concawe review

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Foreword

With Europe at the forefront of the ratification of the Kyoto protocol, CO_2 and, more generally, greenhouse gases (GHG) are now definitely in the limelight and will be a central element in all future environmental studies. When any environmental improvement is proposed, its benefit has to be evaluated against the additional CO_2 emissions generated by its implementation. In this *Review* you will find several articles documenting how CONCAWE is dealing with this new focus.

The first article illustrates the 'well-to-wheels' CO_2 balance when compressed natural gas is used for road transport as compared to conventional fuels. Another article explains how we have updated our European refinery computer models to help evaluate the global CO_2 effect of changes to refinery operations, particularly with regard to the quality of the fuels.

Two further articles describe how sulphur-free road fuels, while increasing CO_2 emissions at the refinery level, are enabling the introduction of advanced engines and exhaust gas after-treatment systems. These can combine very low pollutant emissions with maximum fuel efficiency, thus delivering an overall reduction in CO_2 emissions on a 'well-to-wheels' basis.

In our October 2001 issue, I laid particular emphasis upon the need to base all new environmental legislation on sound scientific principles and upon CONCAWE's firm belief that sound science, transparency and cost-effectiveness must be fundamental to all environmental and health legislation. In the article 'Establishing Air Quality Limit Values: a key element of the CAFE programme' we explore the importance of the Air Quality Limit Values setting process to the ongoing CAFE programme.

The other articles in this *Review* cut across some further disciplines in which CONCAWE is active, such as the health effects of the use of our products, occupational health, water pollution and refinery technologies.

Jean Castelein
Secretary-General, CONCAWE

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A collaborative programme between EUCAR/JRC/CONCAWE has been under way for some time to assess the well-to-wheels energy and GHG (greenhouse gas) balance for a number of potential future European fuel/powertrain options. Following the Commission's previous communications on renewable fuels, DG TREN established the 'Alternative Fuels Contact Group' in June 2002 to advise the Commission on alternative fuels for road transport, with priority on natural gas and hydrogen. Close contacts were established between DG TREN and the EUCAR/JRC/CONCAWE study team. Interim results from the study, covering compressed natural gas (CNG) versus conventional fuels, have been made available and are included in the Contact Group's interim report which was recently published.

Enquiries to: Jean-François Larivé

Sulphur-free fuels are on the way

Which advanced vehicle technologies are emerging? *page 8*

The final version of the revised EU Fuels Directive, requiring the introduction of sulphur-free fuels, was published in March. This article discusses the new Directive and the new vehicle technologies which are now expected to emerge, enabled by the new generation of sulphur-free fuels. It also describes the substantial fuel changes that have been made over the past decade and highlights the need for sound science in any further consideration of fuel changes. This should take full account of the effects from the new technologies now entering the market.

Enquiries to: Neville Thompson

Emissions from modern gasoline vehicles

A problem essentially solved? *page 11*

The first results from a CONCAWE test programme to evaluate gasoline quality effects on emissions from advanced technology gasoline cars are now available. Very low emissions are being achieved through these vehicle technologies, highlighting the fact that the current challenge for gasoline vehicle technology development is to reduce CO_2 emissions while maintaining the now 'near-zero' levels of pollutant emissions. There was little or no short-term response of emissions to fuel sulphur content. Response to other fuel properties, aromatics, olefins, volatility and final boiling point will be reported later.

Enquiries to: Neville Thompson

Modelling the European refining industry

Focus on cost and CO_2 emissions *page 14*

For the past 10 years, CONCAWE has maintained a comprehensive model of the European refining industry. The original emphasis was on the estimation of cost of legislative measures to the industry. In view of the current focus on energy use and CO_2 emissions, the model has been extensively updated and is now capable of evaluating the overall effects in terms of CO_2 emissions, including those related to changes in the composition of refinery products.

Enquiries to: Jean-François Larivé

Establishing Air Quality Limit Values

The WHO provides information on risk assessment of certain pollutants. For setting Air Quality Limit Values, however, a 'risk management' step is also required in order to take into account the many other relevant practical, economic and societal factors. The integrated assessment modelling tools available within the CAFE programme can play a significant role in this process.

Enquiries to: Peter Goodsell

Oil in water analysis

There is no universally agreed method for determining oil in water. Many methods are in use, based on a number of different measurement principles. Different methods give different results so that it is essential that the required standards be defined according to a specific method.

Enquiries to: Eric Martin

Exposure of asphalt workers to bitumen fumes

The study report published in 2001 and concerning more than 80,000 asphalt workers over most of the 20th century has now been reissued together with further analyses of national patterns. The study has been an example of successful collaboration between researchers and industry representatives, while preserving the scientific independence of the researchers. A 'nested case control' study of lung cancer risk is being prepared.

Enquiries to: Jan Urbanus

Occupational exposures to gasoline vapour

Previously missing or out-of-date data relative to relevant exposure scenarios has been collected from CONCAWE member companies. The report (9/02) shows a decreasing exposure trend related to the implementation of vapour emission control measures. It is essential that this up-to-date information is fed into the gasoline risk assessment.

Enquiries to: Jan Urbanus

EUCAR/JRC/CONCAWE well-to-wheels study

Interim results contribute to the Commission's work on alternative fuels

DG TREN's initiatives on alternative fuels for road transport

Following the publication of the Green Paper on the Security of Energy Supply in the autumn of 2001, the EU Commission and in particular DG TREN[1] focused on a number of actions to support the Green Paper's main objectives. These mainly concern the development of alternative fuels for transport, in particular the delivery of reductions in greenhouse gas (GHG) emissions and the enhancement of energy supply security. Three major routes were singled out as the most promising, namely biofuels, natural gas and hydrogen.

Biofuels were addressed through the Directive on the promotion of biofuels which has recently been adopted.

In June 2002, DG TREN established the 'Alternative Fuels Contact Group', the remit of which was to 'give advice to the Commission concerning the technical and economical developments in the field of alternative fuels for road transport, with priority on natural gas and hydrogen, and on the measures by which the Community can promote their use with the purpose to attain a 20% market share by 2020'. Such measures could include legislative actions as well as research and technical development.

The Contact Group brought together all relevant stakeholders including representatives of the automotive and oil industries.

A cooperative approach to well-to-wheels analysis

At the end of 2001, EUCAR[2], JRC[3] and CONCAWE started work on a joint analysis of various alternative road fuels and associated powertrains on a well-to-wheels basis with the following objectives:

- Establish the energy and GHG (greenhouse gas) balance for a number of different fuel/powertrain options in the context of plausible European scenarios;
- Estimate the scale at which such schemes could be developed and the associated investments and operating costs;
- Take into account data from all relevant reliable and authoritative sources;
- Report results in a fully transparent way, including the publication of the database and methodology.

The energy resources considered are crude oil, coal, natural gas, biomass and wind. From these, a variety of fuels can be produced, including conventional road fuels, compressed natural gas (CNG), hydrogen, methanol, dimethyl ester, fuels from Fischer-Tropsch synthesis, ethanol and biodiesel. The powertrains include port-injected gasoline, direct injection gasoline and diesel, dedicated natural gas and fuel cells (with and without reformer), with hybridisation as an option. The study focuses notionally on the 2010 horizon in terms of technologies.

The study gathered pace during 2002 with the assistance of LBST[4] for the well-to-tank part and IFP[5] for the tank-to-wheels part. It soon became clear that the well-to-wheels analysis, already under way in the EUCAR/JRC/CONCAWE collaboration, could be an essential building block in the work of the Contact Group. Close contacts were established between the study team and DG TREN, resulting in a prioritisation of the study work to focus first on natural gas and then on hydrogen.

The well-to-wheels analysis on the conventional fuels and CNG pathways has now been completed and the results presented to the Contact Group. The interim

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[1] *Directorate General for Transport and Energy*

[2] *European Council for Automotive Research*

[3] *The EU Commission's Joint Research Centre in Ispra*

[4] *Ludwig Bolkow System Technik, a German consultancy specialising in alternative fuels and notably hydrogen*

[5] *Institut Français du Pétrole*

report from the Contact Group incorporating the results from the well-to-wheels study was published in April. An overview of the main findings is given below.

