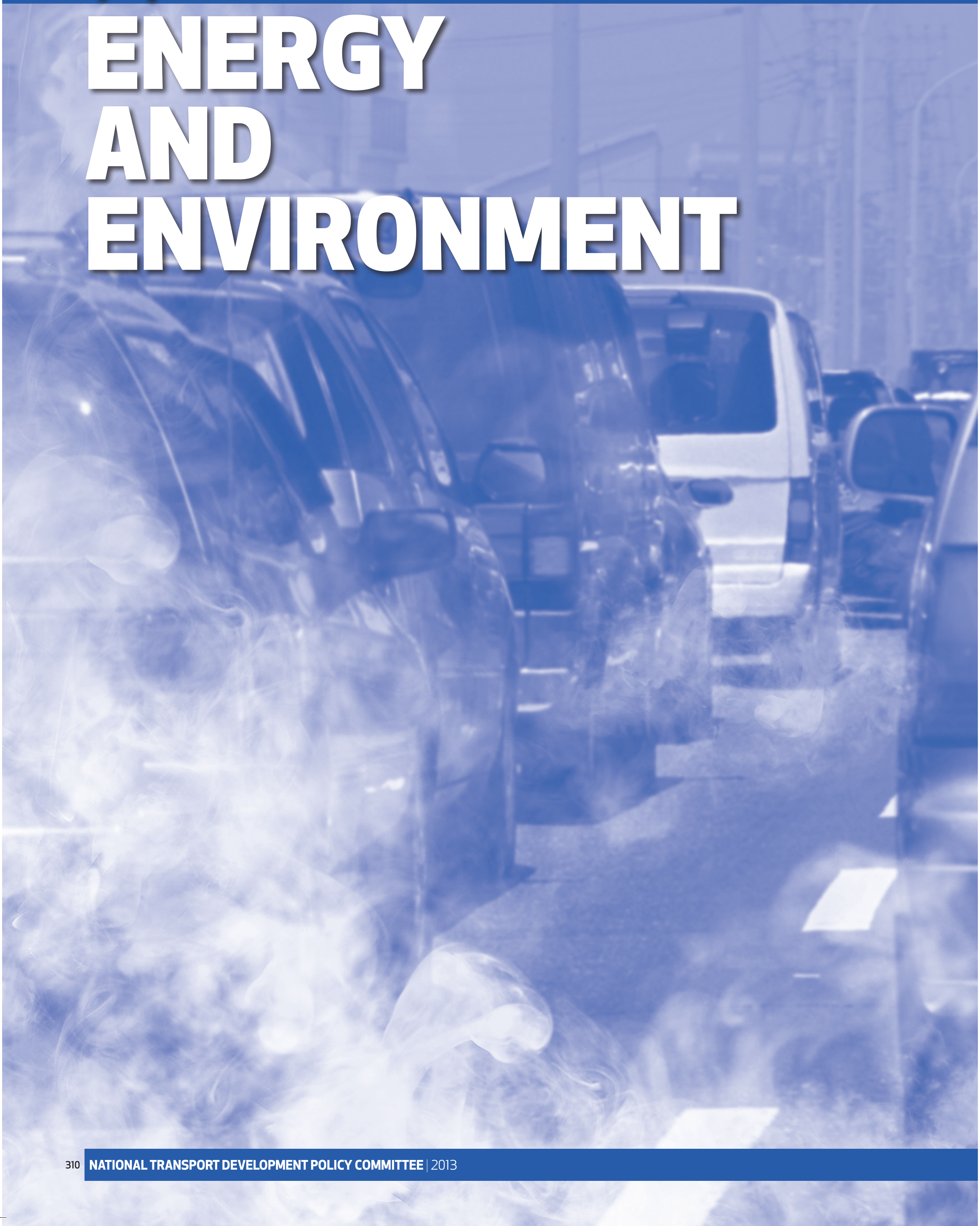
7. ENERGY AND ENVIRONMENT



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7.
ENERGY AND ENVIRONMENT

Vehicle ownership has soared in India over the last two decades. In 1991, according to the Ministry of Road Transport and Highways (MoRTH), the number of vehicles registered in the country was just over 21 million. By 2011, the number had increased to 142 million.

The high growth rate of new vehicle registrations is expected to continue, at least through the remainder of this decade.

The continued growth of the transport sector may be vital for further economic development, but it has exacerbated India's critical air pollution problem: vehicular emissions. Hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_X), particulate matter (PM), and carbon dioxide (CO_2) are a critical issue that has to be tackled on a wartime footing.

In 2011, many Indian cities featured in the World Health Organisation's (WHO) list of the world's 100 most polluted cities. The 2010 Global Burden of Disease (GBD 2010) report listed ambient air pollution as the sixth most important cause of death in South Asia. According to a recent study for six cities—Delhi, Kanpur, Bengaluru, Pune, Chennai, and Mumbai conducted by the Central Pollution Control Board (CPCB), the transport sector is responsible for a majority of NO_X and 30-50 per cent of PM emissions in these cities (Box 7.1).

The problem is widespread. In 2008, the CPCB identified around 70 cities, representing over 80 per cent of cities that were being monitored, that were not complying with the NO_X and PM standards. This was before more stringent air quality standards were brought into effect in 2009. An analysis by the Clean Air Initiative (CAI) Asia of PM concentrations in 130 cities in India also indicated that most of the cities exceeded the national standard, as shown in Figure 7.1. Many of these cities have air pollution levels far above the legal limit, have continuously been in non-compliance for many years, and have no tangible plans to drastically improve air quality in the near future. Increasing vehicular emissions leading to poor air quality have significant negative impacts on public health. Traffic-related air pollution, especially PM and NO_x, has been shown to lead to premature morbidity and mortality. A study supported by the WHO estimated about 154,000 people died in India in 2005 as a result of ambient fine particulate matter ($PM_{2.5}$) alone. This number has most likely increased since.

