LOW SULPHUR FUEL
ENVIRONMENTAL, LEGISLATIVE AND ECONOMICAL ASPECTS

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Abstract
Understanding of urban air pollution and the role of vehicle exhaust are one of the prerequisites for environmental sustainability. Sulphur in gasoline and diesel contributes to overall air pollution that negatively affects the global environment. Concerns related to the air pollution have been a primary driving force in settling sulphur standards. Regulating the sulphur content in fuels has economic and social benefits for society, as well as cost and competitiveness implications for the refining industry. The outcome of European efforts to stop further air pollution was a decision to regulate sulphur to below 50 ppm by the year 2005 and even less by the introduction of zero sulphur fuel with sulphur content below 10 ppm. Zero sulphur fuel with less than 10 ppm clearly reduces the contribution of road traffic to sulphur emissions. Zero sulphur fuel not only has a beneficial effect on particulate, HC, NO_x and CO emissions but also indirectly reduces the CO_2 emissions of road traffic compared to use of current commercially available fuels. Promoting sustainable urban transport through usage of low sulphur fuel is one part in achieving global environmental sustainability and therefore all parties involved have to give a maximum effort in attaining placed goals.

Introduction – Why Lower Sulphur Fuel?
High sulphur levels in fuel increase the emissions of a host of pollutants, as sulphur dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds and fine particulate matter, some of which also contribute to the formation of secondary pollutants such as ground-level ozone. Efforts to reduce emissions from individual vehicles through emissions control technologies are expected to lower the pollution from sulphur compounds. However, based on the increasing number of vehicles in use and increased vehicle usage patterns, the overall contribution of the transportation sector to air pollution is expected to rise over time. The reduction of air pollutants is clearly a priority as a health and environmental challenge for European countries. The outcome of European efforts to stop further air pollution was a decision to regulate sulphur to below 50 ppm (parts per million) by the year 2005 and maybe less by the introduction of zero sulphur fuel that has a content of sulphur below 10 ppm. The sulphur in gasoline and diesel fuel contributes to overall air pollution, which negatively affects the health of population and their environment. Concerns related to the health effects of air pollution, especially in urban areas, have been a primary driving force in settling sulphur standards.

The quantity of vehicle sulphur emissions is governed by several factors that include the sulphur content of the fuel, the emission control technology employed by the vehicle, the operating efficiency of the emission control technology. Fuel composition and vehicle technology (engine and emission control design) are both important factors that affect vehicle emissions. As vehicle emission standards have become increasingly stringent, greater emphasis has been placed on the role of both technology and fuel, to the extent that a total systems approach is now considered key to meeting future vehicle emission standards. Regulating the sulphur content of fuel has economic and social benefits for society, as well as cost and competitiveness implications for the refining industry.

Also, to minimise pollutant fuels as gasoline and diesel, cleaner alternative fuels are currently being developed. They include: compressed natural gas (CNG); liquefied petroleum gas (LPG); bio diesel; hydrogen; alcohol fuels and battery operated vehicles. The intention was to give a closer focus on cleaner fossil fuels, since they are expected to have a major role in next two decades. (1)

The Introduction of Zero Sulphur Fuel

Establishing limits for sulphur in gasoline and diesel fuel is one aspect of a larger program for clean air that has involved many actions worldwide and a broad consultative effort. There are a numerous documented evidences of a concerted effort to address sulphur in fuel. (2)

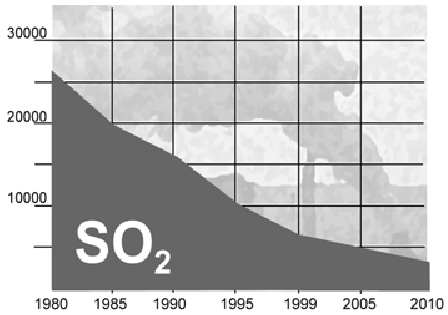

Figure 1: European Union emissions of sulphur dioxide, in thousands of tons, in period 1980-1999 and projection for 2010, according to the NEC Directive,
Source: EMEP

Among EU legal frame, the Directive 98/70/EC is relatively most important one concerning sulphur level of European fuels. This Directive contains fuel quality specifications, which enter into force in two stages, the first one on the 1st January 2000, and the second one on the 1st January 2005. Also it has considered the need to reduce further the level of sulphur in gasoline and diesel below the 50 ppm, level, already mandated for 2005. Furthermore, some European countries and fuel producers have indicated their intention to introduce “zero sulphur” fuels to the European market. Zero sulphur fuels refer to levels of sulphur less than 10 ppm. Other terms such as “near zero”, “low sulphur” or “ultra-low sulphur” fuel may also be used to indicate the same level of sulphur.

