Opening the door to Cleaner Vehicles in Developing and Transition Countries: The Role of Lower Sulphur Fuels

A report of the Partnership for Clean Fuels and Vehicles (PCFV)

Partnership for Clean Fuels and Vehicles

UNEP

About the PCFV

The Partnership for Clean Fuels and Vehicles (PCFV) was launched in September 2002 at the World Summit on Sustainable Development in Johannesburg, South Africa. The PCFV is helping reduce vehicular air pollution in developing and transition countries through the promotion of clean fuels and vehicles.

The PCFV is the leading global initiative to promote cleaner fuels and vehicles in developing and transition countries. It provides a range of technical, financial and networking support for governments and other stakeholders to improve urban air quality. Since its inception, the PCFV has directly supported implementation on the ground in every region of the globe, including over 130 national-level campaigns or workshops.

The Clearing-House of the PCFV is located at the United Nations Environment Programme Headquarters in Nairobi, Kenya. The Clearing-House administers the day-to-day operations of the PCFV, such as organising meetings, overseeing activities, responding to requests for information, and liaising with Partners. An Advisory Group provides guidance on strategic and financial issues and advice on general management.

While the Partnership started with only a few dozen Partners, over the past five years a diverse array of non-governmental organisations, international organisations, national governments, and private sector companies from both the fuels and vehicles industries have joined. There are currently over 115 Partners.

For more information about the PCFV, please visit our website: http://www.unep.org/pcfv

UNEP promotes
environmentally sound practices
globally and in its own activities.
This publication is printed on paper from
sustainable forests including recycled fibre. The
paper is chlorine free, and the inks vegetable-
based. Our distribution policy aims to
reduce UNEP's carbon footprint.

Urban air quality and vehicle emissions

The biggest air quality problem in developing countries is air pollution in urban areas.The World Health Organization (WHO) estimates that almost 800,000 people die prematurely each year from urban air pollution[1]. Most of these premature deaths occur in developing countries.

Photos: UNEP/ Still Pictures

As vehicle traffic grows, the health and economic toll of poor air quality continues to mount on the most vulnerable of residents: women, children, and the elderly who live, play, walk and work on or close to congested urban highways. Yet, despite the seriousness of these problems, this publication demonstrates that political and technological solutions exist.

Vehicle emissions are one of a number of contributing factors to poor urban air quality. In terms of the health impacts, four pollutants are of particular concern – particulate matter (PM), ozone, carbon monoxide (CO), and sulphur oxides (SOx). Health effects associated with ambient particulate matter – which can be inhaled deep into the lungs – include premature death, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), aggravated asthma, and acute respiratory symptoms.

Additional studies have associated exposure to ambient particulate matter with heart disease and changes in heart rate and/or heart rhythm. Diesel particulate matter is of special concern because diesel exhaust has been associated with an increased risk of lung cancer[2]. Finally, scientists increasingly believe that particulate matter can influence the local and global climate. These emissions depend very much on the fuels used and the design of the vehicles. It is expected that globally transport will grow rapidly through 2050, resulting in a doubling of worldwide demand for fuels from

1 World Health Organisation (2002) Reducing Risks, Promoting Healthy Life

2 USEPA (2004) Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines, Page 2-55. http://www.epa.gov/nonroad-diesel/2004fr/420r04007c.pdf

now to 2050[3]. Estimates of motor vehicle contribution to urban air pollution worldwide vary anywhere between 25 and 75 percent, depending on pollutant and the location[4]. In many developing countries, conventional vehicle emissions are expected to continue to increase over the next few decades. Given the present poor quality of fuels and vehicles often found in developing countries urban air pollution problems that are now urgent are set to become even worse if no action is taken

Reducing vehicle emissions

For the last 30 years, air pollution control programmes in developed countries have shown that cleaner fuels and vehicles are an effective pathway to cleaner air. Benefits from cleaner fuels and vehicles programmes in developed countries include lower emissions from the existing fleet through improved fuel quality and enabling the introduction of cleaner vehicles and technology, which additionally reduce transport-related pollution. The PCFV publication *Opening the Door to Cleaner Vehicles in Developing and Transition Countries:The Role of Lower Sulphur Fuels* provides detailed guidance on reducing sulphur levels in fuels and and utlizing cleaner vehicle technology[5].

