Briefing

The Benefits of Low Sulphur Fuels in India

Authors: Gaurav Bansal, Anup Bandivadekar

Date: May 2012

Keywords: low sulphur fuel, emissions, health, India,

Background

Reducing the sulphur content in vehicle fuels has many positive impacts on ambient air quality. Low sulphur fuels reduce tailpipe CO, HC, and NOx emissions from catalyst-equipped gasoline vehicles and PM emissions from diesel vehicles even without oxidation catalysts. Low sulphur fuels also work in tandem with stricter emission standards as they allow aftertreatment technologies such as lean NOx traps (LNTs), selective catalytic reduction (SCR) units, and diesel particulate filters (DPFs) to function optimally.

India has come a long way in reducing the sulphur content in its fuels over the last decade. Gasoline sulphur content fell from 2000 ppm to 150 ppm, and diesel sulphur content fell from 10,000 ppm to 350 ppm between 2000-2010. In twenty metropolitan areas there has been even more progress. These cities now have gasoline and diesel with no more than 50 ppm sulphur.

But under the current system, even the twenty cities with 50 ppm sulphur fuels cannot fully realize their benefits because many vehicles operating within their limits refuel in other areas. India can take steps to implement a policy of "one country, one fuel, one regulation." The advantages of doing so are discussed below.

Fuel Sulphur Effects on Emissions and Health

Extensive studies have been carried out in many countries to understand the linkage between vehicle technology, fuel quality, and emissions [1-5]. These studies have shown that sulphur in gasoline and diesel fuel negatively affects the performance of aftertreatment systems and also contributes to particulate

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Washington
+1 202 534 1600
Brussels
Berlin
San Francisco
+1 415 399 9172
communications@theicct.org | www.theicct.org

sulphate (a PM component) and sulphur oxides emissions (SOx). Hence, the benefits of sulphur reduction are twofold. First, lower sulphur enhances the performance of emission control devices by improving their efficiency, as is the case of the three-way catalyst (TWC) for gasoline vehicles. Second, lower sulphur fuel enables the adoption of certain emission control technologies, such as DPFs, that otherwise would render unacceptable performance and risk damage. Therefore, reducing fuel sulphur enables the adoption of stricter emission standards that take advantage of the latest emission control technologies, and ensures that these technologies will function optimally throughout their designed life [4, 6, 7]. Tables 1 and 2 summarize the effects of fuel sulphur on tailpipe emissions and emission control technologies.

Studies have also looked at the relationship between vehicular emissions—which are higher if fuels with higher sulphur content are used—and public health [8, 9]. An important study in Hong Kong detailed the health benefits of fuel sulphur reduction [10]. It looked at deaths between the years 1985 and 1995, and found that after 1990, when Hong Kong mandated lower sulphur levels in vehicle and power plant fuels, annual all-cause mortality fell 1-2%, respiratory mortality fell 3-9%, and cardiopulmonary mortality fell 0-2% over pre-1990 levels. The study also concluded that average life expectancy increased by 20 days for females and 41 days for males as a result of lower fuel sulphur content. While these health benefits may seem minimal, they represent the benefits of *only* sulphur reduction in fuels. If low sulphur fuels are used as an impetus for stricter emission standards, the benefits are substantially higher.

Table 1: The effects of fuel sulphur on tailpipe emissions by emissions norms from light-duty vehicles, heavy-duty vehicles and motorcycles.

LDV & HDV

Gasoline	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Euro6	Comments
Sulphur ↑	SO_2 ↑	CO, HC, NO_x ↑ ~15-20% as sulphur content ↑ from 50-450 ppm							Onboard Diagnostic light may come on incorrectly
Diesel	**Pre-Euro**	**Euro 1**	**Euro 2**	**Euro 3**	**Euro 4**	**Euro 5**	**Euro 6**	**Euro6**	**Comments**
Sulphur ↑	PM, SO_2 ↑		If oxidation catalyst is used, PM, SO_2, SO_3 ↑						If DPF or LNT used, <50 ppm sulphur is required

Motorcycles

Gasoline	Pre-Euro	India 1	Bharat II	Bharat III
Sulphur ↑	SO_2 ↑	If oxidation catalyst is used, SO_2, SO_3, CO, HC, NO_x ↑		

Table 2. The effects of fuel sulphur on aftertreatment devices.