The introduction of zero sulphur gasoline and diesel is planned by no later than beginning of year 2005. This is consistent with the entry into force in 2005 of the new EURO IV vehicle emission limits and the requirement of some new automotive technologies to use zero sulphur fuels in order to attain these limits. The initial quantities of zero sulphur fuels that will be required will vary between countries according to the levels of new vehicle sales and proportion of these vehicles equipped with the new fuel-efficient technologies. It is also important that zero sulphur fuels are available in sufficient quantities with balanced geographic coverage in order to permit the free-circulation of those new vehicles requiring zero sulphur fuels. The introduction of zero sulphur fuels in limited quantities should not, however, compromise the capacity of fuel producers to supply fuels in 2005 which comply with mandated sulphur limit of 50 ppm. (3)

The optimum saving in greenhouse emission is achieved by phasing the introduction of zero sulphur fuels to match the quantity of fuel actually required by new vehicles. This avoids additional costs and emissions of CO_2 at the refinery. Optimal reductions in conventional air pollutants are obtained by a full market penetration of zero sulphur fuels as early as possible. An added degree of complexity is that the reductions in conventional air pollutants are apparently greater for existing gasoline vehicles than for existing diesel vehicles. Also, the

fuel economy improvement of new gasoline vehicles appears greater than that of new diesel vehicles.

Requirements on Fuel Quality

Many issues have been considered concerning the introduction of zero sulphur fuels, including the cost and benefits, changes in greenhouse gas emissions, the requirement for regulatory clarity, logistical and distribution issues, the encouragement of new technology, the variations in vehicle renewal rates and necessity to ensure the free circulation of new vehicles. Table below summarises the above-mentioned standards and environmental lows and gives us general extract of requirements on fuel quality after year 2000. (4)

	Requirement	EU- Fuel Directive		Worldwide Fuel Charter, EU Proposal
		Year 2000	Year 2005	
Gasoline	Vapour Pressure max kPa	60	60 (?)	60
	Benzene max Vol.%	1	1	1
	Aromatics max Vol.%	42	35	35
	Sulphur max ppm	150	50	10
Diesel	Cetan number min	51	51 (?)	55
	Density max kg/m^3	845	845 (?)	820-840
	Aromatics max Vol.%	-	-	15
	Sulphur max ppm	350	50	10

Table 1: Summarised Requirements on Fuel Quality after Year 2000

Impact of Low Sulphur Fuel on Emissions

Zero sulphur fuel with less than 10 ppm clearly reduces the contribution of road traffic to sulphur emissions. Moreover, zero sulphur fuel not only has a beneficial effect on particulate, HC, NO_x and CO emissions but also indirectly reduces the CO_2 emissions of road traffic compared to use of current commercially available fuel.

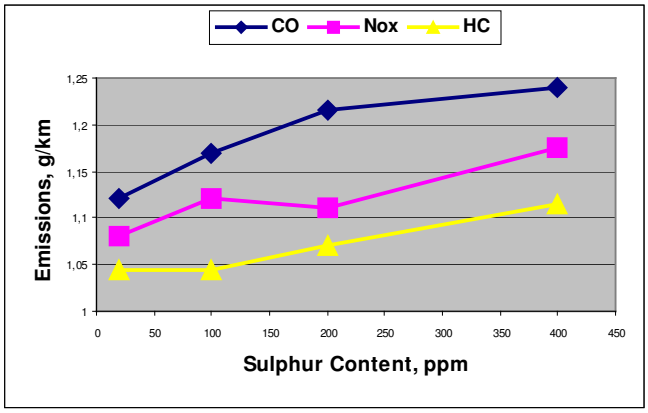

Figure 2: Impact of Fuel Sulphur Levels on Emissions
Source: Clean Fuels – Understanding Urban Air Pollution and the Role of Diesel Exhaust, India, 2000

Benefits of Further Lowering the Sulphur Content of Fuel

Main benefit of adopting further lower sulphur fuels will be improved fuel economy. Quantitative data, mainly from vehicle manufacturers, estimated this benefit to be 1-5% relative to fuel with 50 ppm sulphur. It is not known whether this range reflect variations in the sulphur sensitivity of different technologies, the use of different test methods or an evolving position with the sulphur sensitivity falling as the catalyst technology undergoes further development. For the recognising the variability there is necessity to quantify effects of lower sulphur fuel on existing vehicle, and also on the fuel efficiency of new engine technologies.