Conventional road fuels: marginal analysis is the key

Today, gasoline and diesel fuel account for nearly all of the road fuel market in Europe, as well as in the rest of the world. There is a general consensus that conventional oil-based fuels will continue to supply most of our transport fuel needs for the foreseeable future, alternatives taking a limited share of the market. It is therefore important to assess any shifts in the base gasoline and diesel pool on a marginal basis.

As a result of the pre-eminence of road freight transport and of the high proportion of diesel cars, Europe is structurally long in gasoline and short in diesel fuel. The European refining system struggles to meet the European diesel fuel demand while it over-produces gasoline. The marginal diesel fuel production is therefore more energy intensive than the marginal gasoline production (0.10 and 0.08 MJ/MJ respectively). The complete GHG balance for the marginal conventional fuels, including crude oil production and transportation as well as final fuel distribution, is shown in Figure 1.

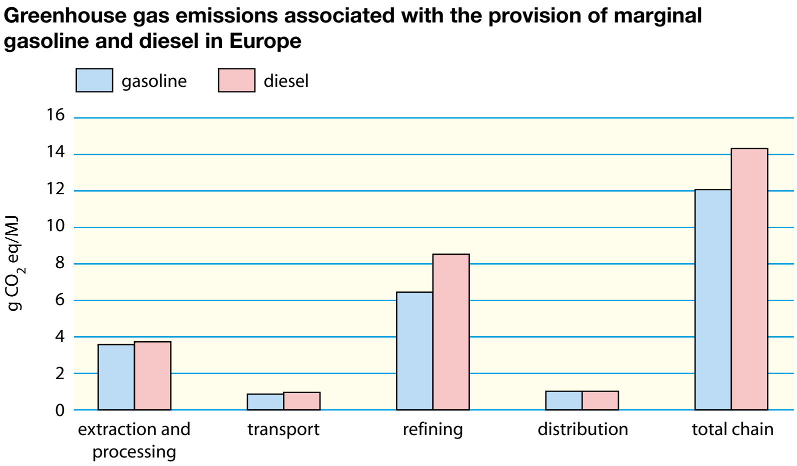

Greenhouse gas emissions associated with the provision of marginal gasoline and diesel in Europe

Figure 1
The marginal diesel fuel production in Europe is more energy intensive than the marginal gasoline production (0.10 and 0.08 MJ/MJ respectively).

Note: the GHG emissions include all identifiable sources of CO_2, methane and nitrous oxide (N_2O), converted into CO_2 equivalent using the Intergovernmental Panel on Climate Change (IPCC) factors of 21 for methane and 310 for N_2O.

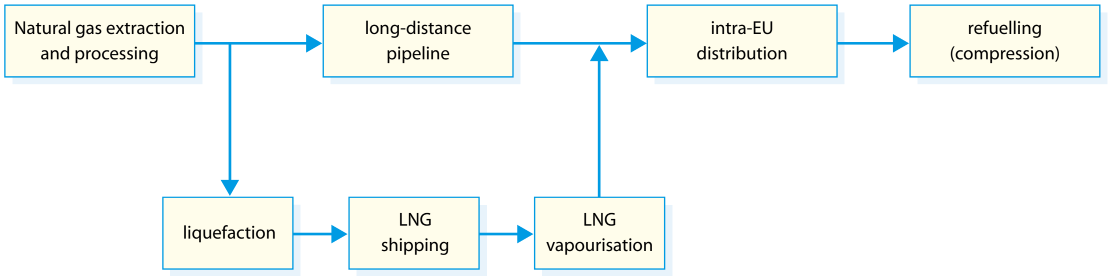
The routes to compressed natural gas

Natural gas is widely available in Europe, distributed through a dense network of pipelines to industrial commercial and domestic consumers. The indigenous European production (mainly from the UK, The Netherlands and Norway) is complemented by sizeable imports mainly from Algeria and Russia. Demand is expected to grow very strongly, mainly to feed the increasing demand for electricity, particularly in view of the nuclear phase out in many countries. World natural gas reserves are very large but European production is set to decline from around the end of this decade so that the share of imports in the European supply will increase steadily. Russia, other countries of the Former Soviet Union and the Middle East are the most credible long-term major supply sources for Europe.

The development of a natural gas market for road transport, in the form of CNG, would require further imports of marginal gas which we have taken as the basis to describe the potential supply chains.

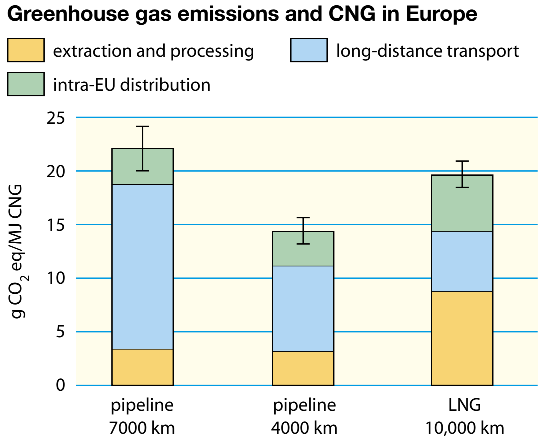
Natural gas can reach Europe either overland via long-distance pipelines or by sea in liquefied form (LNG). We have considered three sourcing scenarios:

- 7000-km pipeline (typically from western Siberia);
- 4000-km pipeline (typically from south-west Asia);
- LNG shipping over a distance of about 10,000 km (typically the Middle East).

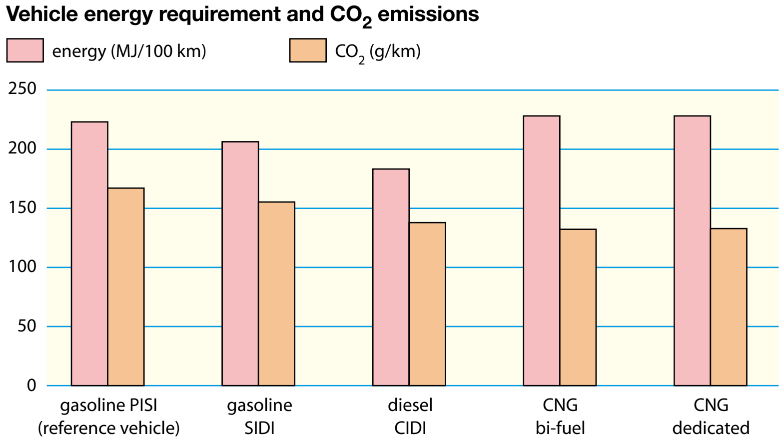


EUCAR/JRC/CONCAWE well-to-wheels study

Interim results contribute to the Commission's work on alternative fuels



Greenhouse gas emissions and CNG in Europe



Vehicle energy requirement and CO_2 emissions

Figure 2 (above left)

The origin of the gas is a major factor determining the energy balance.

Note: The 'uncertainty bars' pertain to the total energy or GHG and represent the plausible range of variation to account for the variety of actual situations and the variability of some of the data from different sources.

Figure 3 (above right)

In terms of CO_2 emissions the CNG engine fares better because of the lower carbon content of natural gas. Fuel economy, however, is no better than the reference gasoline engine.

The well-to-tank GHG emissions for these routes are summarised in Figure 2.

The need to transport the gas over long distances accounts for a large part of the total energy. The origin of the gas is therefore the major factor determining the energy balance. Transport in liquid form is more efficient but this advantage is negated by the energy required for liquefaction so that LNG comes out worse than piped gas (for the 4000-km pipeline case).

The final compression (to 25 MPa in order to refuel the vehicles) also requires a large amount of energy which is highly dependent upon the pressure available in the network. In this study we have assumed the gas is available at 0.4 MPa (gauge), being the pressure of the modern EU networks with a plausible range of 0.1 to 2.0 MPa.

From tank to wheels

In order to evaluate the potential of various alternative fuels it is crucial to consider how and in what vehicle they are likely to be used, complementing the well-to-tank by a tank-to-wheels analysis.

So far in this study we have considered a 'virtual' vehicle based on the VW Golf, a typical European mid-class vehicle. With the help of the ADVISOR[6] software, the vehicle has been 'equipped' with a powertrain and relevant equipment (e.g. fuel tank) pertinent to each fuel. The basic premise is that all vehicle/fuel combinations must equal or exceed a fixed set of customer performance criteria.

