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Costs and Benefits of Cleaner Fuels and Vehicles in India

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INTRODUCTION

Extensive studies have shown that sulfur in gasoline and diesel contributes to higher vehicular emissions[1-6]. The benefits of fuel sulfur reduction are twofold. First, lower sulfur enhances the performance of existing emission control devices. Second, lower sulfur fuel enables the adoption of advanced emission control technologies that otherwise would render unacceptable performance or be damaged.

Studies have looked at the relationship between fuel sulfur and public health [7, 8]. An important study in Hong Kong detailed the health benefits of fuel sulfur reduction[9]. It found that five years after Hong Kong lowered fuel sulfur content to a maximum of 5,000 ppm in 1990, annual all-cause mortality fell 1–2%. While this may seem minimal, it represents the benefits of *only* sulfur reduction in fuels. If low-sulfur fuels are used as an impetus for stricter emission standards, the benefits are substantially higher.

Vehicle technologies to significantly reduce emissions over current Indian standards already exist. While in most of India new vehicles are required to meet Bharat III (Euro 3/III equivalent) standards, and in 20+ cities they must meet Bharat IV standards, Europe, the U.S., Japan, and a few other countries require Euro 6/VI or more stringent standards. Given that auto manufacturers in India have international sales and collaborations, they have access to these technologies.

India has come a long way in tightening fuel quality and vehicle emission standards. Between 2000 and 2010, emission standards went from Bharat I to Bharat III/IV. During the same period, gasoline sulfur content fell from 2,000 ppm to 150 ppm, and diesel sulfur content fell from 10,000 ppm to 350 ppm. Cities mandating Bharat IV standards have seen even more progress; they now have fuels with no more than 50 ppm sulfur. But even these cities often cannot fully realize the benefits of low-sulfur fuels because many vehicles operating within their limits refuel in other areas with higher sulfur levels.

Investing in ultra-low-sulfur fuel (ULSF, fuels with less than 10 ppm sulfur content) and clean vehicle technologies in India will not come without costs. But the benefits of these investments, in terms of reduced healthcare costs and higher productivity, far outweigh the costs. This paper discusses these issues in detail.

COSTS OF ULSF

The two main pathways that remove sulfur from the crude oil are hydrocracking and hydrotreating. In the case that distillates and gas oil feeds already have relatively low sulfur content, hydrocracking and early hydrotreating can be sufficient to reduce sulfur content to ULSF levels. If this is not the case, further hydrotreating is necessary to produce ULSF.

APPROACH AND ASSUMPTIONS

An independent 2012 joint study by Hart Energy and MathPro estimated the costs of moving to ULSF in India[10]. The study combined linear programming models and the PIMS model used by the oil industry to estimate the lowest ULSF production costs for the year 2015. A number of key assumptions of the study are outlined below:

1. ULSF would be available for all gasoline and diesel applications in India.
2. Existing refineries and refineries under construction could be upgraded to produce ULSF using only process technologies already in commerce.
3. Refineries would not switch from a high-sulfur crude slate to a low-sulfur crude slate expressly for ULSF production.
4. The crude oil sourcing pattern would be more or less the same in 2015 as it was in 2010.

To arrive at cost estimates for ULSF production for the year 2015, the study first established an operations baseline for the year 2010 and made assumptions about changes in petroleum production by 2015. Indian refineries were classified into five groups based on their characteristics. Four of the five categories contained refineries existing in 2010, while the fifth category grouped refineries expected to be online by 2015. Characteristics of the five groups are shown in **Table 1**. Costs were calculated for each refinery group based on the optimal method for each to be upgraded to produce ULSF.

Table 1: Indian refinery groupings and their characteristics

Refinery Group	Count	Crude Capacity (k Bbl/day)	Characteristics	Crude Type	
				Low S	High S
A: Large Export	3	1520	State of the art	4%	96%
B: High Distillate Conversion	6	1120	Existing cracking and hydroprocessing capacity	14%	86%
C: Small Sweet	4	98.6	Basic in configuration	100%	-
D: Medium Conversion	6	976.3	Moderate complexity	19%	81%
E: Transition Year Capacity	8	1234	Planned and under construction	40%	60%

Annual increases in refining costs were calculated by combining direct operating costs and annualized capital charges for investments. Direct operating costs included additional hydrogen supplies needed for desulfurization, additional sulfur recovery facilities (though revenue from recovered sulfur offset some of these costs), and costs for the replacement of product yield and fuel quality of gasoline and diesel.