The main contributor to lower emissions in developed countries has been the introduction of cleaner fuels concurrent with the introduction of improved engine technology and after-treatment devices. For petrol vehicles, the introduction of unleaded petrol in the developed countries has paved the way for after-treatment systems, especially catalytic converters. The introduction of very efficient petrol vehicles with additional emissions controls systems will further reduce emissions. For diesel vehicles, there has been significant progress in reducing the level of sulphur in diesel which has gone hand in hand with the introduction of cleaner diesel engines and after-treatment technologies. Further improvements, including advanced after-treatment devices such as particulate

Photo: UNEP/ Still Pictures

3 World Business Council for Sustainable Development (WBCSD) (August 2004) Mobility 2030: Meeting the Challenge to Sustainability (www.wbcsd.org)

4 For example, a study in Kolkata, India, found that between 21 and 26 percent of the respirable particulate matter comes from mobile sources, while a study in Nepal estimates this is about half, and a study in Mexico City estimates 61% of PM10 emissions are from motor vehicles

5 available for download from www.unep.org/pcfv

filters and catalysts, are being introduced, significantly reducing diesel vehicle emissions. The introduction of low-sulphur diesel fuels has made the introduction of after-treatment technologies possible.

Studies show that developing countries that introduce cleaner vehicles and cleaner fuels will be able to follow developed countries in reversing the trend of increasing vehicular emissions if they adopt similar fuel quality and vehicle emission standards[6].

Reducing sulphur-related emissions

Improved fuel quality contributes to lower emissions. In the case of lower sulphur levels, this is specifically in the form of decreased emissions of particulate matter. There are substantial emission reductions to be achieved when sulphur in diesel is reduced from very high levels that are common in many developing countries (e.g many developing and transitional countries have more than 5,000 ppm in diesel fuels).

There are a number of excellent technologies that can be used once diesel fuel has sulphur levels of 500 ppm or less. Reducing sulphur to very low levels (50 ppm and less) not only reduces particulate matter emissions further but also enables the introduction of emission control technologies that provide even greater emission reductions.

Vehicle manufacturers are continuing to improve the design of engines to improve fuel efficiency and reduce emissions. However, these recent diesel engine technologies do not function well with high levels of sulphur in diesel fuels.

Table 1: Components Potentially Affected by Lower Sulpur Levels in Diesel Fuels[7]

Affected Components	Effect of lower sulphur	Potential Impact
Piston Rings	Reduced corrosion wear	Longer engine life, less frequent rebuilds
Cylinder Liners	Reduced corrosion wear	Longer engine life. Less frequent rebuilds
Oil	Reduced deposits, less need for alkaline additives	Reduced wear on piston ring/ cylinder liner, less frequent oil changes
Exhaust	Reduced corrosion wear	Less frequent part replacement

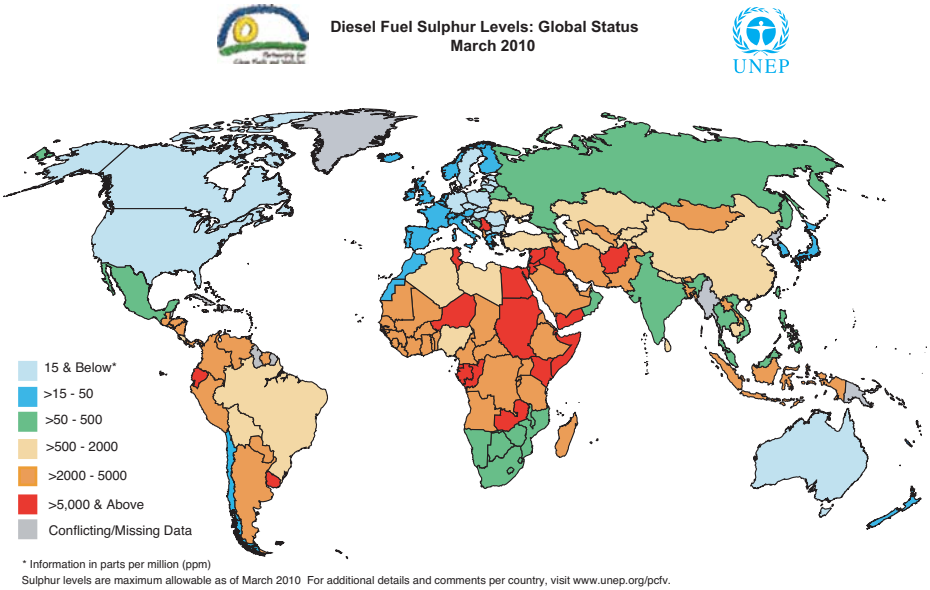
6 See footnote 2
7 http://www.adb.org/Vehicle-Emissions/General/diesel.asp