The engine technologies considered so far are those available in 2002, meeting Euro-3 emission standards. In the next phase of the study the assumptions will be revised to represent the best estimates of the performance of the 2010 technologies (and Euro-4 standard). The emissions and fuel consumption are judged on the basis of the New European Driving Cycle (NEDC).

The reference vehicle has a port-injection spark-ignition (PISI) 1.6 l gasoline engine. For gasoline the lean-burn direct injection (SIDI) technology offers a somewhat more efficient alternative (7%) although the real benefit over the driving cycle is far less than was hoped for a few years ago. The direct injection diesel engine needs to have a larger displacement in order to meet the performance criteria (1.9 l) but delivers the expected robust efficiency improvement (about 18% compared to gasoline).

For CNG, two cases have been considered, either a bi-fuel (gasoline) vehicle based on the 1.6 l gasoline PISI, or a dedicated CNG vehicle. Direct injection is not considered feasible for CNG so the dedicated engine is also a PISI.

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[6] *ADVISOR: a publicly available engine and vehicle simulation software*

EUCAR/JRC/CONCAWE well-to-wheels study

Interim results contribute to the Commission's work on alternative fuels

Well-to-wheels energy requirement of conventional and CNG vehicles

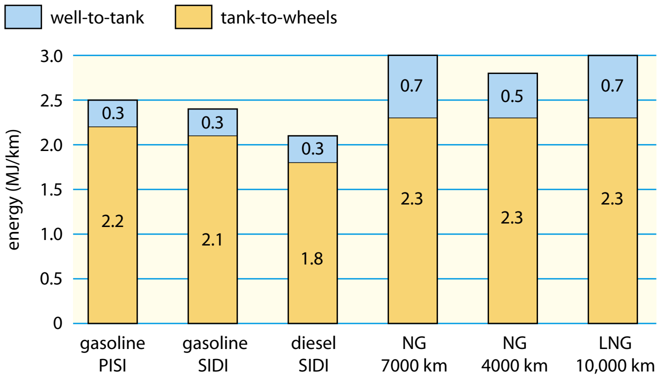


Figure 4a (above left)
CNG chains are generally more energy-intensive than those for conventional fuels.

Greenhouse gas emissions associated with conventional and CNG vehicles

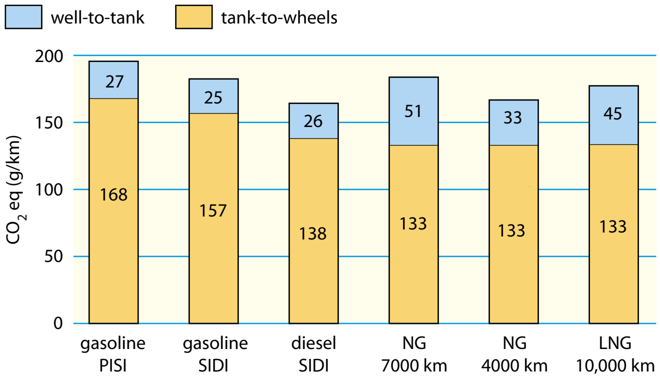


Figure 4b (above right)
CNG chains offer some benefit compared to gasoline because of the lower carbon content of natural gas. There is no benefit when compared to diesel.

The bi-fuel engine suffers a loss of torque when operated on CNG, due to the lower specific energy offered by this fuel. Although the resulting acceleration performance of the bi-fuel vehicle is affected, this has been accepted, as the minimum top speed is reached and as it is representative of a real commercial case. Because the engine is not optimised for natural gas, there is no energy efficiency benefit compared to gasoline. On the total cycle the fuel consumption turns out slightly higher than for gasoline. The dedicated engine can take advantage of the high octane rating of natural gas through an increased compression ratio leading to better efficiency. This advantage is, however, fully counterbalanced by low load inefficiency as a larger displacement (2.0 l) is needed to fulfil the performance criteria. Overall, the dedicated engine comes out as no better than the reference gasoline engine in terms of fuel economy (Figure 3). In terms of CO_2 emissions the CNG engine fares better because of the lower carbon content of natural gas.

Further technical developments such as downsizing and turbo-charging are expected to bring further efficiency improvements to CNG and gasoline engines alike. For diesel, performance gains are also achievable, although the room for such enhancements is more limited, present diesel engines being already direct-injected and turbo-charged.

The overall well-to-wheels picture

The total well-to-wheels picture is shown in Figures 4a and 4b.

CNG chains are generally more energy-intensive than those for conventional fuels. In terms of GHG emissions, this is partly compensated by the lower carbon content of natural gas so that the present CNG chains offer some benefit compared to gasoline but not compared to diesel.

The geographic origin of the gas is the single most important parameter. Future marginal gas supplies to Europe are far away and the associated transport energy penalises the CNG option.

Sulphur-free fuels are on the way

Which advanced vehicle technologies are emerging?

The final version of the revised EU Fuels Directive, 2003/17/EC, was published in March 2003. As expected, sulphur-free gasoline and diesel fuels (10 mg/kg maximum sulphur content), must be available on 'an appropriate balanced geographic basis' from 2005. Full market coverage of sulphur-free fuels is required from 2009, though the end date for diesel fuel remains subject to review. Other fuel properties are unchanged compared to the already agreed 2005 specifications. The Directive does not stipulate any change to the quality of diesel fuel for non-road vehicles for 2005, but requires that the Commission establish the future quality requirements for non-road diesel fuel in parallel with its work on the next stage of emissions standards for compression ignition engines used in non-road applications. The Directive also calls for a further review of the road fuels specifications to be completed by end 2005.

The specifications for the new generation of sulphur-free fuels were established following the Auto/Oil II programme and the EU Commission's subsequent sulphur review. Sulphur-free fuels should enable advanced engines and exhaust after-treatment systems to achieve the new Euro-4 and Euro-5 emissions standards with maximum fuel efficiency, also assisting the motor industry to meet their voluntary CO_2 commitments (European passenger car fleet average 140 g/km CO_2 by 2008).

At the time of the EU Commission's sulphur review in 2000, CONCAWE recognised that sulphur reduction helps the vehicle manufacturers to meet the new emissions standards, but identified that there were only a few vehicle technologies that potentially needed sulphur-free rather than 50 mg/kg maximum sulphur fuels. These highly sulphur-sensitive technologies included lean de-NO_x catalysts (LNTs) and continuously regenerative particulate traps (CRTs). LNT systems also introduced a fuel efficiency and durability benefit from sulphur-free fuels since less frequent purging of sulphate from the catalyst would be required. The subsequent debate over the timing for introduction of sulphur-free fuels hinged largely on two elements:

- the overall well-to-wheels CO_2 balance in relation to the fuel efficiency of advanced vehicle technologies (in particular lean-burn direct injection gasoline engines with regenerative de-NO_x catalysts) versus the increase in refinery CO_2 emissions for producing 10 mg/kg max rather than 50 mg/kg max sulphur fuels; and
- the ability of diesel engines to meet the new emissions standards.

The final adoption of the updated EU Fuels Directive provides a timely opportunity to review the emerging vehicle technologies and potential future fuel implications.

Emerging vehicle technologies

With respect to meeting the future Euro-4 and Euro-5 exhaust emissions standards and CO_2 targets, the challenges lie in different directions for the different engine technologies.

Many gasoline engines today already surpass the Euro-4 emissions limits, well in advance of the 2005 deadline. The real challenge for gasoline engines is to reduce CO_2 emissions, while maintaining their low emissions of regulated pollutants. Lean-burn direct injection engines carry the promise of significant fuel efficiency gains, but require complex exhaust after-treatment systems for control of NO_x emissions. The future predominance of lean-burn direct injection engines that was forecast only two years ago, is now considered less likely. A wide range of other gasoline engine technologies, including stoichiometric systems with conventional 3-way catalysts, will compete with the lean-burn approach. Direct injection, multi-point injection, variable valve actuation, turbo-charging and engine downsizing are all likely to play a role. A much lower market penetration of lean-burn direct injection engines with NO_x storage catalysts is now expected. The introduction of sulphur-free fuels will enable the widest range of vehicle technologies to be employed, though the change in the emerging technologies suggests that the CO_2 balance associated with the change from 50 to 10 mg/kg maximum sulphur fuels is likely to occur rather later than forecast in the EU Commission's sulphur review. The winning technologies are likely to be those that can deliver low CO_2 and pollutant emissions, while achieving good performance, reliability and durability at an acceptable cost to the consumer.