Investments were annualized into capital charges based on numerous economic parameters. **Table 2** shows assumptions for these parameters for India, as well as standard industry baseline values.

Table 2: Parameters used to calculate annual capital charges

Parameter	Value for India	Baseline Value
Construction time	2 years	3 years
Project life	20 years	15 years
Depreciation period	10 years	10 years
Cost of capital (after tax)	5%	10%
Marginal tax rate	30%	30%
Inflation rate	7% per year	2% per year
Annual fixed costs	9% of investment	9% of investment

ULSF PRODUCTION COSTS

Costs to upgrade to ULSF production over current levels by 2015 in India were calculated for each refinery group. Average costs for Groups A through D, and separately for Group E, are shown in **Table 3**.

Table 3: Costs to upgrade to ULSF production in Indian refineries by 2015

	Current Refineries (Groups A-D)	Transition Refineries (Group E)
Refined Products (MMTPA)		
Gasoline	29.6	11.8
Diesel	66.9	31.6
Increased Refining Cost (crore Rs/yr)	**4830**	**665**
Capital Charges & Fixed Costs	3555	495
Refining Operations	1275	165
Final Per Liter Cost Increase (Rs/L)		
Gasoline	**0.45-0.55**	**0.10-0.15**
Diesel	**0.40-0.55**	**0.15-0.20**

COSTS OF VEHICLE TECHNOLOGIES

The availability of ULSF improves the performance of existing emission reduction technologies, such as catalytic converters, and also enables the adoption of many advanced aftertreatment technologies, notably diesel particulate filters (DPF), lean NOx traps (LNT), and selective catalytic reduction (SCR). These technologies are often associated with specific emission limits that require the use of one or more of these technologies. Therefore, vehicles meeting stricter emission standards have additional costs.

Figure 1 shows the per vehicle costs for the average Indian vehicle to move from Bharat Stage III (BSIII), the current emission standards in most of India, to BSVI, as estimated by a recent ICCT study[11]. Costs for two- and three-wheeler are not shown here because they were very low (~$30–60 per vehicle).

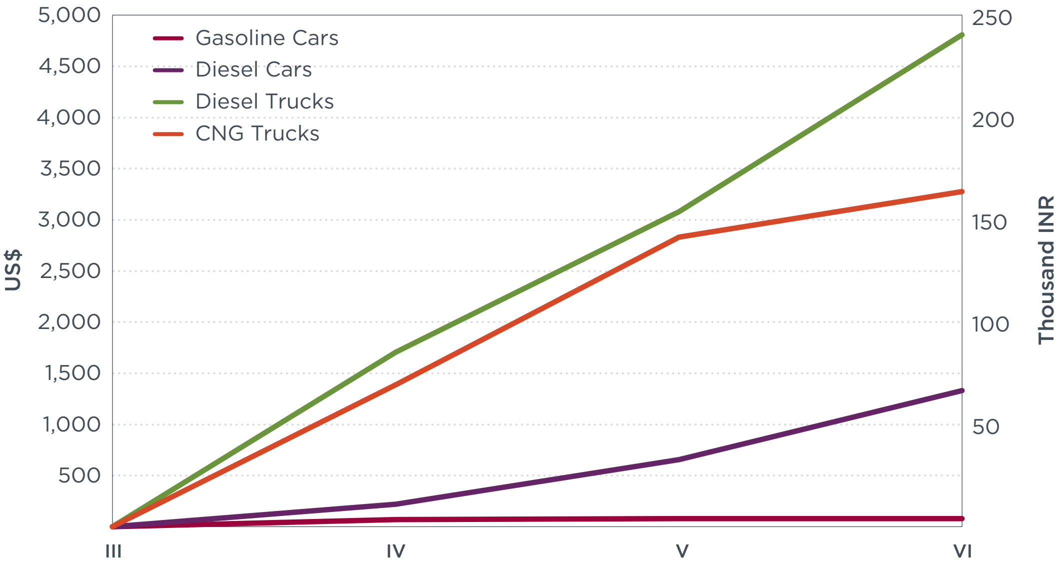

Figure 1: Additional vehicle costs by BS emission standards over BSIII levels

HEALTH AND ECONOMIC BENEFITS OF CLEANER VEHICLES AND FUELS

There are significant health and economic benefits associated with cleaner fuels and vehicles[7]. Lower emissions of carcinogenic fine particulate matter ($PM_{2.5}$) are especially important in reducing mortality and morbidity associated with ambient air quality[12]. Studies supported by the World Health Organization (WHO) have detailed links between increases in ambient $PM_{2.5}$ levels and mortality[13, 14].