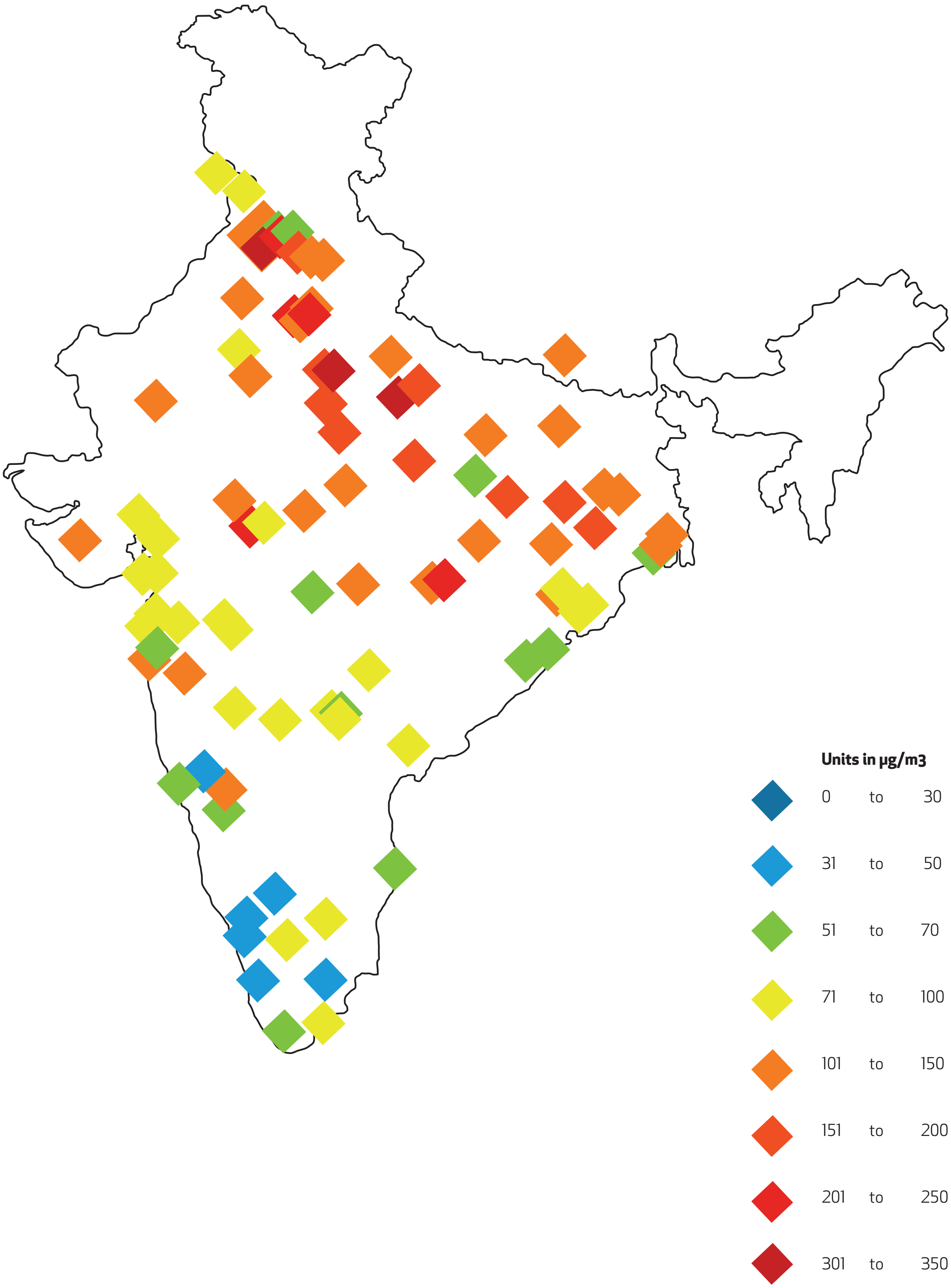
In 2002, the WHO calculated a respiratory disease mortality rate of 58 persons per 100,000 in India. By 2008, this rate had increased to 101 persons per 100,000. A meta-study by the Health Effects Institute (HEI) looked at the effects of air pollutants on human health by analysing numerous studies from around the world. It found 'suggestive' or 'sufficient' evidence that traffic-related air pollution leads to cardiovascular morbidity, asthma incidence and other respiratory illnesses in children, reduced lung function, and all-cause mortality. Studies conducted in India found much of the same results as the HEI meta-study: air pollution is linked to a variety of morbidity and mortality endpoints.

The transport sector accounts for nearly 18 per cent of the total energy consumed in India, second only to the industrial sector. Nearly 98 per cent of the energy needs of transportation are met through petroleum products, and almost half of the total consumption of petroleum products in India occurs on account of transport activities[1]. This demand for energy is expected to grow if no action is taken.

Of the 142 MT CO_2e emissions released by the transport sector in 2007, 87 per cent were on account of road-based vehicular activities[2]. If no action is taken, overall transport CO_2e emissions can come close

1. TERI (2012).
2. Ministry of Environment and Forests (2010).

Figure 7.1
Annual Average PM Concentrations in 137 Indian Cities in 2008



Source: Clean Air Initiative for Asian Cities (CAI-Asia), 2010. "Clean Air Management Profile (CAMP) India: 2010 Edition". CAI-Asia Centre. Pasig City, Philippines.