The challenge for diesel engines is to improve particulate and NO_x emissions, while maintaining good fuel economy and CO_2 emissions. As engine measures to reduce particulate emissions generally increase NO_x emissions and vice versa, some form of exhaust gas after-treatment is likely to be required. Application of LNTs to diesel engines is technically feasible but still requires considerable development and in the near term alternative approaches are more likely to be used.

For heavy-duty diesel engines, the major issue is to achieve the Euro-5 (2008) emissions limits for NO_x and particulates (PM). Towards this objective, two fundamental development routes have been pursued:

- to optimise the engine for low particulate emissions, then to control NO_x emissions with a Selective Catalytic Reduction (SCR) after-treatment system, using urea as the reducing agent; and
- to reduce engine-out NO_x emissions via engine measures, including multiple high-pressure injections together with cooled Exhaust Gas Recirculation (EGR), and then to further control particulates with a particulate filter. The latest systems of this type appear capable of achieving Euro-4 limits without a particulate filter and may eventually even achieve Euro-5 limits without a particulate filter.

The SCR/urea route is currently the leading European option, strongly favoured by the European vehicle manufacturers as it is the most proven technology and provides the best fuel efficiency. A combination of SCR/urea with a particle filter is also feasible but this would negate a significant part of the fuel economy benefit. While SCR/urea systems will benefit from sulphur-free fuels, they are much less sensitive to sulphur content than CRT or LNT systems and their capability to meet the emissions targets with 50 mg/kg sulphur diesel fuels has been demonstrated. The SCR/urea approach does however raise a number of other issues, the main one for the oil industry being provision of urea for the vehicles.

For light-duty diesel vehicles, the Euro-4 standards for 2005 are expected to be achieved via a combination of engine measures, including high pressure injection, EGR, oxidation catalysts and particulate filters. Small vehicles are able to meet the 2005 standards with simple oxidation catalysts. Larger vehicles are likely to require particulate traps, with systems catalysed by fuel additives likely to be used in the near term. Active after-treatment for NO_x reduction is unlikely to be required on light-duty diesel vehicles unless there is a significant further step in emissions standards beyond Euro-4. Application of SCR/urea is considered much less likely in the light-duty sector. Sulphur-free fuels will help the manufacturers to meet the emissions targets and provide flexibility to apply a range of advanced technologies but the timing for 100% market coverage of sulphur-free diesel fuels remains a relevant question.

Looking further ahead, hybrid vehicle concepts are showing potential to reduce CO_2 emissions without any need for further changes to fuels quality. Novel combustion concepts such as Homogeneous Charge Combustion Ignition (HCCI) engines continue to be investigated as a means to reduce engine-out NO_x and PM emissions, thus minimising the need for exhaust gas after-treatment. Such new concepts may impact on fuel quality requirements and this will need to be assessed as these technologies develop.

Fuels have made a substantial contribution

EU fuel specifications have been dramatically tightened over the past decade, culminating in the recent update to the EU Fuels Directive. Table 1 summarises the history of the key gasoline and diesel fuel property changes over the period from 1993–2009. The continuing challenge for

Sulphur-free fuels are on the way

Which advanced vehicle technologies are emerging?

Table 1 Summary of European gasoline and diesel fuel specification developments

Year			1993	1995	1996	2000	2005	2009	WWFC[1]
Gasoline Unleaded 95/85 – EN228									
Sulphur	ppm m/m	max	1000	500		150	50/10	10	5–10
Benzene	% v/v	max	5			1			
Aromatics	% v/v	max				42	35		
Olefins	% v/v	max				18			10
Oxygen	% m/m	max	2.5[2]			2.7			
RVP (summer)	kPa	max	up to 80			60			
E100	% v/v	min	40(s)/43(w)			46			50/55
FBP	°C	max	215			210			195

Year			1993	1995	1996	2000	2005	2009	WWFC[1]
Diesel (standard grade) – EN590									
CI		min	46						52
CN		min	49			51			55
Sulphur	ppm m/m	max	2000		500	350	50/10	10	5–10
Density	kg/m^3	min	820						
		max	860			845			840
T95	°C	max	370			360			340
Aromatics	% v/v	max							15
PAH	% m/m	max				11			2
Lubricity	µm @ 60 °C	max			460				400

[1] WWFC = Engine/vehicle manufacturers World-Wide Fuels Charter; Category 4 fuel requirements

[2] Up to 3.7% at Member State discretion. Individual limits apply to specific compounds

the oil industry is to supply the required market volumes at the specified quality. Apart from the new sulphur limits, diesel volumes are limited by constraints on density and back-end distillation points, while demand increases steadily. For gasoline the challenge is to satisfy the octane and distillation requirements with a decreasing choice of molecules available to the blending pool. Reducing gasoline sulphur to extremely low levels while minimising destruction of valuable high octane molecules, such as olefins, will be achieved through new refining processes.

Enabled by sulphur-free fuels, more advanced emission control technologies are expected to be introduced to meet the legislative requirements for 2005 and beyond, resulting in very low vehicle emissions being achieved. At such low emissions levels, additional changes to fuel quality are unlikely to contribute further to air quality improvement. More extreme fuel changes such as those proposed by Category 4 of the motor industry's World-Wide Fuels Charter (WWFC) would have limited environmental benefit but would increase refinery CO_2 emissions due to the increased processing needed and would potentially restrict the available fuel volumes.

Outlook

A wide range of new low-emission vehicle technologies are expected to enter the market, assisted by major efforts from the oil industry to supply the new generation of sulphur-free fuels. The revised EU Fuels Directive already requires a further review, to be completed by 2005, both of fuel properties and of the end date for 100% market coverage of 10 mg/kg sulphur diesel. It is essential that this review be carried out in a scientifically sound manner, taking full account of the effects of the new vehicle technologies entering the market and of any proposed fuel changes on a well-to-wheels basis. It should also consider the impact of road transport emissions within the context of the overall emissions inventory under the umbrella of the Clean Air For Europe (CAFE) programme. Only such a rigorous and global approach can lead to the best choices for society as a whole.

Emissions from modern gasoline vehicles

A problem essentially solved?

Over recent years, vehicle technologies have developed rapidly with significant improvements in emissions control. Exhaust catalysts were first required on European gasoline cars with the introduction of Euro-1 emissions limits in 1993, with subsequent evolution to the Euro-3 emissions limits of today and 'near-zero' Euro-4 limits from 2005. The current challenge on gasoline cars is to further reduce CO_2 emissions, with vehicle manufacturers currently working towards the voluntary agreement for a European passenger car fleet average of 140 g/km CO_2 emissions by 2008.

In order to meet these targets, a range of advanced gasoline engine and exhaust gas after-treatment technologies are expected to be introduced, facilitated by sulphur-free fuels to enable the most advanced technologies to be employed with maximum fuel efficiency (see companion article on sulphur-free fuels, page 8). The revised EU Fuels Directive mandates the introduction of 10mg/kg maximum sulphur fuels but does not require any additional changes to other fuel properties, recognising that there is a need to first assess the impact of the new Euro-4 vehicles and fuels. It places further consideration of fuel effects in a subsequent review, to be carried out by 2005.

Given the evolution in vehicle and fuel technologies, there is a need to establish sound information on the influence of fuel qualities on exhaust emissions from the more advanced technologies, to provide a firm foundation for future debates. To contribute to this task, CONCAWE is continuing to test new vehicles as they enter the market. The work described here has evaluated the impact of fuel qualities on emissions from advanced gasoline vehicle technologies available in the market in 2002. Although sulphur reduction is mainly aimed at long-term durability and fuel efficiency of advanced after-treatment systems, short-term effects are also of interest in view of the potential impact on the existing vehicle fleet. The overall study has therefore evaluated the influence of gasoline sulphur content, as well as other gasoline properties: aromatics, olefins, volatility and final boiling point. Only the sulphur results are discussed here, as the CONCAWE report on this part of the work is soon to be published. Testing on the influence of the other fuel properties is currently being completed and will be reported separately.