To look at changes in vehicular $PM_{2.5}$ emissions due to the deployment of ULSF and ULSF-enabled clean vehicle technologies, the ICCT developed a fleet emissions model to estimate annual emissions of various pollutants from India's on-road vehicle fleet. First, a baseline business-as-usual (BAU) scenario was developed, in which current standards and trends were assumed to continue into the future. This was compared to an Alternate scenario, which modeled emissions assuming cleaner vehicles and fuels nationwide. Model assumptions of the BAU and Alternate scenarios are shown in more detail in **Table 4**.

Table 4: Model assumptions for the BAU and Alternate scenarios

SCENARIO	EMISSION STANDARDS	FUEL STANDARDS	ENFORCEMENT & COMPLIANCE[1]	CHANGE IN FUEL TYPE
BAU	Bharat IV in 13 cities, Bharat III in rest of India	Bharat IV in 20 cities (50 ppm sulfur diesel), Bharat III in rest of India (350 ppm sulfur)	15% of vehicle fleet are gross emitters	50 (60)% of new car sales diesel by 2020(2030)
Alternate	Bharat V (2014) and Bharat VI (2016), and "SULEV" (LDV) and "Bharat VII" (HDV & 2/3-Wheelers) by 2020	ULSF (10 ppm) in 20 cities and Low-sulfur fuel (50 ppm) in rest of country by 2014; ULSF (10 PPM) countrywide by 2016	By 2020, only 3% of vehicle fleet are gross emitters	15% car sales CNG, 10% LPG by 2030; 75% bus sales CNG by 2030; 50% of 3-wheeler sales CNG by 2030

1. Gross emitters are defined as vehicles where emission controls are non-functional.

Figure 2 shows modeled annual all particulate matter (PM) emissions under the BAU and Alternate scenarios between the years 2010 and 2030.

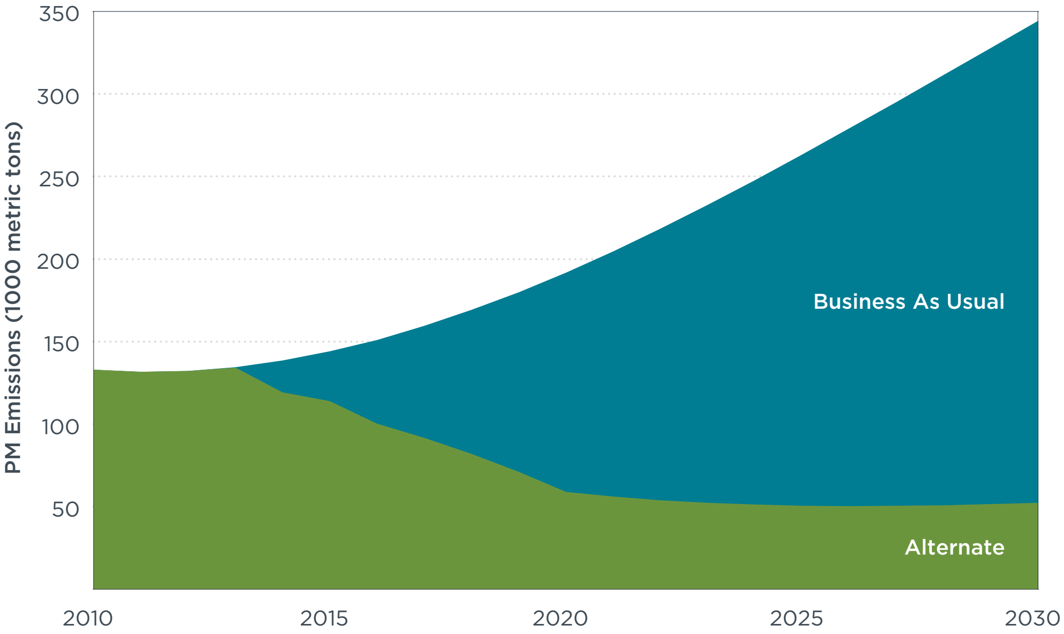

Figure 2: Annual PM_{10} emissions from 2010-2030 under the BAU and Alternate scenarios