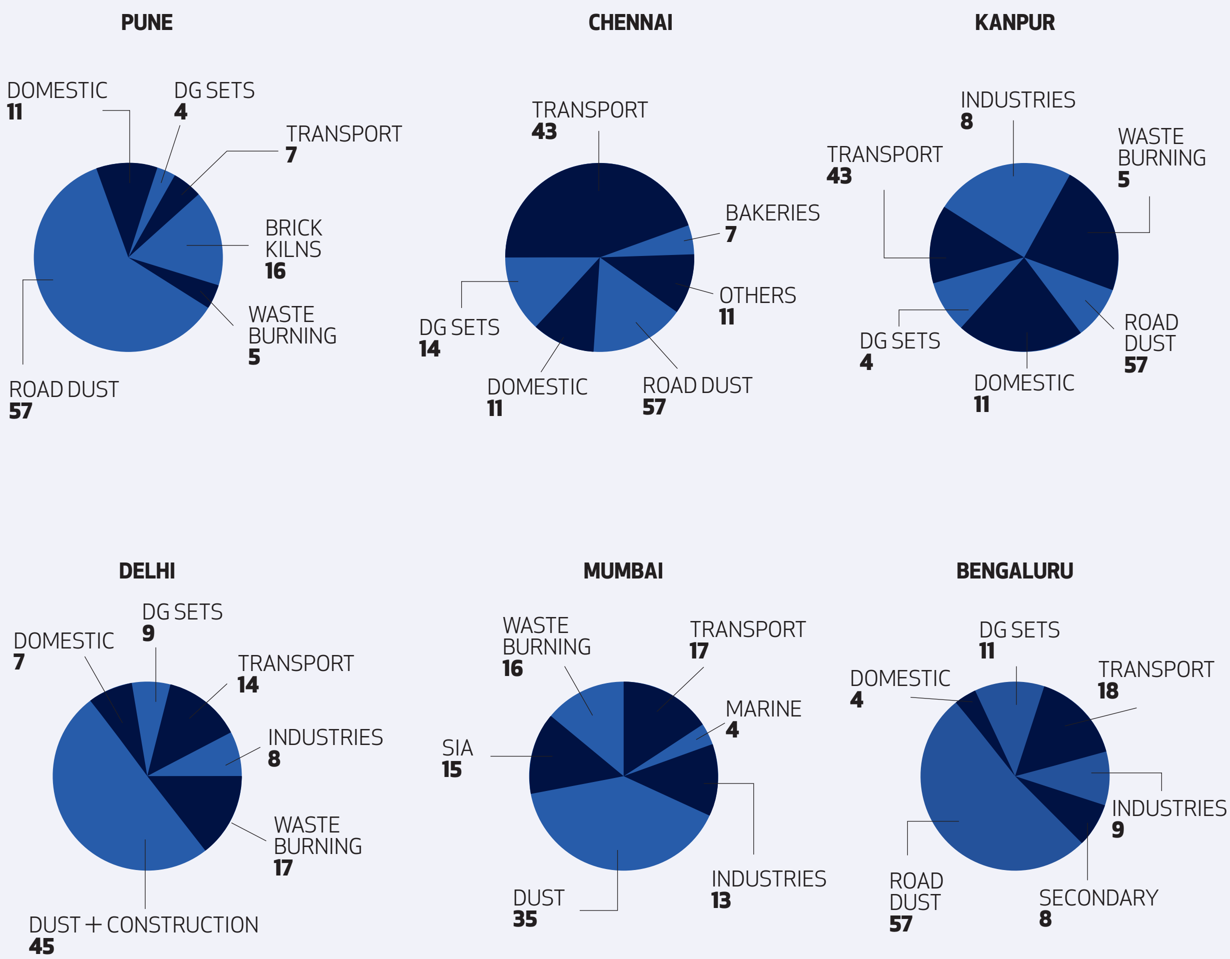
Box 7.1

Transport and Particulate Matter: The CPCB Study

In 2011, the Central Pollution Control Board (CPCB) and the Ministry of Environment and Forests, Government of India, jointly published the results of receptor modelling of particulate pollution in six cities—Pune, Chennai, Kanpur, Delhi, Mumbai, and Bengaluru. The receptor modelling studies are carried out in three steps—collecting samples at representative locations in the city, chemical analysis of the samples to identify the quantities of marker elements for various sources, and statistical mass balance modelling of the results of chemical analysis of the ambient and source samples.

Urban air pollution is a complex issue, fuelled by multiple sources ranging from vehicle exhaust, on-road re-suspended dust due to vehicles, industrial flumes, construction dust, garbage burning, to domestic cooking and heating, and some seasonal sources such as agricultural field residue burning, dust storms and sea salt (for coastal areas). Receptor modelling is one way of apportioning these contributions and this methodology is dependent on the location of the sampling sites. For the six cities, the sampling was carried out at domestic, industrial, and kerbside locations and an average for all samples is presented in the figure below. For total PM emissions (particulate matter with aerodynamic diameter < 10 μm), transport remains an important source—from direct vehicle exhaust emissions and indirect re-suspension of dust due to constant movement of vehicles on the road.

Average Per cent Contributions of Major Sources to Particulate Pollution



Source: CPCB (2011).

Figure 7. 2
Timeline of Implementation of New LDV Standards in Select Countries

<table>
<tr><th colspan="11">LIGHT-DUTY VEHICLE EMISSION STANDARDS SCHEDULE</th></tr>
<tr><th></th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td>India</td><td colspan="5">Bharat II</td><td colspan="5">Bharat III</td></tr>
<tr><td>India - 13 Cities*</td><td colspan="5">Bharat III</td><td colspan="5">Bharat IV</td></tr>
<tr><td>China**</td><td colspan="3">China II</td><td colspan="3">China III</td><td colspan="4">China IV</td></tr>
<tr><td>Europe</td><td colspan="5">Euro 4</td><td colspan="4">Euro 5</td><td>Euro 6</td></tr>
<tr><td>Brazil**</td><td colspan="2">Proconve L3 (Euro 2)</td><td colspan="2">Proconve L4 (Euro 3)</td><td colspan="4">Proconve L5 (Euro 4)</td><td colspan="2">Proconve L6 (Euro 5)</td></tr>
<tr><td>Thailand</td><td colspan="7">Euro 3</td><td colspan="3">Euro 4</td></tr>
<tr><td>Argentina</td><td colspan="2">Euro 2</td><td colspan="2">Euro 3</td><td colspan="6">Euro 4</td></tr>
</table>

Source: NTDPC Research.
Note: *Delhi, Mumbai, Kolkata, Chennai, Bangalore, Surat, Agra, Hyderabad, Pune, Ahmedabad, Kanpur, Lucknow, Solapur
**Select cities have more stringent standards

to 1000 MT by 2030, a fourfold increase from 260 MT in 2010[3].