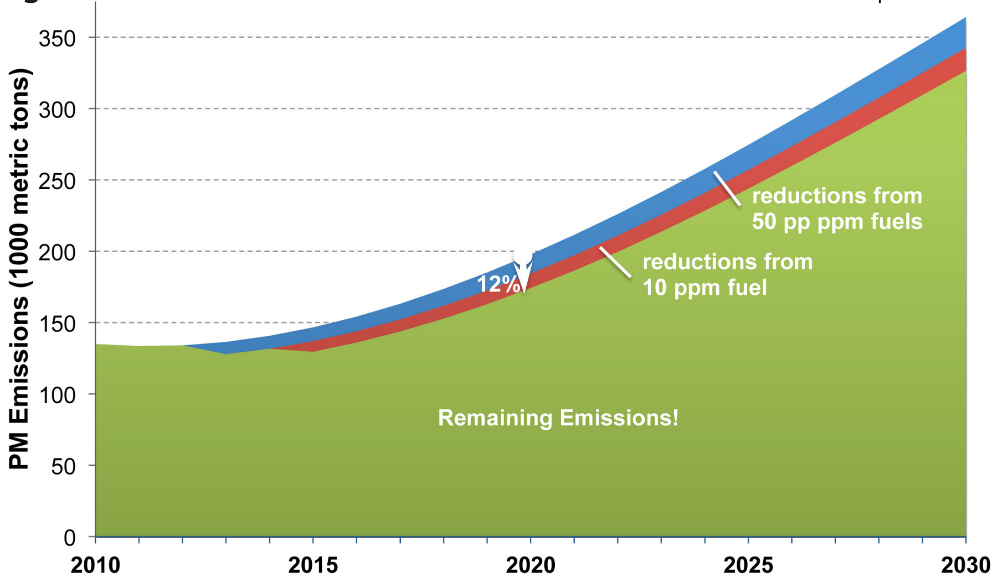
Aftertreatment	Study	Test conditions	Effects	S level -> efficiency	Max. Sulfur
DPF – PM reduction	DECSE	ESC – 13 mode on Caterpillar I-6, 7.2 L, 275 hp	Increasing sulfur level reduces DPF efficiency with respect to engine-out values.	PM reduction eff.	S≤50 ppm
	(NREL, 2001)		Filter regeneration temperature increases with S levels.	3 ppm -> 95%	
				30 ppm -> 73%	
				150 ppm -> 0%	
				300 ppm -> -130%	
	JCAP (Oyama & Kakegawa, 2003)		No deterioration in PM control.	No effect on DPF efficiency	S≤50 ppm
			Fuel economy was reduced by 7%.		
DOC – HC, CO, PM reduction	DECSE	FTP 75 on Cummins ISM370, I-6, 11 L, 280 hp	PM emissions increase if S≥150 ppm at high load.	HC reduction efficiency.	S≤ 500 ppm
			HC oxidation capacity is reduced for some DOCs (depending on catalyst formulation).	3 ppm -> ~100%	
			CO emissions are not affected.	350 ppm -> 91%	
LNT – NOx Reduction	DECSE and MECA (2007)	Engine Prototype – I-4, 1.9 L, 81 hp	Sulfur compounds interfere with NOx storage function.	3 ppm -> 90%	S≤10 ppm
SCR – NOx reduction	Girard, 2009.	Simulated diesel exhaust gases	Vanadium SCR systems can operate at S levels of 50-500 ppm.	For zeolite SCR: Exposure at 600 ppm reduced the NOx conversion efficiency from ~90% to ~50%. Conversion ~70% after sulfur regeneration	S<500 for vanadium SCR
	Chatterjee, 2008		Zeolite SCR systems are susceptible to S>50 ppm levels.		S≤ 350 ppm for Iron-Zeolites
					S≤ 50 ppm for Copper-zeolites

Vehicle Fleet Emissions with Cleaner Fuels

The ICCT developed a fleet emissions model to estimate the effect of various vehicular policies on vehicular emissions in India. Scenarios were developed that modelled temporal changes in new vehicle emission standards, fuel sulphur levels, the number of gross emitters, and a shift from conventional fuels to alternative fuels and electric vehicles, among other things. The BAU scenario modelled what India had accomplished through 2010, assumed on-going trends would continue, and that no further policy action would be taken.

The model was then used to study the future effects of reducing sulphur content in fuels on tailpipe emissions of PM, all else being the same. All aspects of the BAU were kept unchanged with the exception of sulphur content in fuels. Two scenarios were modelled: one in which 50 ppm sulphur gasoline and diesel were made available throughout the country by 2013, and another in which India went a step further and

Figure 1. Annual PM emissions under the BAU scenario and low sulphur fuel scenarios.



leapfrogged to 10 ppm fuels by 2015. These were compared to predicted emissions under the current system, in which 50 ppm fuels are mandated in twenty cities but up to 150 ppm sulphur gasoline and 350 ppm sulphur diesel are allowed elsewhere. Figure 1 shows vehicular PM emissions resulting only from reductions in fuel sulphur content.