The decline in PM emissions envisioned by the Alternate scenario leads to a quantifiable reduction in premature mortality. Using a methodology developed by the WHO, we calculated avoided premature deaths associated with adult (over age 30) cardiopulmonary disease and lung cancer, and child (under age 5) respiratory infections under the Alternate scenario compared to the BAU scenario in India's 337 largest cities[13]. National level PM emissions were converted to $PM_{2.5}$ emissions based on the approximation that the $PM_{2.5}$/PM emission ratio for vehicles is 76%[15]. National emissions were then disaggregated to individual cities based on their population share of the national population. While this method likely underestimates the number of vehicles in most cities, it was the best proxy in the absence of better data. Emissions were converted to ambient concentrations using an intake fraction method [16]. Estimates of avoided deaths in each city were calculated based on changes in ambient concentrations, and were summed to get national aggregates. This is shown in **Figure 3**.

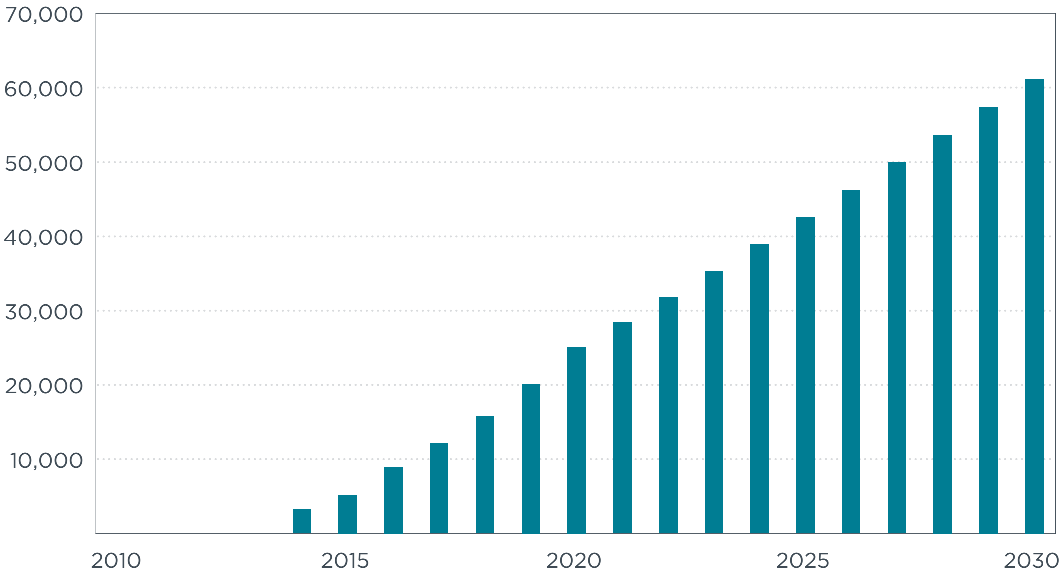

Figure 3: Annual avoided premature deaths under the Alternate scenario versus the BAU scenario

Cumulatively, due to reductions in $PM_{2.5}$ emissions between now and 2030, about 535,000 urban premature deaths can be avoided. This is likely an underestimate. Certainly the number would be higher if impacts on rural populations were evaluated, if years beyond 2030 were modeled, and if pollutants other than $PM_{2.5}$ were taken into consideration.

ECONOMIC BENEFITS

Avoided premature mortality leads to a stronger economy because of increased worker productivity and reduced healthcare costs, among other reasons. These economic benefits can be quantified using the value of statistical life (VSL) method.

To monetize the health benefits of cleaner vehicles and fuels in India, we used a year 2006 VSL value of $1,550,000 (Rs. 7.75 crore)[17]. This value was increased in correlation with predicted increases in annual gross national income (GNI) at purchasing power parity (PPP) in India.

A mortality lag was taken into account to monetize benefits. This was done because the benefits of reduced emissions would likely be seen in years subsequent to the reductions. Therefore, we lagged annual benefits according to the following methodology:

1. 30% of the monetized benefits occur in Year 1.
2. 50% occur in Years 2 through 5.
3. 20% occur in Years 6 through 20.