India requires appropriate measures for urban planning, transport infrastructure development, and stringent standards and enforcement to reduce fuel consumption and emissions to curb this extraordinary growth in transport sector energy consumption and pollutant and greenhouse gas (GHG) emissions,. The current approach to urban planning and infrastructure development, that incentivises vehicle use, will have to change. The latest emissions control technologies that are already available will have to be taken advantage of to leapfrog to tighter emission standards and reduce fuel consumption. Additionally, current emission test cycles will need to be replaced by more stringent ones and in-use emissions compliance programmes will have to be solidified to ensure strict enforcement of regulations.

In many cases, these diverse problems overlap. Solutions for one help solve others. For example, measures to reduce vehicle PM emissions also help reduce Black Carbon (BC) emissions, which is a growing concern. This not only improves air quality and public health, it mitigates global warming. Similarly, many vehicle technologies that reduce pollutant emissions also improve vehicle fuel efficiency.

This chapter takes a holistic look at India's road transport sector's growing energy consumption and emissions, and it highlights the negative effects of these and possible ways to mitigate them.

VEHICULAR AIR POLLUTION IN INDIA

The impetus for vehicle emissions regulations in India began in the 1980s, with laws such as the Air Act, 1981, Environment (Protection) Act, 1986, and Motor Vehicles Act, 1988. In 1985, an expert committee was constituted to determine vehicle emission norms for new vehicles, finalise vehicle testing procedures, and approve laboratories. The committee's recommendations were notified in 1990 and India's first-ever new vehicle emission limits and pollution under control (PUC) programme for in-use vehicles were established.

In the early 1990s, a new committee led by retired Justice K. N. Sakia was appointed under the direction of the Supreme Court with the aim of examining measures to further reduce vehicle emissions in the short- and long-term. The Sakia Committee's recommendations focused on Delhi, but it established precedents that were applicable for the rest of the country.

In 1992, a separate committee constituted by the CPCB and led by Prof. H. B. Mathur recommended fuel quality and emission standards for the rest of the decade. As a result, lead in fuels was gradually phased out, fuel sulphur content was reduced, and emission limits for new vehicles were progressively tightened.

At the turn of the century, a committee led by Dr. R. A. Mashelkar was formed at the request of the Prime Minister. The Mashelkar Auto Fuel Policy Committee called for progressively tighter vehicle emission and fuel quality standards, based mostly on European regulations. The committee also recommended two sets of standards: one with more stringent norms for a few targeted cities, and the other for the remainder of the country. The Committee's recommendations were applicable through the year 2010. In January 2013, the Government of India constituted a new Auto Fuel Policy Committee to recommend vehicle emission standards and fuel quality regulations through 2025.

3. TERI (2009).

Figure 7.3
Timeline of Implementation of New HDV Standards in Select Countries

HEAVY-DUTY VEHICLE EMISSION STANDARDS SCHEDULE										
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
India	Bharat II					Bharat III				
India: 13 Cities*	Bharat III					Bharat IV				
China** China IV	China II		China III						China IV	
Europe	Euro IV			Euro V					Euro VI	
Brazil**	Euro II	Proconve P5 (Euro III)						Proconve P7 (Euro V)		
Thailand	Euro 3							Euro 4		
Argentina	Euro II	Euro III			Euro IV					

Source: NTDPC Research.
Note: *Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Surat, Agra, Hyderabad, Pune, Ahmedabad, Kanpur, Lucknow, Solapur
**Select cities have more stringent standards

CURRENT VEHICLE EMISSION STANDARDS

Light-Duty Vehicles (LDV) India follows the European pattern for LDV emission regulations. Thirteen cities are at the Bharat IV (Euro IV equivalent) level, while the rest of India is at Bharat III. Europe is at Euro V, and plans to move to Euro VI by 2014. This means that new Indian vehicles are not fitted with the most advanced emission reduction technologies, despite these technologies being available to Indian automakers.

India also lags behind Brazil and China, both of which are fast developing countries like India and base emission regulations on the European pattern. China implemented China IV standards nationwide in 2011 with Beijing further ahead at China V. Thailand, too, has moved ahead to Euro IV nationwide. Brazilian LDV emission standards were behind Indian standards in 2005, but since then, Brazil has jumped well ahead. Similarly, Argentina moved to Euro IV in 2009. Figure 7.2 shows the timeline of implementation of new LDV standards in select countries.

HEAVY-DUTY VEHICLES (HDV)

For HDV regulations too, India follows the European pattern. The 13 cities with Bharat IV LDV standards also mandate Bharat IV HDV standards while the rest of country follows Bharat III.

India lags behind Europe, China, and Brazil in HDV emission standards. Euro VI emission standards, which require diesel particulate filters, went in to effect in January 2013 for new engines and in January 2014 for all engines sold across Europe. China implemented China IV HDV standards from July 2013, while Beijing implemented China V standards from February 2013 onwards. Thailand implemented Euro IV standards in 2012. Brazil mandated Euro V equivalent standards for HDVs at the beginning of 2012, leapfrogging over Euro IV. Argentina moved to Euro IV in 2009. Figure 7.3 shows the timeline of implementation of new HDV standards in select countries.

TWO- AND THREE-WHEELERS

India does not follow the European regulatory pattern for two- and three-wheelers. Instead, it uses the India Drive Cycle (IDC) to test their emission, and set emission limits accordingly. Currently, Bharat III standards are mandated nationwide for all two- and three-wheelers.

Since India does not follow European regulations for two- and three-wheelers, established Bharat IV and higher regulations do not apply to this class of vehicles. India will have to develop new emission limits to tighten standards under the IDC. Europe, which is currently at Euro III for two- and three-wheelers, has already planned to go to Euro VI by 2020. A recent expert report detailed pathways for similar action in India.

NON-ROAD VEHICLES

India first regulated non-road vehicles in 1999, with the implementation of emission standards for agricultural tractors. These were tightened over the next decade. It then implemented separate standards for construction equipment in 2007. Since then, India has worked to unify emission limits for both categories, although a few differences remain.