Test vehicles, fuels and design

Four vehicles were selected for evaluation in this programme, chosen to provide examples of those advanced gasoline vehicle technologies expected to become more significant in the near-term future car populations. A brief description of the vehicle characteristics is given below.

The influence of fuel sulphur was evaluated by doping a low sulphur unleaded base gasoline with thiophene in order to achieve a range of sulphur levels. Four fuels with sulphur contents from 4 to 148 mg/kg sulphur were tested.

	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Displacement (cm^3)	1998	1796	1997	1598
Max power (kW @ rpm)	103@5500	85@5500	107@6000	81@5800
No. of cylinders	4	4	4	4
Valves per cylinder	4	4	4	4
Combustion/injection/ control system	Stoichiometric DI*	MPI** Variable valve actuation	Lean DI	Lean DI
Catalyst system	TWC***	TWC	TWC + NO_x trap	TWC + NO_x trap
Emissions compliance	Euro-3	Euro-4	Euro-3	Euro-4

** direct injection ** multi-point injection *** 3-way catalyst*

Emissions from modern gasoline vehicles

A problem essentially solved?

A rigorous statistically-based test design was employed, providing several long-term repeat tests on each vehicle/fuel combination. Specific vehicle conditioning and de-conditioning procedures were used in order to minimise any effects from sulphur carry-over. Exhaust emissions were measured over the standard European test cycle (NEDC), with data evaluation over the full cycle, in addition to the ECE (urban driving part) and EUDC (extra urban driving cycle) segments. Continuous raw exhaust analysis pre- and post-catalyst was also carried out to support understanding of the basic test cycle data.

Sulphur effects on regulated emissions

The main interest of this work was the effect of gasoline sulphur content on the regulated emissions: NO_x, HC and CO. Plots of the mean NEDC emissions for all four cars are shown in Figures 1 to 3 below, compared with the Euro-3 and Euro-4 emissions limits.

In all four vehicles, there was little short-term response of emissions to fuel sulphur content. There were no statistically significant sulphur effects over the NEDC cycle for any pollutant in any vehicle, and no evidence of higher emissions sensitivity at low sulphur levels.

In all cases, the vehicles achieved very low levels of emissions, well beyond their certification levels. Car A, the Euro-3 stoichiometric DI, was just above the Euro-4 limit for NO_x, but well below the Euro-4 limits for HC and CO. Car B, the advanced MPI technology vehicle, was well within the Euro-4 limits for all three emissions. Car C, the Euro-3 lean-burn DI, was close to the Euro-4 limits for HC and NO_x, and well within the Euro-4 limit for CO. Car D, the Euro-4 lean-burn DI was well within the Euro-4 limits for all emissions.

In order to check whether higher sulphur effects on the catalysts could be observed during the hot part of the emissions test cycle, when the catalyst is fully operational, the EUDC data were examined. In all cases, emissions during the EUDC part of the cycle were very low. Statistically significant sulphur effects on HC and CO emissions were demonstrated in some cars, though these effects were small in absolute terms. For NO_x, there was no statistically significant sulphur effect in any car.

Figures 1, 2 and 3

■ car A
(Euro-3 stoichiometric DI)

▲ car B
(Euro-4 MPI)

◆ car C
(Euro-3 lean-burn DI)

● car D
(Euro-4 lean-burn DI)

— Euro 3 limit

— Euro 4 limit

Advanced gasoline test vehicles showed low emissions of NO_x, HC and CO, but little sensitivity to fuel sulphur content.

Figure 1 Regulated (NEDC) emissions data: NO_x

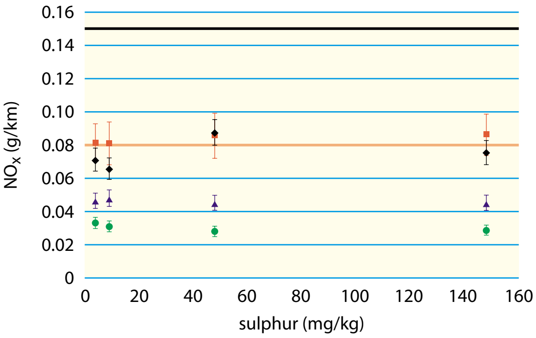


Figure 2 Regulated (NEDC) emissions data: HC

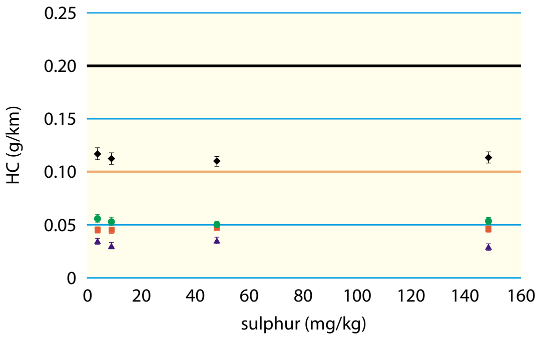
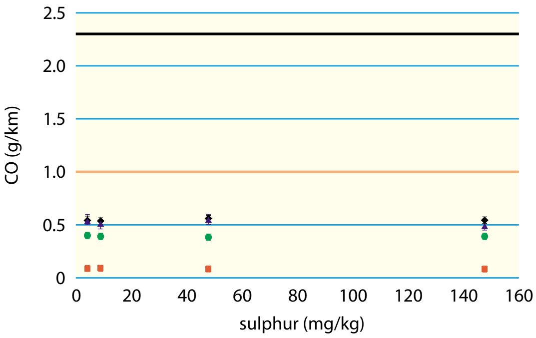


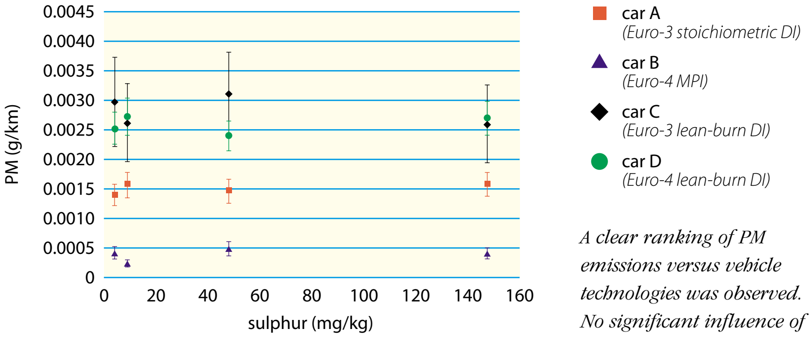
Figure 3 Regulated (NEDC) emissions data: CO



Particulate mass emissions

Although particulate emissions are not regulated on gasoline cars, particulate mass (PM) emissions were measured in order to determine whether there were any important effects. A clear ranking of PM emissions versus vehicle technologies was observed (lean-burn DI > stoichiometric DI > advanced MPI) as shown in Figure 4. However, even the lean-burn DI vehicles gave PM emissions which were an order of magnitude below the Euro-4 light-duty diesel limit of 0.025 g/km. No significant influence of gasoline sulphur content on PM emissions was apparent on any of the vehicles.

Figure 4 Regulated (NEDC) emissions data: PM



A clear ranking of PM emissions versus vehicle technologies was observed. No significant influence of gasoline sulphur content was apparent.

Vehicle effects

Apart from the general differences between vehicle technologies highlighted above, several other specific effects were observed during this work which had much more influence on the overall emissions than the sulphur content of fuels. These included:

- a significant influence of dynamometer load on CO_2 emissions, especially for the more advanced technology vehicles;
- HC storage and release from the catalyst during the first 30 seconds of operation, which could dominate the total cycle emissions;
- air-fuel ratio (AFR) strategy of the 'lean-burn' DI cars was highly dependent on engine speed; and
- smaller but significant changes in AFR strategy for the stoichiometric DI car which influenced NO_x and HC emissions.

Comparison of sulphur effects with other studies

The current data were compared with previous studies of sulphur effects on emissions from gasoline cars, including studies from EPEFE, USA and California. Detailed analysis revealed that, in these studies, some vehicles showed much greater sensitivity to sulphur than others and that these vehicles could have a marked effect on the test fleet average results. Some of the lower emitting vehicles showed a low sensitivity to sulphur, as observed in the current CONCAWE work. Vehicles that showed the highest sulphur sensitivity did not necessarily have the lowest emissions.

