Is a 10-ppm sulphur limit on road fuels desirable?

The German government proposal for the introduction of road fuels with less than 10 ppm sulphur issued at the end of last year re-launched the debate on the sulphur issue. In the meantime, the auto industry has been vocal in demanding 'ultra low sulphur' (ULS) fuels which it deems essential to meet its commitment on vehicle CO_2 emissions. In May of this year, the EU Commission submitted a 'call for evidence' to all stakeholders to gather facts and opinions on the various implications of a move to sulphur levels of 30 and 10 ppm in EU road fuels. This article gives an overview of CONCAWE's response and reiterates the key messages.

IS THERE A NEED FOR ULTRA LOW SULPHUR FUELS?

Although some after-treatment technologies are reported to require ULS fuels, other available options have to be considered as well. In addition, technologies are evolving fast. Detailed cooperative investigations should be conducted to evaluate the optimum level of sulphur in the fuels on an integrated basis.

In order to support its commitment to a reduction of CO_2 emissions from vehicles, the EU motor industry is looking at new engine technologies. As all such technologies must also meet the increasingly stringent exhaust emissions limits, they must be linked to an appropriate after-treatment system. Much research has been and is being carried out in these fields and a number of options have emerged.

Currently, the most promising route to improved gasoline engine efficiency is the lean-burn G-DI engine technology. Such engines need effective reduction of NO_x. Although G-DI technology as such is not sulphur-sensitive, the NO_x storage catalyst systems required to reduce the NO_x emissions to the desired (Euro 4) level are currently affected by sulphur.

Although the effect is mostly reversible, higher levels of sulphur in the fuel result in faster catalyst deactivation and more frequent regeneration and desulphation cycles. Such regeneration and desulphation cycles involve a temporary change to a rich mixture with an associated increase in fuel consumption and therefore CO_2 emissions. Very little data are publicly available to quantify the fuel efficiency penalty as a function of the fuel sulphur content. According to the limited information published so far, such gasoline NO_x storage catalysts would satisfactorily operate with fuels up to 50 ppm sulphur.

NO_x storage catalysts are a viable option for direct injection gasoline engines with a lean burn concept to optimize engine efficiency. Similar technologies are still in the research and development phase for light-duty diesel vehicles and may become a valid option for heavy-duty engines. For the latter, after-treatment technologies such as the Selective Catalytic Reduction (SCR) systems are options that can operate satisfactorily with a maximum of 50 ppm sulphur level in the fuel. Among the particulate trap systems the Continuous Regenerating Trap (CRT) is reported to require a lower sulphur level. Detailed evidence is, however, not yet available to determine to what extent ULS fuels would allow this technology concept to deliver its full potential.

CONCAWE's submission to the Commission includes a detailed analysis of the vehicle technologies available to the auto industry to contribute to both its CO_2 commitment and the mandated exhaust emission levels.

OIL INDUSTRY INVESTMENTS AND EMISSIONS

Although technologies to produce ULS fuels exist, the cost of implementation is high and the additional emissions of greenhouse gases from refineries would be significant. The extra financial pressure on refiners could result in under-investment and tightening of the supply.

Refinery technology

A reduction of sulphur from 50 to 10 ppm in road fuels may seem small in absolute terms but would be far from trivial for the refiners. Taking into account the margins required to ensure the specification is met at the pump, refineries would have to produce fuels at a sulphur level of 6–7 ppm. This is indeed nearly one order of magnitude less, a very significant change in terms of, for example, the required desulphurization catalyst activity.

The bulk of the sulphur in gasolines originates from the FCC (Fluid Catalytic Cracker) streams that would therefore need to be almost completely desulphurized. This leads to some olefin saturation resulting in turn in a loss of octane. Technology is moving fast in this field and it is now possible, by a suitable combination of splitting and treating, to remove most of the sulphur while still keeping a fair proportion of the olefins. Some octane loss is still unavoidable and needs to be counterbalanced by increased use of high-octane components such as oxygenates or reformate, use of the latter being limited by the aromatics specification. Many gasoline components hitherto considered as 'sulphur-free' do in fact contain a few ppm of sulphur (e.g. alkylates, oxygenates, butane). While, with higher sulphur limits, they serve as a sulphur diluent, this is no longer the case for ULS scenarios where they have to be considered at best as sulphur neutral. In some cases additional treatment would also be required.

