, up to 2.7% oxygen by weight can be blended into gasoline in most countries through the use of oxygen-containing components at up to 5% by volume of ethanol (E5[1]) or higher volumes of ethers, such as ETBE, MTBE and others. Ethanol from renewable sources can be used to manufacture ETBE and the renewable fraction of the ETBE blending component counts toward the renewable mandate. In the future, more bio-derived methanol may also be used to manufacture MTBE in order to increase the renewable fraction in gasoline blending.

For diesel fuels, esterified natural oils, called fatty acid methyl esters (FAME), can be blended up to 7% by volume in diesel fuels (B7[1]) as long as they comply with the EU FAME standard (EN 14214) before blending. Many different vegetable oils, animal fats and used cooking oils are now routinely used in Europe to produce oxygen-containing FAME, while some fraction of these natural oils is also hydrogenated to produce an oxygen-free blending component. The European Committee for Standardisation (CEN) is making progress revising the EU-wide fuel standards which will increase the allowed percentages of biofuels to higher levels in transport fuels for compatible vehicles.

CONCAWE's market fuel survey

To find out more about the oxygenates that are actually being used in different European countries, CONCAWE conducted a survey of gasoline and diesel fuels from 17 countries covering the winter months of 2010–11. Fuel samples were collected directly from service stations that were selected to provide a good geographical distribution within each country and a representative cross-section of different fuel grades. The number of samples from each of the 17 countries was selected to reflect the relative fuel demand in different countries with more samples picked up from the larger countries and fewer from the smaller countries.

Overall, 100 gasolines and 142 diesel fuels were collected and analysed in a single laboratory to ensure consistent results. Special precautions were taken to safeguard the quality of the fuel sample from the time that it was collected until the analysis had been completed. The survey focused primarily on oxygenate concentrations and types, and did not verify that they were all produced from renewable sources. Other measurements were completed to compare the quality of the market fuels to the prevailing specifications. For the diesel fuel samples, the presence of any hydrogenated natural oils was not measured because these components are almost indistinguishable from the diesel fuel itself.

The survey results

Figure 1 shows the average oxygenate contents that were measured in the 100 gasoline samples. As can be seen, the oxygenate contents varied substantially from one country to the next, ranging from about 2.5% vol-

[1] Biofuel contents are expressed as the percentage of bio-component in fossil fuel on a volume basis. For example, E5 stands for 5% volume ethanol in gasoline while B7 stands for 7% volume fatty acid methyl ester (FAME) in diesel fuel.

Figure 1 Oxygenate contents in gasolines from 100 service stations

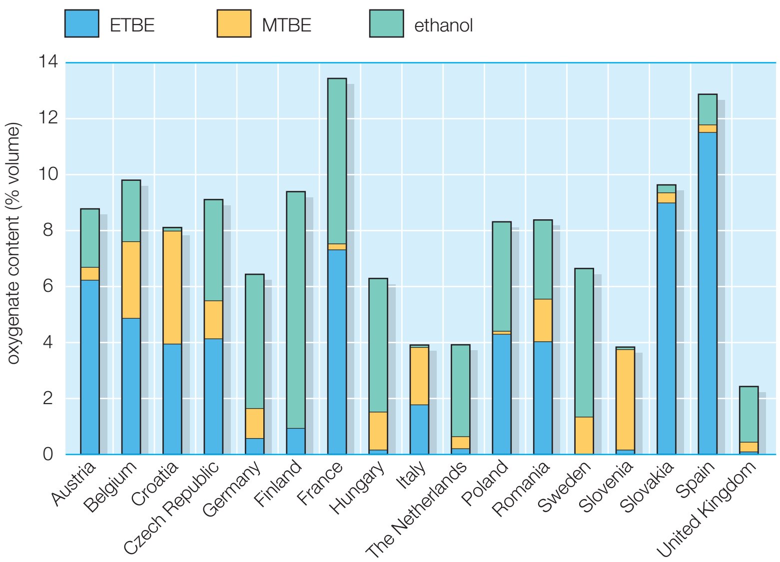
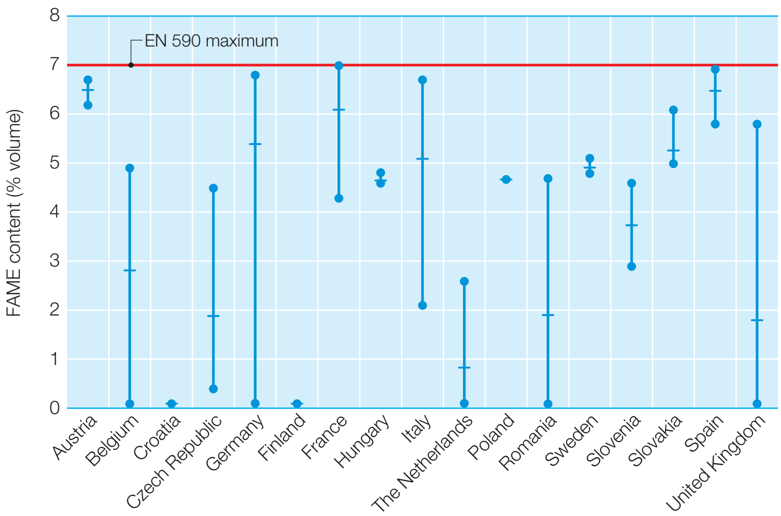