Global snapshot

Global levels of sulphur in fuels differ greatly, by country and by region. Depending on the crude oil used and the refinery configurations, sulphur levels in petrol range from below 10 ppm to as high as 1,000 ppm or more. In diesel fuel, levels range from below 10 ppm to more than 10,000 ppm. Europe, the US, and Japan have all put in place measures to reduce sulphur to lower levels (below 10-15 ppm), often along with emission standards that require advanced emission control technologies that cannot be used with higher sulphur fuels.

Developed and emerging economies such as India and China are moving toward low sulphur fuels, while the picture in developing and transition countries is mixed. As of March 2008, countries that have switched to diesel fuel with 500 ppm (or less) include: Belarus, Bolivia, Botswana, Brazil (in metropolitan areas), Chile, China, Ecuador (premium grade), India, Lesotho, Malaysia, Mexico, Namibia, Philippines, Singapore, South Africa, Swaziland, Thailand and Vietnam.

Figure 1: Sulphur levels in diesel fuels in parts per million as of March 2010



For more information on the reduction of sulphur in fuels around the world, please visit the PCFV website at: http://www.unep.org/pcfv.

Fuel sulphur - key to reducing vehicle emissions

Recognising that fuels and vehicles work together as a system, the greatest emission benefits can be achieved by combining lower sulphur fuels with appropriate vehicle emission control technologies. This approach has proven to be more effective than treating fuels, engines, or emission controls separately.

Reducing sulphur levels in fuels is especially important in reducing the smallest particles and can reduce vehicle emissions in two ways:

1. Reducing sulphur in fuels reduces direct emissions of both sulphur dioxide and sulphate particulate matter from all vehicles, old and new. Sulphur dioxide (SO2) emissions from diesel and petrol vehicles and particulate matter from diesel vehicles tend to increase in direct proportion to the amount of sulphur in the fuel.

2. Sulphur poisons or reduces the effectiveness of vehicle emission control technologies for petrol and diesel vehicles, resulting in increased vehicle emissions of CO, hydrocarbon (HC), nitrogen oxide (NOx), and PM. It also poisons or reduces the effectiveness of new types of emission control devices such as advanced catalytic converters and diesel particle traps, which can further reduce NOx, HC and PM emissions. For petrol vehicles, studies show that lowering sulphur enhances threeway catalyst operation and reduces HC, CO, and NOx emissions.

Existing and new diesel vehicles

Recent technological innovations have greatly improved the performance of diesel engines. This, along with their higher fuel economy compared to petrol vehicles, is making their use in passenger vehicles increasingly popular. Over the last 15 years, engine manufacturers have introduced a variety of engine modifications to reduce emissions, improve performance and increase efficiency. These modifications include direct injection, high-pressure injection, computer controls, multiple injections, exhaust gas recirculation (EGR), and aftercooling. In the U.S. these modifications have led to significant reductions in overall emissions, including PM and NOx, when compared to uncontrolled diesel engines. Although most of these technologies by themselves do not require specific fuel sulphur levels, most if not all, will be more durable with lower sulphur fuel, which reduces fuel injector corrosion, piston ring corrosion, oil acidification, and overall engine wear.