Virtually all diesel components would require desulphurization. Recent advances in hydrodesulphurization (HDS) catalysts make it possible to extend the range of this process to the very high levels of desulphurization compatible with the production of ULS diesel. This can be achieved in some of the existing plants, albeit at the cost of a capacity reduction, and/or in new plants similar to existing HDS plants but with comparatively larger amounts of catalyst and generally higher pressure levels. Deep hydrogenation (involving a second treatment stage on noble-metal catalysts) would not be required. Extra hydrogen and energy consumption would consequently be relatively small in absolute terms. Other properties of the product (such as density, cetane, aromatics) would only be marginally changed. ULS diesel would, however, have very low lubricity and conductivity and extra additives would have to be used to maintain quality, at a significant extra cost.

Although most of the processes required for both gasoline and diesel are based on proven technology some would use novel catalysts and/or processing schemes. In terms of practical day-to-day operation, reducing gasoil sulphur by three to four orders of magnitude is largely uncharted territory. This raises concerns with regard to the reliability of the HDS process with the potential for relatively frequent disturbances in production. Generally a learning curve would undoubtedly apply to the new processing schemes and might result in decreased reliability and localized short-term supply disturbances.

Logistics and distribution

Refinery oil movements and shipping systems as well as distribution networks, all of which are shared to some extent, would need to be carefully reviewed. Hardware as well as operating procedures would have to be adapted to minimize the risk of contamination (as little as 0.1 per cent of jet fuel could be enough to make a batch of diesel off-spec for sulphur whereas it would still be perfectly suitable with regards to other specifications). This would lead to additional costs as well as a reduction in general efficiency and therefore some increase in energy consumption (as an example, introduction of 50 ppm diesel in the UK has led to trucking back to refineries cross-contaminated material from multi-product pipelines). It also has the potential for creating short-term supply disruptions.

Refinery investments and extra CO_2 emissions

The CONCAWE methodology for evaluating the cost of a certain measure, based on linear programming (LP), has been described in detail in CONCAWE report 99/56. It is assumed that EU refineries would invest in order to continue to meet the forecast demand while having access to the same crudes (only one Middle Eastern crude is allowed as marginal feedstock). In this way possible trading options which would change the EU-15 global import/export balance are factored out. In reality a mixture of investment and trading options would be used but market forces would then ensure that the global cost remains more or less the same. The results of the CONCAWE study for the production of 10 ppm sulphur fuels are summarized in the box below.

The extra costs and CO_2 emissions to move from 50 ppm sulphur to ULS fuels are of the same order of magnitude as the figures previously published for the Auto/Oil I measures and some Auto/Oil II scenarios.

Results of the CONCAWE study for the production of 10 ppm sulphur fuels

		Gasoline	*Diesel*	*Total*
Net Present Value*	GEUR	4.8	6.7	11.5
Extra CO_2 emissions**	Mt/a	3.1	1.5	4.6
	% of total for road fuels	0.3	0.2	0.5

*As per Auto/Oil I methodology:
**Including changes in fuel heating value

For gasoline, investments would mainly concentrate on the generally larger and more complex FCC refineries and aim at both removing sulphur and re-establishing the octane balance. With only a small extra hydrogen requirement, the additional energy consumption would mainly be due to the energy use inherent to the additional processing plants.

For diesel, most refineries would have to invest in larger, higher-pressure HDS plants or at least in major revamps of existing plants. Generally the new plants would not consume much more energy than the existing ones while the extra hydrogen consumption would be small. For that reason additional CO_2 emissions are relatively limited. Investments as well as extra operating costs (e.g. for extra additivation) are high.

In reality, some refiners may decide not to invest and to produce limited volumes through a combination of throughput reduction, appropriate crude selection and components trading. This could potentially cause serious tensions on the markets and lead to volatility and localized supply shortage. In this respect gradual introduction, following the market demand for such fuels and possibly linked to tax incentives, would allow phasing of investments as supported by market conditions. Logistics would, however, be much more complicated (e.g. to ensure that the new fuels are used by the cars that need them).

IMPACT ON AIR QUALITY

For all the pollutants of concern the introduction of ULS fuels would have a negligible impact on either emissions or regional, as well as urban, air quality. Ammonia emissions would potentially increase leading to higher levels of secondary particulates.