Figure 2 FAME contents in diesel fuels from 142 service stations



ume in the UK to more than 13% volume in France. More interestingly, the types of oxygenate that were used in each country were also quite different, with Finland using mostly ethanol, Spain and Slovakia using mostly ETBE, and Slovenia using mostly MTBE. Other countries, like France, Poland, Belgium, and Romania, used a mixture of ethanol and ether while Croatia and Italy used a mixture of ETBE and MTBE.

In Figure 2, the average FAME contents, as well as the maximum and minimum values, are shown for the 142 diesel fuels. The red line at the 7% volume mark shows the maximum FAME content that is currently allowed by the European diesel fuel specification (EN 590).

Again, clear differences can be found from one country to the next. For example, many countries, like Austria, Germany, France, Italy, Slovakia and Spain, showed average FAME contents higher than 5% volume with occasionally large differences between the maximum and minimum values. FAME contents less than 5% volume were found in Belgium, the Czech Republic, The Netherlands, Romania, Slovenia and the UK, again with reasonably wide variations in the maximum and minimum values. Essentially, no FAME was found in the samples from Croatia and Finland.

Although the oxygenates varied from country to country in this survey from the winter of 2010–11, it is important to note that all of the fuels dispensed from service station pumps were in compliance with the prevailing EU and national specifications. And, because today's newer vehicles are compatible with the oxygenate levels found in this survey, the EU's objective of reducing GHG emissions from the fuels used by the transportation sector may be just a little closer to reality.

Abbreviations and terms

AQ	Air Quality
BREF	Best Available Techniques Reference Document
CAFE	Clean Air For Europe
CEN	European Committee for Standardization
CHP	Combined Heat and Power
COPEX	CONCAWE Oil Pipeline Operators Experience Exchange
ECHA	European Chemicals Agency
EII®	Energy Intensity Index®
EMS	Energy Management System
EN 590	European Standard: 'Automotive fuels. Diesel. Requirements and test methods'
EN 14214	European Standard: 'Automotive Fuels. Fatty acid methyl esters (FAME) for diesel engines. Requirements and test methods'
ETBE	Ethyl Tertiary-Butyl Ether
FAME	Fatty Acid Methyl Esters
FCC	Fluidised Catalytic Cracker
GHG	Greenhouse Gas
IUCLID	International Uniform Chemical Information Database
LRA	Lead Registrant Agreement
MTBE	Methyl Tertiary-Butyl Ether
NH_3	Ammonia
NO_x	Nitrogen Oxides
NREAP	National Renewable Energy Action Plans
OPMG	Oil Pipelines Management Group
PM	Particulate Matter or Mass
$PM_{2.5}$	Particulate Matter with diameter of 2.5 micrometres or less
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
SCS	SIEF Collaboration Service
Seveso II Directive	EU Council Directive 2003/105/EC amending Council Directive 96/82/EC on the control of major accident hazards involving dangerous substances
SFF	SIEF Formation Facilitator
SIEF	Substance Information Exchange Forum
SMCG	SIEF Management Coordination Group
SNAP	Selected Nomenclature for sources of Air Pollution
SO_2	Sulphur Dioxide
TSAP	Thematic Strategy on Air Pollution
VOLY	Value of a Life Year
YOLL	Years of Life Lost

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