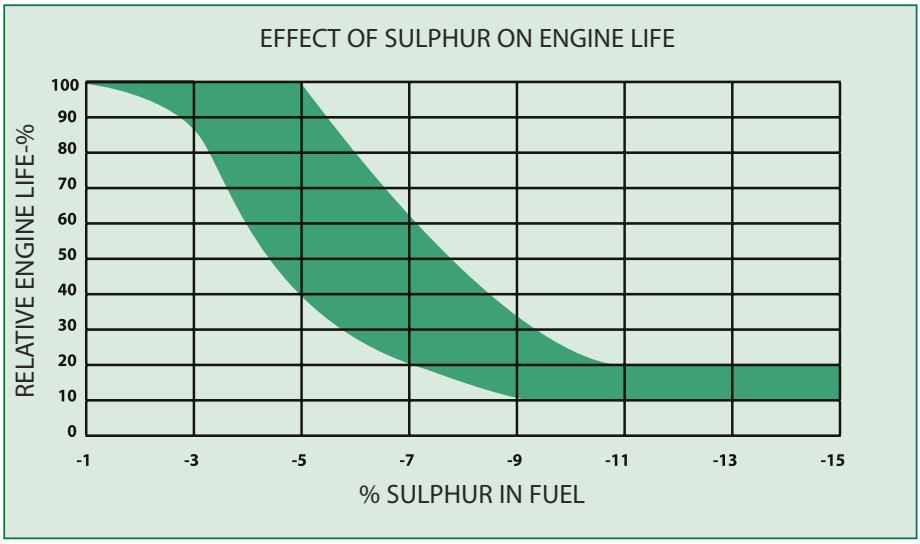
Particulate emissions from diesel vehicles are an order of magnitude higher than PM emissions from properly functioning petrol vehicles. Vehicles without any controls will benefit from lower sulphur fuel by directly reducing SO2 and particulate emissions.

For diesel vehicles, fuels with 500 ppm or less sulphur enable the introduction of newer vehicles that are equipped with diesel oxidation catalysts. This level of fuel sulphur also makes it possible for certain older diesel vehicles to be retrofitted with emission control technologies – a strategy that is increasingly used in many cities. Even greater reductions can be achieved by going to very low sulphur levels (below 50 ppm) after which diesel particulate filters can be introduced. These filters are able to remove 95% of particulate emissions from vehicles.

Diesel oxidation catalysts are already standard on millions of vehicles worldwide, and use of diesel particulate filters is already standard in the US and Canada, with the European Union starting in 2009 through the Euro 5 standards.

Technologies to control NOx emissions are also being developed. Examples of NOx controls include NOx adsorbers, and Selective Catalytic Reduction. While NOx adsorber systems are still in the demonstration phase, selective catalytic reduction systems are currently in use in Europe. Detailed explanations of these technologies are provided in the PCFV publication *Opening the Door to Cleaner Vehicles in Developing and Transition Countries:The Role of Lower Sulphur Fuels* available for download from www.unep.org/pcfv.

Figure 2: Decrease in engine life due to increasing sulphur levels in fuel



Repair/rebuild: Perform routine maintenance and rebuild engines back to manufacturer's specifications
Refuel: Use cleaner fuel
Retrofit: Equip your vehicle with cleaner technologies such as filters and catalysts
Repower: Remove the old engine and repower it with a newer vintage engine
Replace: Replace vehicle if other options are not cost-effective

Petrol vehicles

For petrol vehicles, reducing sulphur levels to 500 ppm and below improves the performance of catalytic converter systems that are standard in developed countries and are now being introduced in most developing countries through new car sales and second hand car imports. Very low sulphur levels enable the use of the most advanced emission control technologies and may enable the use of fuel efficient lean-burn spark ignition engines.

The most wisely used device to reduce pollutants from petrol vehicles is the three-way catalyst. These catalysts dominate new vehicle production globally, and as of 2000, about 85% of new petrol vehicles were equipped with this technology.

Catalyst technology is advancing, and more advanced catalysts can reduce emissions to virtually insignificant levels, depending on the fuel quality. Sulphur greatly reduces the efficiency of these devices by blocking active catalyst sites. The impact of sulphur on advanced catalysts increases in severity as vehicles, and their emission control equipment, are designed to meet stricter emission standards.

Photo: Thomas Harrison Prentice

Going low sulphur – the options

In considering reductions in sulphur levels, policymakers in each country must weigh several factors, including the importance of the vehicle emission contribution to urban air pollution as well as the comparative costs and benefits of cleaner fuels and vehicles relative to other available strategies. However, cost-benefit analyses of fuel sulphur reductions performed in the US, Canada, Europe, Mexico, China, Brazil (including incremental costs of fuels and vehicles) have all concluded that benefits of reducing sulphur from fuels far outweigh the refinery investment and distribution costs.