Summary

The four vehicles tested all met Euro-3 emissions limits, and in most cases emissions were lower than Euro-4 limits. This reinforces the view that the issue of pollutant emissions from gasoline cars will be essentially solved from 2005. Focus should then shift to improving CO_2 emissions while maintaining these 'near-zero' pollutant emissions.

All four vehicles showed little sensitivity to sulphur for all pollutants measured, despite having very low emissions. Analysis of earlier studies that had shown a stronger sensitivity to sulphur showed that fleet average results were influenced by a number of very sensitive vehicles. Overall, it is concluded that low emission vehicles are not necessarily highly sensitive to fuel sulphur content; sulphur sensitivity appears to be principally influenced by catalyst system design. Several specific hardware effects were observed which can have an important influence on emissions, including CO_2.

The main driver for the introduction of lower fuel sulphur levels continues to be to enable advanced exhaust catalyst systems, including regenerative NO_x storage systems, to be introduced with maximum fuel efficiency and long-term durability. The planned sulphur reduction to 10 mg/kg seems unlikely to bring substantial emissions benefits for the existing vehicle fleet.

Modelling the European refining industry

Focus on cost and CO_2 emissions

Ten years of modelling experience

It is now nearly 10 years since CONCAWE decided to develop a tool to model the European refining industry and evaluate the likely impact of future changes such as legislative measures affecting the quality of refinery products.

There are about 85 refineries in the current EU and an additional 10 in the so-called accession countries. Each refinery has a unique combination of geographic location, access to feedstocks and markets, process units, storage facilities etc. Comparing refineries is a difficult exercise and there is no such thing as a 'typical' EU refinery.

A model with nearly 100 refineries may not be impossible to create but would be rather unwieldy. It would, in any case, only be of interest if all actual circumstances could be specified in terms of crude oil supply, product demand, exchanges with other refineries and/or chemical plants and so on. Such detailed data is not normally available. The model needs, therefore, to be a compromise, including enough detail to be realistic but requiring input data which are readily available.

From the outset, CONCAWE decided to represent Europe through a number of regions covering one or several countries. The model originally covered seven regions and has now been extended to nine regions to include the accession countries (EU-25).

Region	Countries
Scandinavia	Denmark, Finland, Norway, Sweden
UK and Ireland	Great Britain, Ireland
Benelux	Belgium, Luxembourg, Netherlands
Mid-Europe	Austria, Germany, Switzerland
France	France
Iberia	Portugal, Spain
Mediterranean	Cyprus, Greece, Italy, Malta
Eastern Europe	Baltic States, Czech Republic, Hungary, Poland, Slovakia, Slovenia
South Eastern Europe	Albania, Bosnia, Bulgaria, Croatia, Macedonia, Romania

In the model, each region has its own market that the refineries must serve. Exchanges between regions are allowed, at a cost and within limits that are considered feasible in practice. Within each region the refining industry is represented by a single 'virtual' refinery having, for each process unit, the cumulative capacity actually installed in the region. This is of course a simplification that can lead to over-optimisation. Consequently a further level of detail has been added whereby each region can be modelled separately as four refineries. The main purpose of this was originally to study the vulnerability of different refinery configurations to certain measures (e.g. simple versus complex, hydrocracker versus catalytic cracker). As product specifications have tightened, refineries have, however, increasingly had to exchange key intermediates and blending components to minimise investment costs so that 'regional optimisation' is nowadays close to being achieved.

The original objective of the model was to assess the potential cost to the industry of legislative measures affecting product quality, particularly road fuels. The model makes use of the Linear Programming technique and is driven by a financial objective function based on feed and product prices, operating and investment costs. Individual refineries have, in principle, the option of meeting new requirements or constraints either by modifying their feed diet or by investing in new processing facilities. The extra cost is related to price differentials between feed types in the former case, and to investment in the latter case. Forecasting the future developments of crude oil and product prices is highly speculative and the model is normally used to focus on investment as a means to meet the requirements. We believe this approach is fully justified to represent the effects for Europe as a whole because:

- at the European level, the medium-term scope for increasing the proportion of high quality crudes (light, low-sulphur) is virtually non-existent; and
- the individual decisions to invest or not will influence the development of price differentials between different qualities of crude oil.

In other words the decision of one refinery to improve its feed diet will be compensated by investment in another refinery allowing the use of more low-quality crude, driven by an increasing price differential.

The new focus on energy and CO_2 emissions

If cost remains an important issue, the aspect of energy usage and CO_2 emissions, both at the refinery site and globally, has become essential in the past few years. The CONCAWE model was recently overhauled in order to be able to estimate the impact of measures on the energy used by the refineries and on both the local and global CO_2 emissions. This new requirement implies that the model is balanced, not only in terms of mass but also of energy, sulphur, carbon and hydrogen. This has been successfully achieved and allows us to give a complete description of the potential impact of a measure in terms of energy and CO_2 emissions.

As an example, most of the recent legislation on road fuels quality has resulted in products that contain an increasing proportion of hydrogen compared to carbon. The refinery provides this additional hydrogen by 'decarbonising' hydrocarbons as well as using some of the hydrocarbon energy to split water, and produces CO_2 in the process. The energy used in the refinery is the sum of the net chemical energy required for the reactions and of the losses related to the thermodynamic efficiency of the processes. The refined products contain more hydrogen and therefore more energy per unit mass so that the chemical energy is recovered when these products are burned. CO_2 emissions are effectively displaced from the end-user to the refinery. Unless the latter enjoys higher fuel efficiency as a result of the change, the global CO_2 emissions increase.

From a modelling point of view, this is represented by expressing the demands for fuel products in energy rather than mass terms. The demand figures will generally be constant except in those cases when the quality change under study is expected to have an impact on the efficiency of the final energy converter (engine, power plant, etc.).

This new feature of the model makes it invaluable for estimating the global 'well-to-wheels' impact of measures affecting the quality of fuels and forecasting their effect on energy consumption and CO_2 emissions from refineries.

Establishing Air Quality Limit Values

A key element of the CAFE programme

As part of the Commission's Clean Air For Europe programme (CAFE), the World Health Organization's (WHO) European Centre for Environment and Health has been contracted to update its guidance with respect to the health effects of fine particulates and ozone. These pollutants are foreseen as the main drivers for any further measures resulting from the CAFE programme. In the past, WHO guidance has provided important input to the process of establishing Air Quality Limit Values (AQLVs) as set forth in the various EU Air Quality Daughter Directives.

Along with the critical loads/levels established within the UN-ECE process, compliance with these AQLVs has been the policy objective of most air related regulative initiatives in the EU and wider Europe over the past decade e.g. the European Auto/Oil Programmes, the National Emission Ceilings Directive and the Gothenburg Protocol. It is clear that the establishment of AQLVs has a direct consequence on policy and the practicality/economic consequences of delivering that policy.

In this article we briefly explore the importance of the AQLV setting process within the context of the ongoing CAFE programme. In particular, we examine how it fits within the Integrated Assessment Modelling (IAM) framework that is designed to underpin the programme.

Risk assessment and risk management

The WHO, in publishing its guidance, recognises that risk assessment is, by its very nature, 'single issue' focused, therefore a subsequent and separate 'risk management' process is required to account for the other important factors in our 'multi-issue' world[1]. Here is a quote from the preface to their most recent published guidelines:

> *'It should be emphasised, however, that the guidelines are health-based or based on environmental effects, and are not standards* per se. *In setting legally binding standards, considerations such as prevailing exposure levels, technical feasibility, source control measures, abatement strategies, and social, economic and cultural conditions should be taken into account.'*[2]

It is vital that we understand the importance of what the WHO are saying here. Their guidance is based on a 'risk assessment' of a given pollutant. As such it provides important data on the relationship between exposure level and risk. However, in taking these data forward to the establishment of binding limit values many other practical and societal factors need to be accounted for. It is interesting to note that among these the WHO themselves recognise the importance of economic factors.