TEST CYCLES

India currently uses European test cycles to determine emissions from LDVs and HDVs. For two- and three-wheelers, it uses its own unique test cycle. For non-road vehicles, it follows US test cycles and procedures. In these test cycles, the emissions are often quite different from those under real-world conditions. While it is impossible to create test cycles that represent real-world conditions with perfect accu-

Figure 7. 4
Timeline of Gasoline Sulphur Content Reduction in Select Countries

<table>
<tr><th></th><th colspan="10">GASOLINE SULPHUR CONTENT SCHEDULE (PPM)</th></tr>
<tr><th></th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td>India</td><td colspan="5">500</td><td colspan="5">150</td></tr>
<tr><td>India - 2010 Cities**</td><td colspan="5">150</td><td colspan="5">50</td></tr>
<tr><td>India - 2012 Cities*</td><td colspan="5">500</td><td colspan="2">150</td><td colspan="3">50</td></tr>
<tr><td>China§</td><td colspan="5">500</td><td colspan="5">150</td></tr>
<tr><td>Brazil§</td><td colspan="9">1,000</td><td>50</td></tr>
<tr><td>Europe</td><td colspan="4">50</td><td colspan="6">10</td></tr>
<tr><td>Japan</td><td colspan="3">50</td><td colspan="7">10</td></tr>
<tr><td>Thailand</td><td colspan="7">150</td><td colspan="3">50</td></tr>
</table>

Source: NTDPC Research.
Note: *Puducherry, Mathura, Vapi, Jamnagar, Ankleshwar, Hissar, Bharatpur, Daman, Diu, Silvasa, Unnao, Raebareli, and Aligarh
**Delhi, Mumbai, Kolkata, Chennai, Bangalore, Surat, Agra, Hyderabad, Pune, Ahmedabad, Kanpur, Lucknow, Solapur
§ - Select cities have lower sulphur content

racy, India has been a party to the development of world-s-test cycles, along with other countries. These include a much wider variety of driving conditions than current Indian test cycles. Therefore, they are much more comprehensive in their requirements and make it harder to create a vehicle that 'beats' the test cycle but emits much more in reality.

Europe already has plans to replace its test cycles with world-harmonised test cycles for all vehicle types. India has taken the positive step of allowing the world-harmonised motorcycle test cycle (WMTC) to be used in place of the IDC for two-wheeler testing, but it has yet to do the same for other vehicle types.

EVAPORATIVE EMISSION

As exhaust emissions fall, evaporative emissions become increasingly relevant. Anticipating a move to Bharat VI and beyond in the future, India can begin to establish evaporative emissions now.

Apart from evaporative emissions from vehicles, fumes emitted during refuelling are harmful to human health and the environment. There are a number of vapour recovery systems that can minimise them. India should assess these options.

HISTORY OF FUEL QUALITY STANDARDS

For progressively tighter vehicle emission standards to be implemented, it is important to set fuel quality standards that enable clean vehicle technologies to function optimally.

An important achievement has been the removal of lead from all fuels in the country since the year 2000. After lead, sulphur content is the most important element that affects vehicle emissions. Fuel sulphur inhibits the proper functioning of many emission control systems. India has successfully reduced sulphur content in all its fuels over the last 20 years. Nevertheless, sulphur levels remain higher than what is necessary for the latest clean vehicle technologies to be implemented effectively.

There are other fuel quality parameters too that affect emissions, albeit less significantly. India has made important progress in improving fuel quality on all these parameters.

CURRENT FUEL QUALITY STANDARDS

India's current fuel quality standards took effect in 2010, at the same time as the implementation of the latest vehicle emission standards. Bharat IV fuel quality standards were mandated in 13 cities. Since then, 13 more cities have started receiving Bharat IV fuel. A total of 63 cities should receive Bharat IV fuel by 2015.

The current dual fuel status leads to a situation where Bharat IV vehicles, designed to operate on lower sulphur fuel, refuel in Bharat III areas. This is particularly problematic for commercial vehicles, which often do not operate in just one metropolitan area. Since many emission control technologies require low sulphur fuel to function correctly, Bharat IV vehicles refuelling on Bharat III fuel are likely to emit more than they are designed to.

GASOLINE FUEL QUALITY STANDARDS

India has made important progress in reducing gasoline sulphur content, roughly consistent with fuel sulphur content in China over the last few years. But it yet remains well behind international best practices. Europe and Japan have mandated a maximum sulphur content of 10 ppm in gasoline, and Brazil plans to leapfrog to 50 ppm sulphur gasoline by 2014. Thailand introduced 50 ppm gasoline in 2012. Figure 7.4 shows the timeline of gasoline sulphur content reduction in India and other countries.

DIESEL FUEL QUALITY STANDARDS

As with gasoline, India has significantly reduced the sulphur content in diesel over the last two dec-

Figure 7. 5

Timeline of Diesel Sulphur Content Reduction in Select Countries

<table>
<tr><th colspan="11">DIESEL SULPHUR CONTENT SCHEDULE (PPM)</th></tr>
<tr><th></th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td>India</td><td colspan="5">500</td><td colspan="5">350</td></tr>
<tr><td>India - 2010 Cities**</td><td colspan="5">350</td><td colspan="5">50</td></tr>
<tr><td>India - 2012 Cities*</td><td colspan="5">500</td><td colspan="2">350</td><td colspan="3">50</td></tr>
<tr><td>China§</td><td colspan="7">2,000</td><td colspan="3">350</td></tr>
<tr><td>Brazil§</td><td colspan="4">2,000</td><td>1,800</td><td colspan="4">1,800-500[1]</td><td>500</td></tr>
<tr><td>Europe</td><td colspan="4">50</td><td colspan="6">10</td></tr>
<tr><td>Japan</td><td colspan="2">50</td><td colspan="8">10</td></tr>
<tr><td>Thailand</td><td colspan="7">350</td><td colspan="3">50</td></tr>
</table>