Petrol and diesel fuels are produced from crude oil, which naturally contains sulphur. The amount of sulphur in crude oil may vary considerably between 'sweet' and 'sour' crudes; crudes from the North Sea and Nigeria tend to be lower in sulphur (or 'sweet'), while those from the Middle East are higher in sulphur ('sour'). Numerous options exist to reduce the sulphur levels in petrol and diesel; the approach taken will be based upon the fuel supply infrastructure in a country.

Table 2: Characteristics of Selected Crude Oils

	Light ('Sweet') Crude		Medium Sulphur Crude		High Sulphur ("Sour") Crude	
	High Gravity (Bonny Light)	Low Gravity (Bonny Medium)	Light (Murban)	Heavy (North Slope)	Light (Arabic)	Heavy (Bachequero)
Gravity °API	37.6	26.9	39.4	26.8	33.4	16.8
Average Sulphur (ppm)	1,300 ppm	2,300 ppm	7,400 ppm	10,000 ppm	18,000 ppm	24,000 ppm
Sulphur Range (Wt.%)	0 - 0.5	0 - 0.5	0.51 - 1.0	0.51 - 1.0	1.0+	1.0+

Does your country import fuel?

If your country imports fuel, introducing lower-sulphur products is very straightforward. Lower-sulphur fuels can easily be purchased on world markets, and importing from a supplier that has lower-sulphur options is a quick and efficient way to benefit from cleaner fuels. Botswana, Lesotho, Namibia, and Swaziland all enjoy cleaner fuels because they import from South Africa, which produces petrol and diesel with lower sulphur levels.

Does your country refine fuel?

If your country refines fuel, there are a number of options and alternatives available, depending on the configuration of your refinery. Numerous countries (including developing countries) have successfully and quickly introduced cleaner fuels to their domestic markets. For example, some countries have done so by importing lower-sulphur crude oil as their refinery feedstock. This approach was taken by China in lowering their sulphur levels

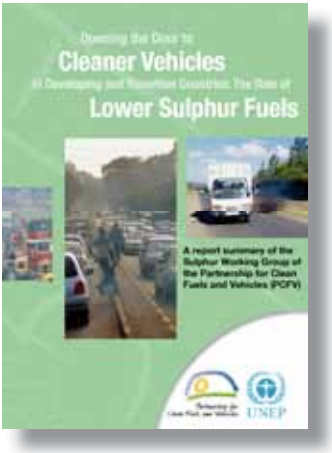
Another option to decrease sulphur levels in refined fuel is to invest in refinery technologies designed for this purpose. Desulphurisation units such as hydrotreaters or hydrocrackers are routinely used to produce cleaner fuels. Newer and alternative technologies that can reduce operating costs, capital costs or both are beginning to be used at some refineries. The cost of these technologies is lowering as demand for them increases. Every refinery is different, and so every country will have a different experience.

Photos: UNEP/ Still Pictures

A combination of import-switching and upgrades may also be necessary; this dual approach can be taken as a temporary measure by countries with refineries that need to be upgraded. India and the Philippines imported lower-sulphur fuel while refinery modifications were underway.

What else do I need to know?

Introducing lower-sulphur products may have some impacts on other aspects of your fuel supply. In order to maximise the health and environmental benefits of moving to cleaner fuels, these impacts must be considered when weighing the various options available to you:



- distribution and storage of fuels should be devised to avoid cross-contamination between lower- and higher-sulphur products
- refinery processes that produce cleaner fuels may change other properties of the diesel or petrol (such as cetane/octane, lubricity, aromatic content); fuel specifications must be considered
- some refinery upgrade options require the use of additional hydrogen; the source and cost of additional hydrogen must be assessed
- some refinery processes also require additional energy use and result in more carbon dioxide emissions
- measures to prevent adulteration of fuels (such as mixing of diesel fuel with cheaper, higher-sulphur kerosene) should be taken

The PCFV can help your government to consider available options for going low sulphur, and to help address any concerns by providing access to international experience and industrial expertise. Detailed guidance on going low-sulphur is provided in the PCFV publication *Opening the Door to Cleaner Vehicles in Developing and Transition Countries: The Role of Lower Sulphur Fuels* available for download from www.unep.org/pcfv.