With regard to sulphur level there is general thinking that 30 ppm would produce marginal benefits, and therefore that further production has to be concentrated on less than 10 ppm sulphur level. Since the new engine technologies, that could potentially deliver additional fuel savings with low sulphur fuel, are just entering the market, and therefore the benefits of a full transition to such fuels was not justified before 2008-2010. The effect of low sulphur fuel, in reducing exhaust emissions from the current vehicle fleet with associated benefits to local air quality, could merit partial market transition. (5)

Furthermore, there is problem of incremental refining cost. The production of near zero sulphur fuels is technically feasible, with such grades already in production in some countries. The cost of doing this consists of capital investment in new plant and some increased running costs. These costs will vary between refineries, reflecting their present configuration and sulphur content of the crude oils they operate with. Since, southern European refineries generally operate on more sour crude oils therefore could face higher desulphurisation costs. Incremental costs of going from 50 ppm sulphur to less than 10 ppm sulphur fuels range from about 0.1 to 4.3 € cents per litre for gasoline and 0.2 to 4.3 € cents per litre for diesel, reflecting refinery variations. A short-term move to low sulphur diesel for the full market would reduce refinery capacity by 10-20%. However, a phased move would avoid this, while minimising costs since the capital investment could be incorporated in normal refinery up grades. The new catalyst developments could reduce the impacts of desulphurisation on both costs and CO_2 emissions.

If we look forward towards the introduction of new vehicle propulsion or power plant technology there are some things that have to be considered. Internal combustion engine technology is expecting to be dominant, at least up to 2010, with few submissions considering alternatives such as fuel cells and hybrid systems. However, it has to be noted that fuel cells stacks were sulphur intolerant and vehicles with on-board production of H_2 from gasoline would need a maximum of 5-10 ppm sulphur in the fuel to avoid poisoning the reformer.

Cost – Benefit Analysis of Further Lowering the Sulphur Content of Fuel
Modelling the precise costs and effects of the availability of zero sulphur fuels was complicated. Zero sulphur fuel has different effects on different vehicle types and these effects are not known with certainty. The take up and use of these fuels depends not only on market prices but also other determinants of consumer behaviour that is difficult to predict. The additional costs of producing lower sulphur fuel may vary from place to place depending on the refinery configuration and crude oil used. The relative reductions in emissions of carbon-dioxides and conventional pollutants from vehicles using fuels with less than 10 ppm sulphur, compared to fuels with less than 50 ppm are given in next table. (6)

Vehicle type		**Emissions reduction on 10 ppm sulphur fuels relative to fuels with 50 ppm (%)**			
		CO_2	**NO_x**	**HCs**	**PM**
EURO I, II, III	**Gasoline**	**0**	**10**	**10**	**0**
	Diesel	**0**	**0**	**0**	**5**
EURO IV	**Gasoline**	**1-5**	**0**	**0**	**0**
	Diesel	**1-3**	**0**	**0**	**0**

Table 2: Assumptions on vehicle emission changes,
Source: www.epa.gov

Second, the production of zero sulphur fuel may be more energy intensive. In such cases there will be additional CO_2 emissions at the refinery in line with the volume of zero sulphur fuel refined and produced.
Also, to asset the costs of using zero sulphur fuel we have to set additional costs of refining zero sulphur fuel against the value of potential fuel cost savings that arise

from the greater fuel efficiency for EURO IV vehicles. There are likely to be additional investment and refinery operating costs associated with lowering the sulphur content from a maximum of 50 ppm to a maximum of 10 ppm. There will also be a geographical difference and the main driver of that cost difference between north and south European Union is the quality of the crude oil, in particular the sulphur content that the refineries are currently set up to handle.

Other assumptions have also been made. The current European Union price before tax fuel is around €0.24 per litre for gasoline and €0.23 per litre for diesel. The cost increases at the refining stage from lowering the sulphur content to 10 ppm, therefore represent an increase of around 1-2%. At the gasoline stations, however, the percentage increase seen by the consumer will be much smaller, as around three quarters of the price of fuel to the consumer is made up of excise duties and taxes.

One more thing is necessary to stress at the end. The further desulphurisation process is becoming more and more complicated and more expensive as we are approaching to the lower content of sulphur in fuel. It was less expensive to make a step toward the 50 ppm of sulphur content. Each other percent of lowering sulphur content, specially above 10 ppm, is becoming more and more difficult to achieve and this is something that all have to be aware and also this represents a base for the further technological achievements toward real zero sulphur fuels.

Necessity of Zero Sulphur Fuel – Conclusion

Fuel constituents directly affect emissions of air pollutants. Fuel changes can immediately impact on emissions and therefore on air quality. Fuel composition can enable or disable pollution control technology. All of these statements confirm the fuel importance in our environmental system. Low sulphur fuel is one of the goals that have to be achieved, concerning vehicle exhaust and air pollutant emissions. Sulphur poisons the catalyst and sulphur impact is irreversible. Future low emissions technologies are even more sensitive to fuel sulphur content. Carbon oxides, hydrocarbon and nitrogen oxides emissions all improve with low sulphur gasoline. These are only main reasons why it is necessary that a detailed approach have to be given to the further lowering fuel sulphur content.

The final conclusions of this analysis could include that effective enforcement is critical and also that a strong public awareness program should be introduced worldwide. As a summary of reviewed data it could be stressed that clean fuels have a critical role in clean air. Understanding urban air pollution and the role of vehicle exhaust are prerequisites for environmental sustainability.

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