Source: NTDPC Research.
Note: *Puducherry, Mathura, Vapi, Jamnagar, Ankleshwar, Hissar, Bharatpur, Daman, Diu, Silvasa, Unnao, Raebareli, and Aligarh
**Delhi, Mumbai, Kolkata, Chennai, Bangalore, Surat, Agra, Hyderabad, Pune, Ahmedabad, Kanpur, Lucknow, Solapur
1 - Transitional: 1800 ppm will gradually be substituted by 500 ppm
§ - Select cities have lower sulphur content (10-50 ppm) to enable Euro V equivalent trucks and buses

ades. Despite this, diesel sulphur content remains higher than gasoline sulphur content in most of the country, and well below international best practices. Europe and Japan have mandated a maximum of 10 ppm sulphur in diesel. Mexico is in the process of implementing 15 ppm sulphur. Thailand implemented 50 ppm diesel nationwide in 2012. Figure 7.5 shows the timeline of diesel sulphur content reduction in India and other countries.

FUTURE VEHICLE EMISSION & FUEL QUALITY STANDARDS

Since 2010, there has been no real initiative in India to move to more stringent standards, or to expand Bharat IV to cover the entire country. This means India will continue to lag behind international best practices, and the gap will only widen as other countries take action while India does not.

The Mashelkar Committee had recommended in 2003 that an Auto Fuel Policy Committee be formed every five years to review progress and keep abreast of international regulatory and technology developments. The Government of India constituted a new Auto Fuel Policy Committee in January 2013 finally to recommend vehicle emission standards and fuel quality regulations through 2025.

CURRENT COMPLIANCE & ENFORCEMENT MECHANISMS

In any country, set standards are only as good as the compliance and enforcement mechanisms. In India, there are many laws and legal precedents that establish mechanisms for the enforcement of vehicle emission and fuel quality standards. A number of government ministries and agencies work on these issues.

MoRTH is the nodal ministry for vehicle emission regulations, collaborating with other ministries and agencies to carry out its duties.

Compliance and enforcement of vehicle emission regulations are separate for new vehicles and in-use vehicles. New vehicles undergo Type Approval (TA) and Conformity Of Production (COP) testing to ensure they meet set standards. These are usually conducted by certified testing agencies. In-use vehicles undergo PUC checks. Vehicle owners are responsible for taking their vehicles to local certified centres for these tests.

But TA and COP are not linked with PUC. The former two are national programmes that rely on new vehicle standards. PUC enforcement is done at the local or state level, and it relies on separate standards uncoupled from the vehicle's original emission standards. India does not have a national in-use testing programme that looks at a vehicle's original emission standards and set deterioration rates.

Another problem is that responsibility for compliance and enforcement is splintered. The MoRTH is ultimately responsible for vehicle compliance issues, but the primary vehicle testing agencies it relies on for this fall under the aegis of the Ministry of Heavy Industries (MoHIPE).

The MoHIPE only partially funds these agencies. They have to rely on automobile companies, the very companies they are regulating, for much of their funding. In 2003, the Mashelkar Committee had recommended the creation of a single, government-funded agency responsible for all vehicle emission and fuel quality issues, including compliance and enforcement. Unfortunately, this recommendation was not adopted by the government.

Table 7.1
Estimated On-Road Vehicular Population in India in 2030

STUDY	ESTIMATED ON-ROAD VEHICLE POPULATION IN 2030
ICCT (2012)	430 Million
TERI (2009)	315 Million
Guttikunda and Jawahar (2012)	426 Million
ADB (2006)	373 Million*

* For 2035

Officially, fuel quality regulations are handled by the Ministry of Petroleum & Natural Gas (MoPNG). In reality, it is usually managed by oil companies, which test fuel quality at various stages of production and distribution. While representatives from the MoPNG are required by law to be present at refineries and oil depots to sign off on every batch of fuel, there is little evidence that this actually happens. Fuel transporters are required to have permits issued by state governments, up-to-date lists of the retailers they supply, and quantities of fuels supplied to them.

But again, there is little evidence that this is done properly. A 2006 study by the Indian Institute of Management (IIM) Ahmedabad found that the reporting and recordkeeping on the part of fuel transporters was sloppy at best. Little was being done to ensure that trucks were going to their assigned destinations. Tracking each supply truck was not deemed feasible. Exacerbating the situation, corruption among transporters and those responsible for enforcing rules was high, especially among lower level employees.

Lax enforcement, corruption and government subsidies for certain fuels over others gives rise to fuel adulteration, in which cheaper fuels, such as diesel and kerosene, are mixed with more expensive fuels, such as petrol. Both the IIM Ahmedabad study and an earlier study by the Centre for Science and Environment (CSE) found adulteration to be a problem in many parts of India. A special anti-adulteration cell within the MoPNG was set up in 2001 to specifically tackle this issue, but it itself was laden with corruption and shut down in 2004. Another result of inadequate government vigilance of fuel quality compliance is that independent fuel testing laboratories, such as one established in Noida, are not utilised to their full potential. These labs do not have the authority to obtain samples themselves, nor to administer punishment to oil companies, fuel transporters, or retail outlets for violations of standards.

FUTURE OUTLOOK

India has taken a number of positive steps to reduce vehicle emissions over the last two decades. Per vehicle emission of the four regulated pollutants (CO, HC, NO_x, and PM) has fallen. Total vehicle emission of PM have also reduced over the last decade and total NO_x emission growth has slowed. But vehicle ownership in India is expected to continue to rise at a high rate. If no further action is taken to reduce per vehicle emissions, the benefits of past actions will be erased.