The elimination or marginalisation of such economic considerations is perceived within some stakeholder communities as the 'environmental high ground' but does this stand up to close examination? In light of the many problems facing society, how is the legislator to fulfil his responsibility to ensure that societal monies are spent in a way that maximises overall health/environmental benefit to society?

One response to this concern has been the growing use of studies that attempt to place a monetary valuation on the benefits. Here, if the valuation of benefits equals or exceeds the cost of delivering them, 'it must be justified'. Beside the enormous uncertainties attached to it, this process has, in the past, largely failed to develop the 'marginal cost' vs. 'marginal benefit' relationship vital to the risk management process, i.e. what is the cost/benefit ratio for each increment in benefit?

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[1] *Although reference is made to various additional factors to be accounted for in the setting of Air Quality Limit Values in the EU Air Quality Framework Directive, the WHO provides much more comprehensive guidance by devoting a complete chapter to the subject.*

[2] *Preface to* Air Quality Guidelines for Europe, Second Edition, *WHO Regional Publications, European Series, No. 91*

Furthermore, the process is 'single issue' focused and therefore fails to address the key question of whether a much greater benefit would derive from spending this money on a different problem. The availability of Integrated Assessment modelling tools within the CAFE programme offers a much more robust alternative.

Integrated assessment modelling in the risk management process

To be in a position to judge wisely whether or not to act or at what point it would be better to stop spending on one issue and address another, it is vital that the relationship between cost and the reduction in the level of risk is properly understood. Figure 1 provides an Industry perspective on how the Integrated Assessment Modelling capabilities available within the CAFE process could be used to provide such input to the risk management process. Clearly, in setting an AQLV or a Target Load/Level, the legislator needs to know at what point costs climb steeply for little further reduction in 'risk'. This is especially important for pollutants for which the WHO have not established a threshold of effect. Importantly, in this process it is not necessary to enter into the very uncertain waters of seeking to place a monetary value on the reduction in risk.

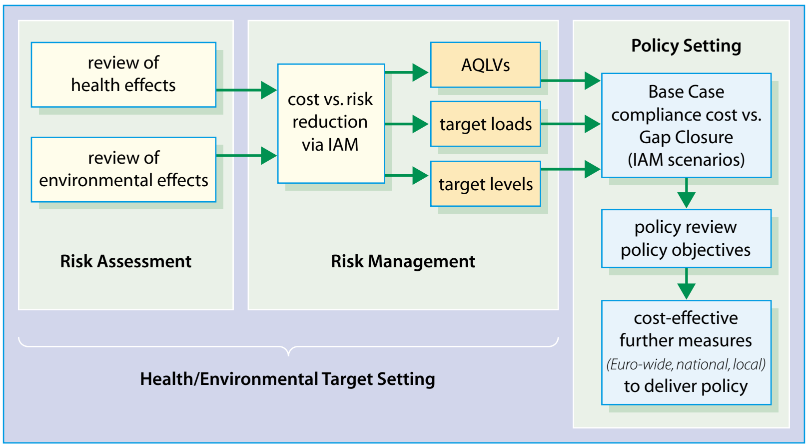

Figure 1
Key stages in CAFE process

The role of established AQLVs in subsequent attainment policy

It is important to recognise that AQLVs, when they have been established via a risk management process, express in concrete terms the level to which the legislator believes a given risk should be controlled. In other words, a policy that delivers concentrations below the AQLVs is not appropriate since it infringes the risk management judgements that underpin it, i.e. when to stop spending on a given risk. This is why the policy setting step shown in Figure 1 is separate from the risk management step and is designed to deliver (or make substantial progress in delivering) the AQLVs or Critical Loads/Levels in a cost-effective manner.

Conclusion

In line with the WHO, CONCAWE believes that establishing revised AQLVs (or Critical Loads/Levels) within the CAFE programme needs to include a separate 'Risk Management' step based on the risk assessment guidance from the WHO. This step can be facilitated by the use of the Integrated Assessment Modelling capabilities available within the programme to provide essential data on the relationship between cost and risk reduction. However, once revised AQLVs or Critical Loads/Levels have been established, the achievement of these targets should be the basis for policy.

Oil in water analysis

What is being measured?

The determination of the oil content of refinery effluent water has long been a subject of studies. CONCAWE first published a report on oil in water analysis in 1972. Although we all know what 'oil' is, it cannot be defined scientifically as it may contain millions of compounds ranging from gases to tars. We therefore have to measure some surrogate property, and the value we obtain for oil therefore depends upon the analytical method.

CONCAWE published an additional report in 1984 (1/84) which considered the methods used by refineries at that time for the determination of oil in their effluents. It concluded that the most suitable method consisted of acidification of the sample before extraction with carbon tetrachloride, treatment of the extract with a sorbent and analysis of the extract by infra-red (IR) spectroscopy at three wavelengths. The absorbance was then to be compared with that of a known standard. This method became known in many quarters as the 'CONCAWE method' although it was really more of a recommendation to adopt one of a number of national standard methods which used this technique.

Since that time, most of the refineries in Europe have used variations on this method, although a few refineries have used methods based on different principles such as gravimetry (the standard method in the USA) or ultraviolet (UV) spectrometry. The use of carbon tetrachloride being discouraged on health grounds, it was, in most cases, replaced by Freon 113 which has similar (although not identical) properties. This solvent was later found to be an ozone depleter and therefore its use was also banned for most purposes under the Montreal Protocol[1]. A special derogation, now withdrawn, allowed its use in this particular test for several years.

A few years ago the UK Institute of Petroleum developed a new test which was similar to the old 'CONCAWE' method but with tetrachloroethylene (TTCE) as solvent. This test has been adopted by the refineries in the United Kingdom but by few others. Other refineries have recently changed to a gas chromatographic method (GC). CONCAWE's Water Quality Management Group has recently carried out a limited survey of European refineries which revealed that that a range of methods and therefore of solvents and physical properties for determining oil are in currently use. What does this mean in respect of the reporting and comparison of measurements of oil in refinery effluents?

Oil in water analysis contains a number of steps, namely:

- sampling;
- sample pre-treatment;
- extraction;
- treatment of extract; and
- analysis.

Even before analysis starts, sampling and subsequent handling is very important. Samples should be taken in an area of high turbulence so that the effluent is well mixed. Also, the whole sample, including the container, has to be extracted to achieve an accurate result, otherwise oil may have stuck to the walls of the container. The sample is then usually treated with acid which stabilises the sample and makes separation during the extraction phase easier. Acid can, however, catalyse chemical reactions and thus alter the result.

The solvent used for extraction has a large effect on the amount and types of compounds extracted. Treating the extract with an adsorbent such as Florisil removes polar compounds from the extract, which are certainly not oil but would otherwise be recorded as such. The different types of analysis also all measure different things. For example, IR determines the number of carbon–hydrogen bonds. As the level of adsorption is

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[1] *Agreement on substances that deplete the ozone layer, September 1987*

not the same for all such bonds, the absorption is normally compared with a standard, either synthetic, or made from the type of oil likely to be present. If the composition of the oil in the sample is very different from the standard, systematic errors will creep in.

With a gravimetric analysis, the low-boiling solvent is evaporated and the remaining oil weighed. During this process, low-boiling material is lost. A similar limitation applies to the new GC method which also uses a low boiling hydrocarbons solvent.

Thus, every method measures something different and the result it gives will be different from other methods, sometimes very different. Comparative tests have shown that changing the solvent from Freon to TTCE does not affect the results significantly. However, comparative tests carried out in The Netherlands showed that the GC and IR methods did not consistently give similar results.

Do these differences matter? It cannot be said that any of the methods gives the 'correct' answer but it must be realised that the result obtained depends on the method. If the method is changed, any standards based upon it should also be changed. This needs to be stressed to the regulatory Authorities.

Finally it is important to consider why oil is being measured in the first place. If it is a concern that oil in effluents could form a slick in a river or the sea, then it is the heavier oil which is of concern. The gravimetric or GC methods will give a good prediction of this tendency as the lighter ends would evaporate. This was the situation when the first CONCAWE refinery effluent survey was conducted in 1969. Today, however, when refinery effluents contain less than 1% of the oil reported in that first survey and nearly all European refineries apply biological treatment, floating oil is no longer likely and so the IR method could be the appropriate one.