While a lag was incorporated for valuation of economic benefits, we did not lag our estimates of avoided premature deaths (shown in **Figure 3**). This is because we are estimating that those are the number of lives that could be saved by reducing $PM_{2.5}$ emissions in the years shown, even if the lives are not saved in the same years.

COST-BENEFIT ANALYSIS

Economic benefits were compared with extra costs associated with ULSF production and cleaner vehicles. Per liter cost increases for ULSF production were multiplied by projections for on-road fuel consumption in India. Similarly, clean vehicle costs per vehicle were multiplied by projected vehicle sales.

Figure 4 compares annual costs and benefits under the Alternate scenario between 2010 and 2030. The chart shows that while there are costs associated with clean fuels and vehicles, benefits far outweigh costs. Benefits continue to rise, as vehicle population increases and lower ambient $PM_{2.5}$ concentrations reduce premature mortality. On the other hand, learning and economies of scale stabilize costs in the long-term.

Cumulatively from 2010-2030, fuel costs add up to $19 billion (Rs. 94,000 crore) and vehicle costs add up to $170 billion (Rs. 850,000 crore). These compare to cumulative benefits of $673 billion (Rs. 3,365,000 crore). Subtracting costs from benefits, India stands to gain a net benefit of about $484 billion (Rs. 2,400,000 crore) by 2030 by implementing ULSF nationwide and tightening emission standards as envisioned by the Alternate scenario.

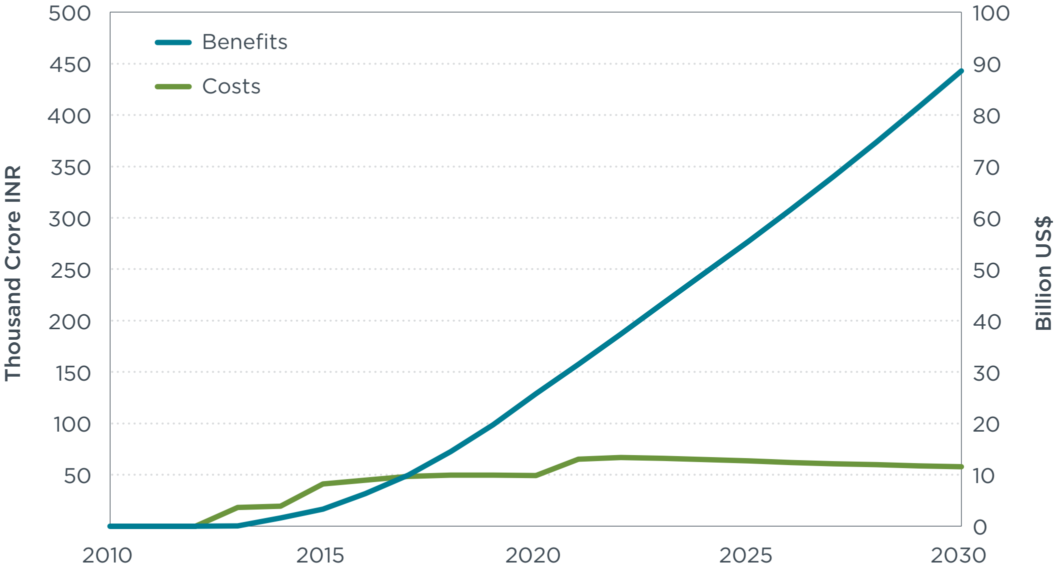

Figure 4: Annual costs and benefits under the Alternate scenario

CONCLUSION

In the long-term, India stands to gain tremendously by implementing ULSF and tighter vehicle emission standards. While the costs of these to the nation's oil and automobile industries will initially require significant investments, the resulting potential reduction in premature mortality due to lower vehicular air pollution, and the corresponding monetized benefits on India's economy, will far outweigh the costs in the long-term.

The first key step here is to implement ULSF nationwide as soon as possible. This will enable the implementation of clean vehicle technologies, which the Indian automobile industry has the capability to produce. On a per liter basis, the costs of implementing

ULSF are not substantial (under 50 paise* per liter). Given that diesel and gasoline prices are around Rs. 50 and Rs. 70 per liter, respectively, adding half a rupee to the price will not be significant. But the government of India needs to give oil companies the flexibility to raise fuel prices to recover the investment costs needed to produce ULSF.

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*Correction 2013.02.13. Original read, in error, "under Rs. 50 per liter."