VEHICLE EMISSIONS

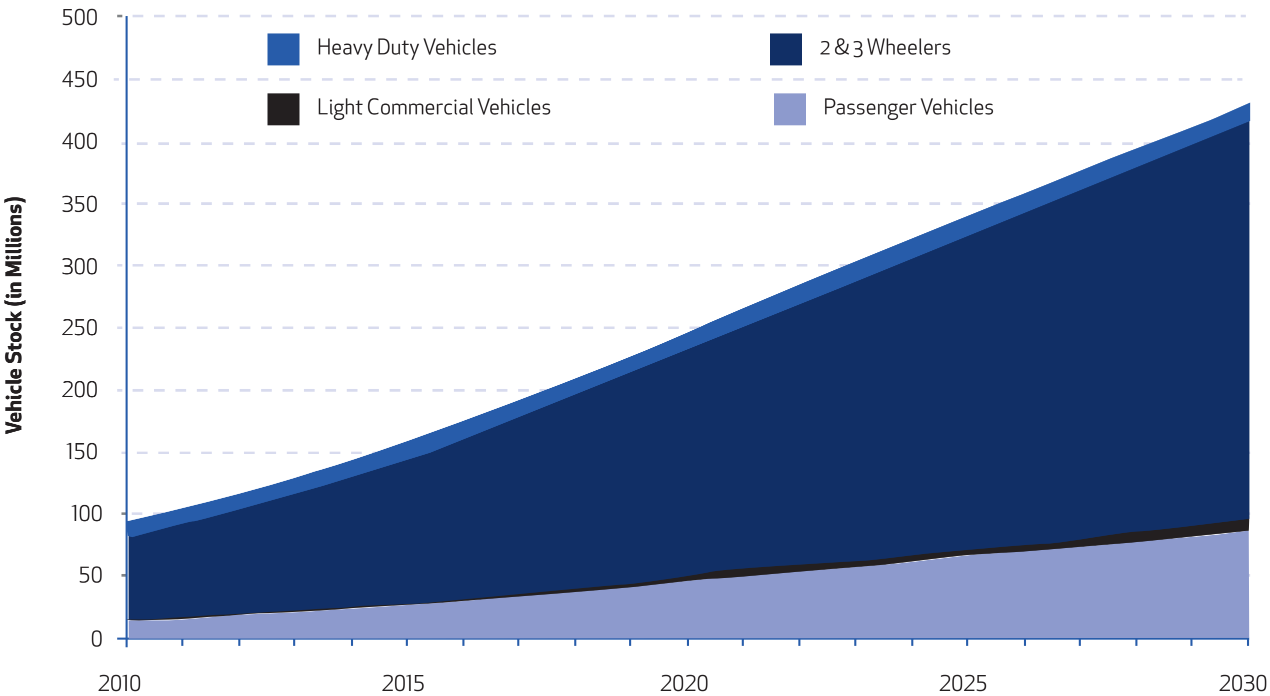
The Society of Indian Automobile Manufacturers (SIAM) estimates passenger car sales in India will be close to 5 million vehicles by 2020. A study by the University of Michigan had even higher projections of 7.7 million.

A study by the United Nations (UN) predicted India's total highway vehicle population to be between 206 and 309 million by 2040. Various estimates are presented in Table 7.1. Most of these studies indicate about a five to six times increase in two-wheeler and car population by 2030. Figure 7.6 shows the ICCT's projections of vehicle population breakdown by vehicle type through 2030.

Several estimates show that if no further regulatory action is taken, the trend of declining vehicle PM emission will reverse in the near future. NO_x emission will also increase at a rate faster than they are today. Figures 7.7 and 7.8 show annual PM and NO_x emission, respectively, by vehicle type between 2000 and 2030 under a business-as-usual (BAU) scenario, which assumes current policies and trends will continue. Box 7.2 gives the spatial distribution of emission concentrations in 2010 and 2030, and indicates the regions in the country that are going to be affected the most by vehicular air pollution.

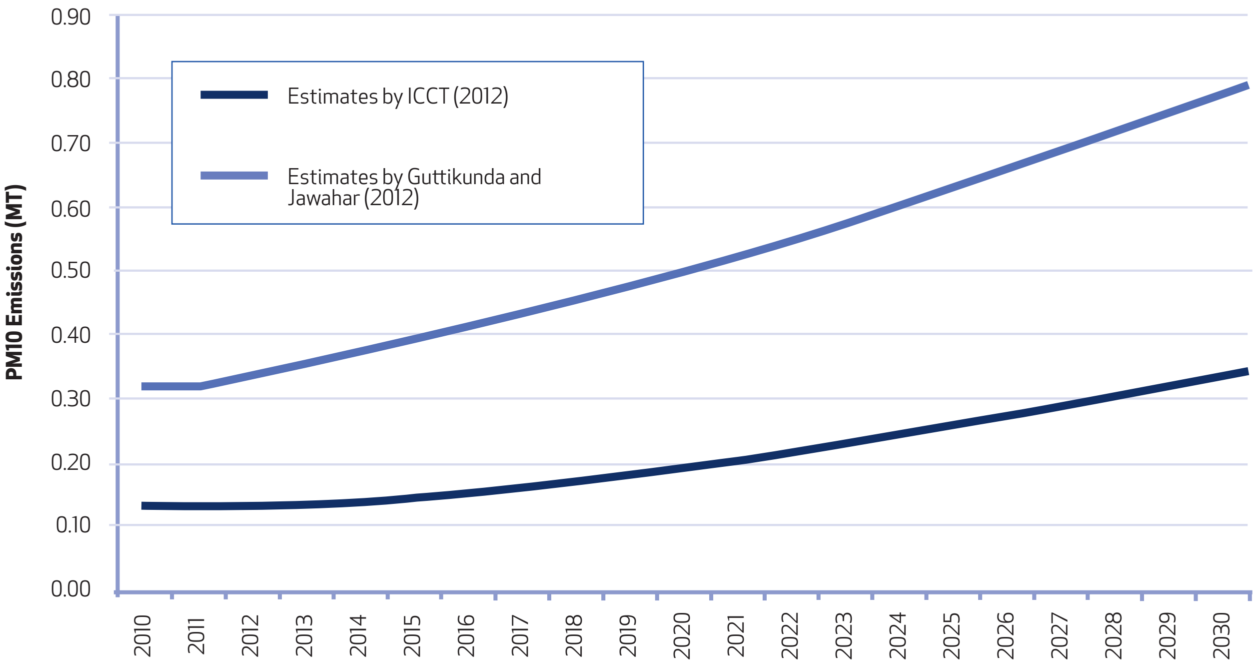
Of the different types of vehicle emissions, NO_x and PM are especially problematic in India. The CPCB recently identified over 70 cities that do not meet national ambient air quality standards (NAAQS) for NO_x and PM. In almost all these cities, vehicles are an important source of pollution. Emission could continue to grow well beyond 2030 if per vehicle emission is not mitigated significantly. The harmful effects of vehicle emission will take a toll on air quality and public health in India, as well as negatively impact global warming. To model what is possible in India, a few studies have developed alternate scenarios which envision tighter vehicle emission and fuel

Figure 7.6
ICCT Projections of Vehicle Population Breakdown by Vehicle Type in India Through 2030



Source: ICCT (2011).