PCFV - Working together to promote cleaner fuels for life

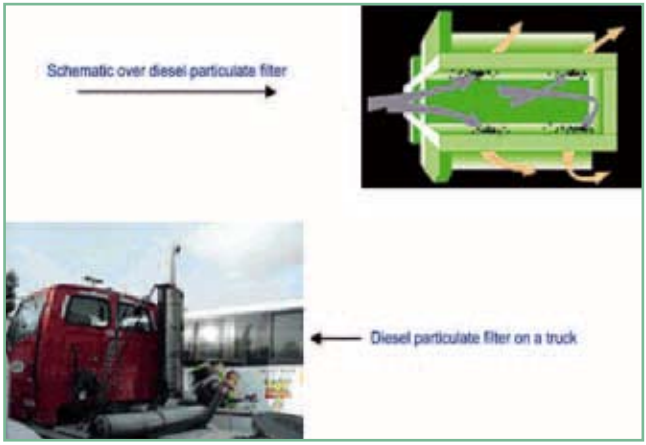
What have other countries done?

Numerous countries around the world have been taking steps to lower the sulphur levels in both diesel and petrol fuels, thus reducing harmful emissions and improving air quality. While each government's approach is based on its unique situation, there are some general methods that have been used.

Photo: Fleet Forum

The process favoured by many countries is to introduce lower sulphur fuels in metropolitan areas first, with gradual expansion to non-metropolitan areas later. This approach has been taken by Argentina, Brazil, Chile, Colombia, Mexico, and Morocco.

Other governments have adopted the sulphur limits of countries or regions with stricter standards. For example, a number of countries in Asia use the European Union standards as a baseline for sulphur reductions. Countries that are currently using or plan to use the "Euro" standards include: China, India, Indonesia, Japan, Malaysia, Republic of Korea, Singapore, and Thailand.



Diesel Particulate Filter. Photo: MECA

What can I do?

The first step is to contact the PCFV, who has been supporting governments around the world in their efforts to lower sulphur levels and improve air quality. The PCFV will discuss with you what the current fuel supply situation is in your country, what Partners you may want to work with, and various options available to you. The PCFV is committed to working with countries to support them in their move to improve air quality, and based on each country's situation, can provide a range of technical, financial, and networking assistance.

The PCFV has made available a number of resources to assist countries that are taking steps to lower sulphur levels in fuel., including technical and policy guidance, financial assistance for development of strategies and technical projects, and awareness and training.

Because PCFV staff members have been working closely with a range of countries around the world, they are also able to offer guidance on best practices and site-specific issues associated with lowering sulphur levels in fuel.

Materials are available on the PCFV website (http://www.unep.org/pcfv) or from the PCFV clearing-house. If you require special materials because of the situation of your country, discuss this with the PCFV – they may be able to provide assistance in acquiring or producing these materials.

Photo: UNEP/ Still Pictures

Other PCFV Publications

- ***Black Carbon Policy Summary - A policy-relevant summary of black carbon climate science and appropriate emission control strategies***

- ***Hybrid Electric Vehicles: An overview of current technology and its application in developing and transitional countries***

- ***Working together to promote cleaner fuels and vehicles for life***

- ***Cleaner Motorcycles - Promoting the use of four-stroke engines***

- ***Recommended Practices for the Decommissioning, Dismantling and Disposal of lead Alkyl Compound Facilities and Equipment***

- ***Opening the Door to Cleaner Vehicles in Developing and Transition Countries:The Role of Lower Sulphur Fuels***

- ***Valve Seat Recession Working Group Report***

- ***Cleaner Relief – Reducing the environmental impacts of humanitarian operations***

- ***How to Clean Up your fleet, Interactive CD for Clean Fleet management***

Copies of these Publications are also available at http://www.unep.org/pcfv

For more information please contact:
United Nations Environment Programme
Partnership for Clean Fuels and Vehicles
P. O. Box 30552, Nairobi, Kenya
Tel: +254 (0) 20 7624184 Fax: (+254 20) 7625264
Email: pcfv@unep.org