In percentage terms, implementing 50 ppm sulphur fuels by 2013, even without the adoption of new emission standards or other emission control measures, would reduce vehicular PM emissions by almost 7 per cent annually over current levels. Moving to 10 ppm sulphur fuels by 2015 would reduce annual vehicular PM emissions by up to 12 per cent. This amounts to over 450,000 metric tons of vehicular PM not being emitted in the 2013-2030 time period, which is well over three times the amount emitted by all Indian vehicles in 2012 alone.

Policy Steps for India

The adoption of 50 ppm sulphur fuels, and subsequently 10 ppm sulphur fuels, will also open the door for the adoption of many aftertreatment technologies that currently cannot be deployed due to the lack of appropriate fuel. Moving to stricter emission standards that require DPFs, LNTs, and other technologies will further reduce vehicular PM and NOx emissions. Low sulphur fuels will also allow in-use vehicles to be retrofitted, where possible, with the latest emission control technologies.

Table 3. Assumptions of the World Class Scenario modelled in the IEM.

Scenario	Emission Standards	Fuel Standards	Enforcement and Compliance[1]	Change in Fuel Type[2]
World Class	Bharat V (2013) countrywide and Bharat VI (2015) and "SULEV" (LD) and "Bharat VII" (HD) by 2020	Low sulphur fuel (50 ppm) by 2013 and ultra low sulphur fuel (10 PPM) by 2015	By 2020, only 3% of vehicle fleet are gross emitters	15% of LDV sales CNG and 10% LPG by 2030; 75% bus sales CNG by 2030; 50% of 3-wheeler sales CNG by 2030

1. Gross polluters are defined as vehicles where emission controls are non-functional.
2. LDV means PC only. Increases in CNG and LPG vehicle market share are assumed to happen at the expense of diesel market share.

Analysing the possibilities of linking cleaner fuels with other vehicular emission control measures, a scenario envisioning tighter emission standards along with 10 ppm sulphur fuels, stricter in-use vehicle regulations and compliance, and a gradual shift away from traditional fuels was modelled. The details of this scenario, called

Figure 2. Annual NOx emissions under the BAU and World-Class scenarios.

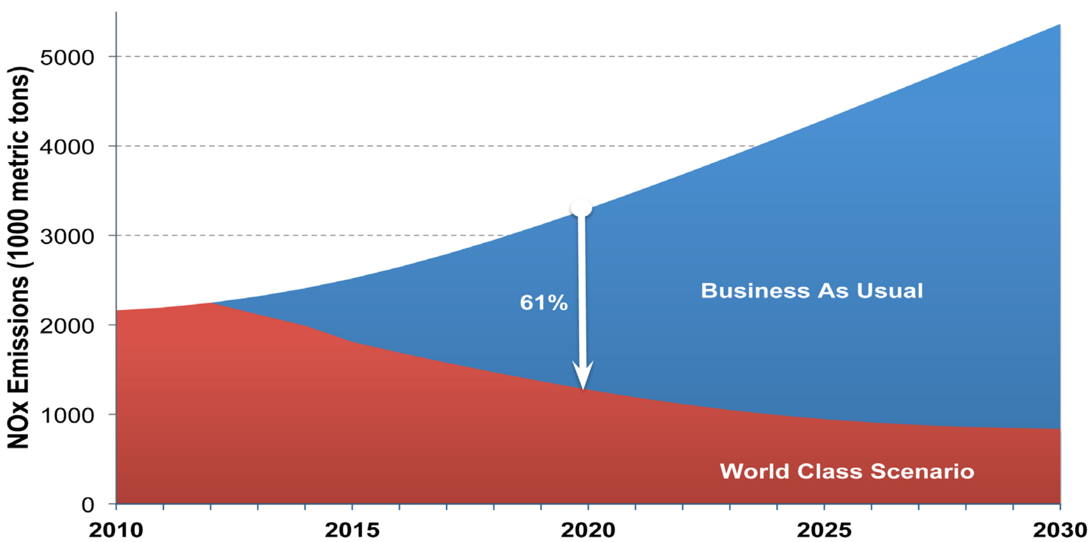
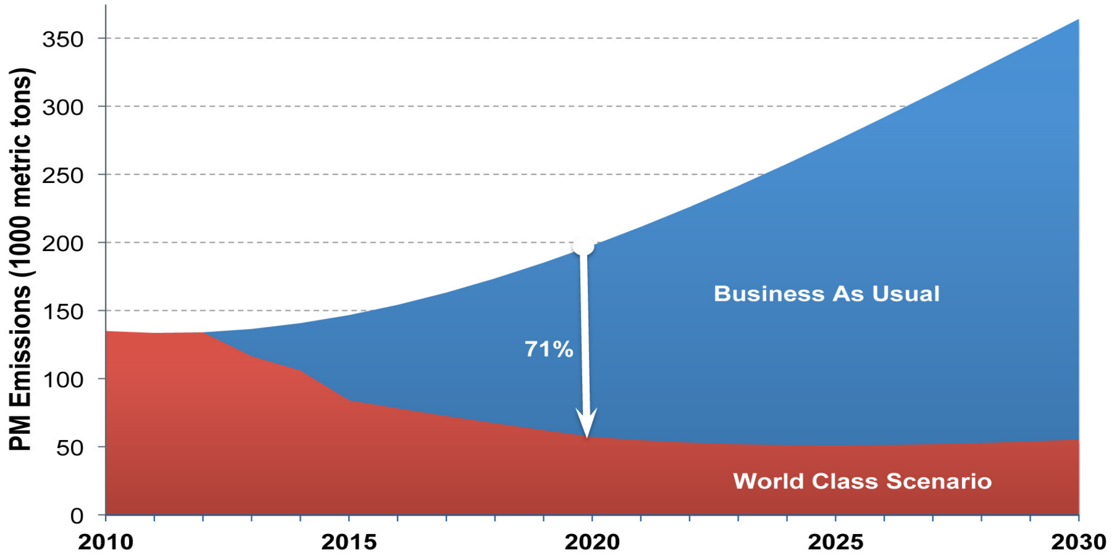