Given that measuring oil is difficult, particularly at very low concentrations, there seems to be little point in analysing for oil at all, or in setting oil effluent standards. Other measurements routinely carried out, such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) or Total Organic Carbon (TOC), give a better indication of what is being discharged. Indeed, the European Polluting Emissions Register (EPER) regulation which requires all IPPC[2] sites (including refineries) to report their emissions does not include oil in the list of pollutants to be reported.

Although CONCAWE has no current plans to research this issue, it will evaluate any new method through its Water Quality Management Group and keep refineries informed so that they can choose the optimum solution in their local context.

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[2] *Integrated Pollution Prevention and Control*

Exposure of asphalt workers to bitumen fumes

Independent epidemiological study by IARC

Bitumen is a product with a long history of use as construction material in a wide variety of applications, such as road paving.

Under normal ambient conditions bitumens are solid and do not present health or environmental hazards. However, most bitumen applications are carried out at high temperatures (from 150 to 230°C) at which fumes may be generated. Excessive exposure to these fumes can cause respiratory irritation. Occupational exposure limits have therefore been set in many countries while bitumen suppliers promote good working practices, including temperature control.

Several years ago a number of studies investigating a possible cancer risk in workers exposed to bitumen fumes were published. During EU hazard classification discussions at the time, it was concluded that these studies did not provide a clear indication of bitumen fume carcinogenicity, as they had not been adjusted to take into account other occupational exposures and lifestyle factors of the workers.

Industry, including CONCAWE, Eurobitume and the European Asphalt Paving Association, therefore took the initiative of supporting an independent epidemiological study to address this issue.

The study was designed and managed by the world-renowned International Agency for Research on Cancer (IARC) in France, which is part of the UN's WHO (World Health Organization). Many national organisations and research institutions took part, and supporting funding was obtained from the EU's Research Directorate General as well as several EU Member States and research bodies. The study design involved a feasibility investigation, followed by the establishment of a cohort of exposed workers and, contingent on the outcome of the cohort analysis, a more in-depth 'nested case-control' study, taking into account all possible risk factors.

In 2001 IARC published the internal technical report of the cohort phase. This contained the results of the epidemiological investigation of causes of death in a large-scale international cohort of 80,695 workers employed between 1913 and 1999 in road paving and asphalt mixing companies in seven European countries (Denmark, Finland, France, Germany, the Netherlands, Norway and Sweden) and in Israel. This same body of work, supplemented by further analyses of national patterns, has now also been published in the open scientific literature.[1]

The cohort analysis indicated reduced mortality from all causes compared with the general population, a phenomenon not uncommon in the working population.

In comparison with another cohort of the working population, the study found a slightly increased lung cancer rate amongst asphalt worker populations in

Asphalt road paving under way

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[1] *January 2003 issue of the American Journal of Industrial Medicine*

some countries. However, the report clearly stated that the results did not allow conclusions to be drawn on either the presence or absence of a causal link with exposure to bitumen fumes, because of insufficient information on exposure of the cohort members to other known lung cancer risk factors, in particular those related to the use of coal tar in asphalt mixes and tobacco smoking.

Importantly, the study recorded a decrease of exposure to bitumen fumes at an average rate of some 6% per year between 1970 and 1997, presumably as a result of improving working practices.

The study has been an example of successful collaboration between researchers and industry representatives, while preserving the scientific independence of the researchers. It has established an important database on asphalt paving workers which can be accessed by experienced epidemiologists and industrial hygienists in many countries.

IARC has proposed, in line with the original study plan, to carry out a 'nested case control' study of lung cancer risk. This detailed study will focus on a relatively small number of workers and will include a more detailed assessment of:

- their overall historical exposure to bitumen fumes within the asphalt industry also covering employment periods in companies not participating in the original cohort;
- their overall historical exposure to known lung cancer risk factors, in particular to coal tar; and
- exposure to non-occupational factors, in particular tobacco smoking.

Development of a detailed study protocol is in progress.

As part of its ongoing commitment to improving workplace practices and workers' health, our industry strongly supports the use of good working practices to minimise exposure to bitumen fumes, including control of the temperature in bitumen applications.

Occupational exposures to gasoline vapour

Additional data collected and analysed

The risk assessment methodology requires data on exposure in order to make comparisons between so-called 'no-effect-levels', arising from health effect studies, and exposure cases as they occur during normal handling and use of the substance.

Exposure information may to some degree be estimated using modelling approaches or analogies, but in general it is preferable to make use of actual measured data. CONCAWE therefore initiated several years ago, a programme to prepare an inventory of exposure levels to gasoline in anticipation of the planned risk assessment for that substance. The first phase of this activity consisted of the collation of existing data from member companies' monitoring programmes. The resulting overview was published in report 2/00. This overview indicated that for several occupational scenarios the exposure information was either out of date or absent. Consequently, a measurement campaign was organised in CONCAWE member company operations to address these shortfalls. The results were recently published in report 9/02. In support of this campaign, the recommended method of obtaining detailed exposure information, speciated by chemical constituent, was also revised and re-issued (report 8/02).

Some of the main findings of this work are discussed in this article.

The impact of vapour recovery systems

Concerns about ground-level ozone formation led to the introduction of vapour recovery systems in the 1990s.

In distribution operations vapour recovery (VR) is being introduced stepwise in accordance to the requirements of directive 94/63/EC, a process that is due for completion in 2004. In many cases these systems also resulted in reduced worker exposure levels. From the data collected, it appears that vapour recovery combined with bottom loading reduced the exposure of road tanker drivers and rail car loading operators by a factor of three when filling up at depots and terminals.

In attended service stations, where occupational exposure is already low, vapour recovery further reduces occupational exposure by half.

When comparing the average data from the present surveys with the work published in 1987 (CONCAWE report 4/87) and with data published in the open scientific literature, it becomes apparent that, in the oil refinery work environment, exposure to gasoline vapour has been reduced by a factor of five. This is a reflection of the introduction of vapour recovery systems, as well as increased production automation and improved design and engineering practices.

Benzene exposure

The implementation of the Road Fuels Directive (98/70/EC) has led to a reduction of benzene levels in gasoline, and consequently in gasoline vapour, by a factor of three since early 2000.

Almost all of the detected exposures in the post-2000 surveys comply with the exposure limit in force as of mid-2003 as defined in Directive 97/42/EC. The remaining elevated exposure levels that were recorded mainly relate to old technology scheduled to be replaced (e.g. railcar loading without vapour recovery).

Consequences for gasoline risk assessment

Feeding this up-to-date exposure information into the gasoline risk assessment process is essential in order to reach conclusions which take into account environmental controls already implemented.

CONCAWE news

Secretariat staff

The longest-serving member of the secretariat staff, our accountant Martien Sijbrandij, retired at the end of March 2003 after a career of 26 years with CONCAWE. Martien joined the association in 1977 when it was based in The Hague and in 1990 he accompanied its relocation to Brussels. Whilst his work over the years has been largely 'behind the scenes', he has nevertheless played an essential part in the smooth day-to-day running of the organisation. We take this opportunity to thank Martien warmly for his conscientious and loyal contribution to CONCAWE and to wish him and his wife, Annelies, all the best for a long and enjoyable retirement.

Eric Martin will also shortly be leaving CONCAWE. Eric joined CONCAWE on secondment in June 1992 after a long career in research and environmental management in BP. Prior to his secondment he was already active in CONCAWE, representing BP on a number of working groups. His first duties were Secretary to the Board and Council and Technical Coordinator for the Safety Management Group. He soon took on the additional roles of Technical Coordinator for OP/MG and WQ/MG. In 2000, after 8 years in Brussels, Eric retired from BP but continued his job as Technical Coordinator, working from his home in England. He has now decided to take full-time retirement. Eric's wide-ranging expertise and his extensive knowledge of CONCAWE's different activities will be sorely missed. Our best wishes go to him and to his wife Christine for the years to come.

Eric's responsibilities for SMG and OP/MG have been taken over by Jean-François Larivé. Philip Chown, a secondee from BP, will be joining CONCAWE shortly as the new Technical Coordinator for Water Quality. Philip will also be responsible for CONCAWE's CEC activities, currently handled by Neville Thompson.

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