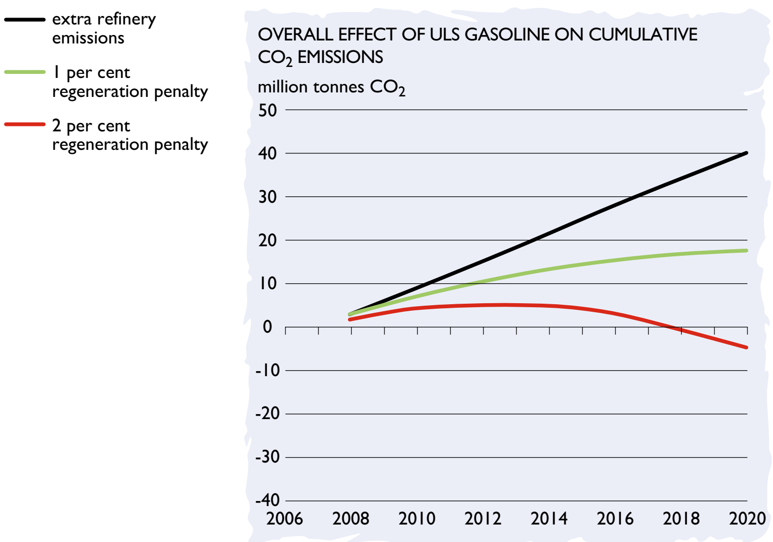
At the 50 ppm level mandated for 2005, the contribution of road transport to the total SO_2 emissions is already extremely small. For other air pollutants, the maximum effect is less than 0.5 per cent. The Auto/Oil II emission trends based on 50 ppm sulphur fuels from 2005 are not visibly affected by a move to ULS fuels from 2008. It is evident that such a minute change in emissions from transport would have a negligible impact on air quality in an urban environment. Given the negligible impact on NO_x and VOC emissions, a move to ULS sulphur fuels offers essentially no contribution to improving the level of ozone attainment in the EU.

Gasoline engine catalysts are known to emit small amounts of ammonia. Once emitted in the atmosphere ammonia will neutralize acidic sulphate or nitrate aerosols to form the ammonium salt, thus adding to the total mass of secondary particulates. There is some evidence to suggest that lower sulphur in the gasoline will result in higher ammonia production, thus contributing adversely to air quality. Although the true magnitude of the increase is uncertain the growing concerns about the health effects of particulates warrants more study of this phenomenon.

GLOBAL EFFECT ON GREENHOUSE GASES EMISSIONS

In terms of CO_2 emissions, the benefits from ULS fuels would not necessarily surpass the CO_2 debit due to extra refinery processing. N_2O emissions could increase, further contributing to the overall greenhouse gases load.

Although it is reported that ULS fuels would allow an increase in the overall fuel efficiency of lean burn G-DI cars equipped with NO_x storage catalysts, there is little published data to indicate the magnitude of the effect. On the basis of what limited information is available we have considered two scenarios assuming that the fuel efficiency would be improved by 1 to 2 per cent when reducing gasoline sulphur level from 50 to 10 ppm. The CO_2 benefit over the years depends very much on the rate of introduction of such sulphur-sensitive technologies. We have derived figures from projections recently published by ACEA/EUCAR and have assumed that ULS gasoline would be introduced from 2008.



Unless the vehicle efficiency gains are well above 1 per cent, the CO_2 increase in the refineries is not adequately compensated, so that the cumulative CO_2 load only becomes negative over a very long time horizon. For diesel engines the development of NO_x storage catalysts is, in our understanding, less advanced and scenarios of overall CO_2 balances are therefore even less clear.

Vehicles equipped with a three-way catalyst produce N_2O before the catalyst has reached full operating temperature. There is a strong possibility that the increased catalyst activity in a sulphur-free environment would lead to increased N_2O formation. Although warm-up time will be significantly reduced with the introduction of more advanced catalyst systems to meet the new exhaust emission standards taking effect from 2000 and 2005, N_2O emissions from the total vehicle fleet will continue to be of importance for a number of years to come. As a greenhouse gas, N_2O may be as much as three hundred times more potent than CO_2 so that even a modest increase in emissions would markedly affect the global greenhouse gases load. Based on available COPERT[1] data, we have estimated that a 20 per cent increase in the N_2O emissions is plausible. This would result in an increased greenhouse gases load of some 2.3 Mt/a CO_2 equivalent.

CONCLUSIONS

Although ULS fuels might bring benefits to certain vehicle technologies, there are a number of identified counterbalancing effects in terms of cost and CO_2 emissions. There is also some evidence of potentially negative consequences in terms of air quality and greenhouse gases that require further studies. It is CONCAWE's opinion that the desirability of ULS fuels should be studied in a comprehensive joint programme that would uphold the principles of cost-effectiveness, sound science and transparency as well as be consistent with the Precautionary Principle.

[1] *Computer Programme to Calculate Emissions for Road Transport*