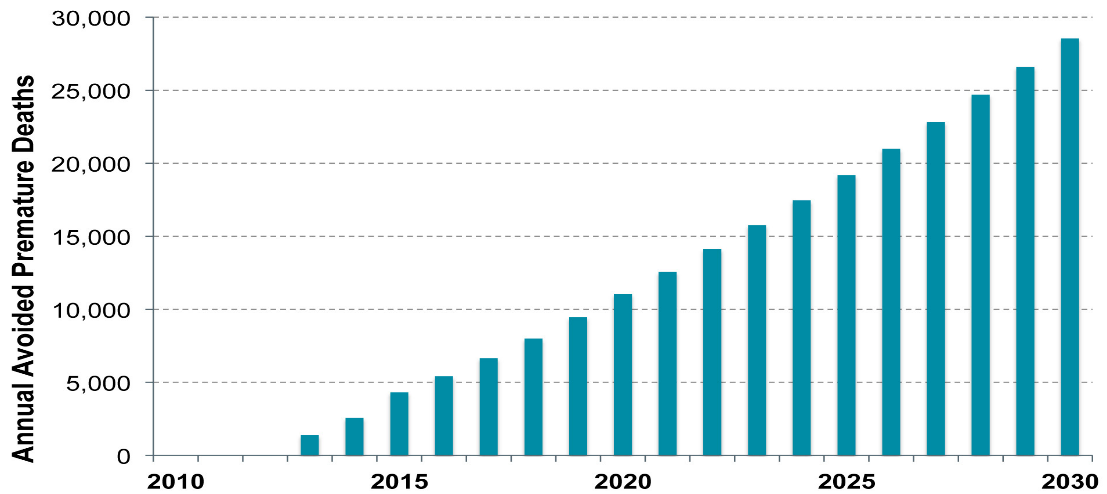
Figure 3. Annual PM emissions under the BAU and World-Class scenarios.



the World-Class scenario, are shown in Table 3. Figures 2 and 3 show NOx and PM emissions under the World-Class scenario compared to the BAU scenario.

By 2030, vehicular emissions of both PM and NOx can be reduced by 87% by implementing policies envisioned in the World-Class scenario. In the entire 2013-2030 time period, a total of 3 million metric tons of PM and 43 million metric tons of NOx emissions can be avoided.

Figure 4. Annual average avoided premature deaths under the World-Class scenario.



The ICCT also developed a health assessment model that estimates annual avoided premature deaths due to reduced vehicular PM emissions. The model predicts over 250,000 premature deaths can be avoided in the 2013-2030 time period by implementing policy measures envisioned in the World-Class scenario. These avoided deaths will certainly have economic benefits in terms of reduced healthcare costs and increased worker productivity. Figure 4 shows estimated annual avoided premature deaths under the World-Class scenario.

Conclusion

In short, India stands to gain much more by implementing lower sulphur fuels in tandem with other vehicular emission control measures. In particular, these benefits will stem from adopting a "one country, one fuel, one regulation" policy and reducing fuel sulphur levels to be on par with international best practices. These steps by themselves will have positive impacts on air quality in India, particularly in its most polluted cities. They will also open the door for other emission control technologies and policies to be adopted to further improve air quality and public health.

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