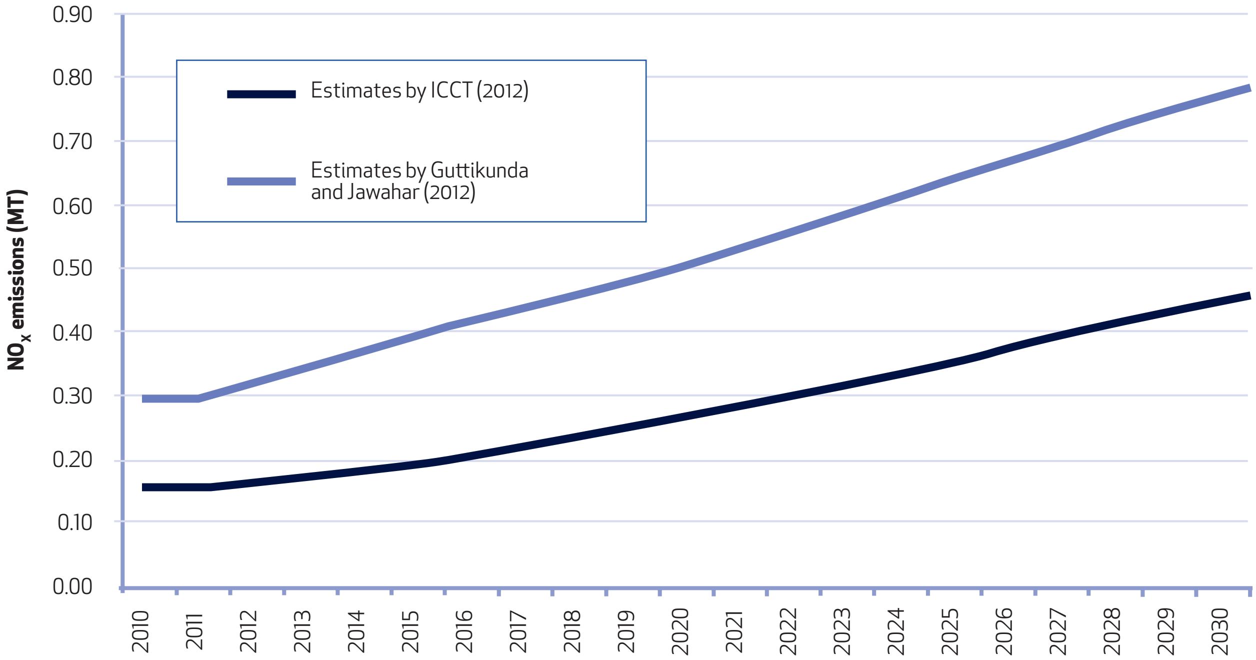
Figure 7.7
Annual PM Emission by Vehicle Type Between 2000 and 2030



Source: ICCT (2011).

quality standards, better compliance and enforcement, and a shift away from conventional fuels. Table 7.2 shows the assumptions made under the BAU and Alternate Scenario in the study carried out by ICCT in 2012. The changes envisioned in the Alternate Scenario are expected to lead to reductions in all vehicular emission, particularly problematic NO_x and PM. Figures 7.9 and 7.10 show annual vehicle NO_x and PM emission between 2010 and 2030.

Figure 7.8
Annual NO_X Emission by Vehicle Type Between 2000 and 2030

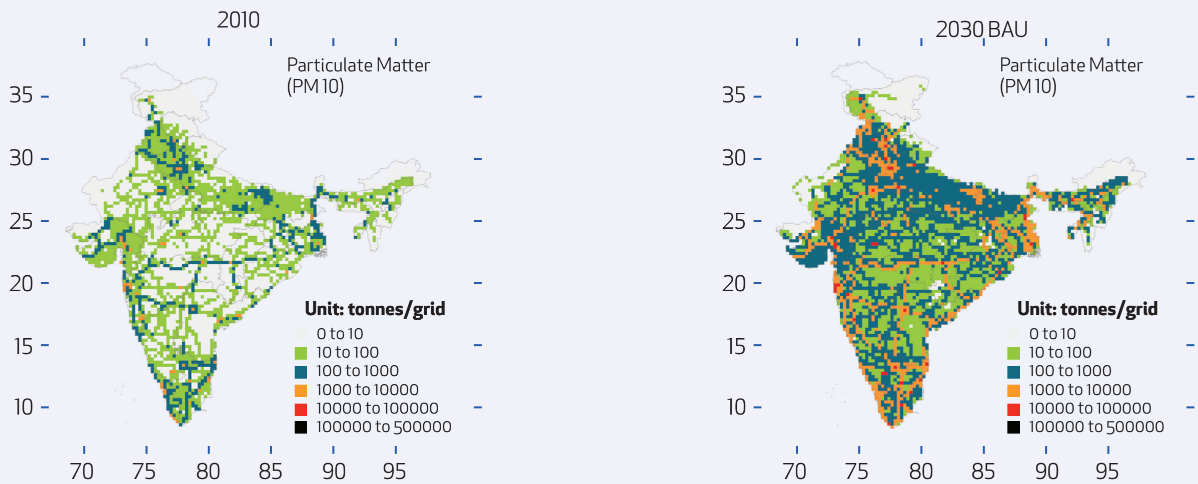


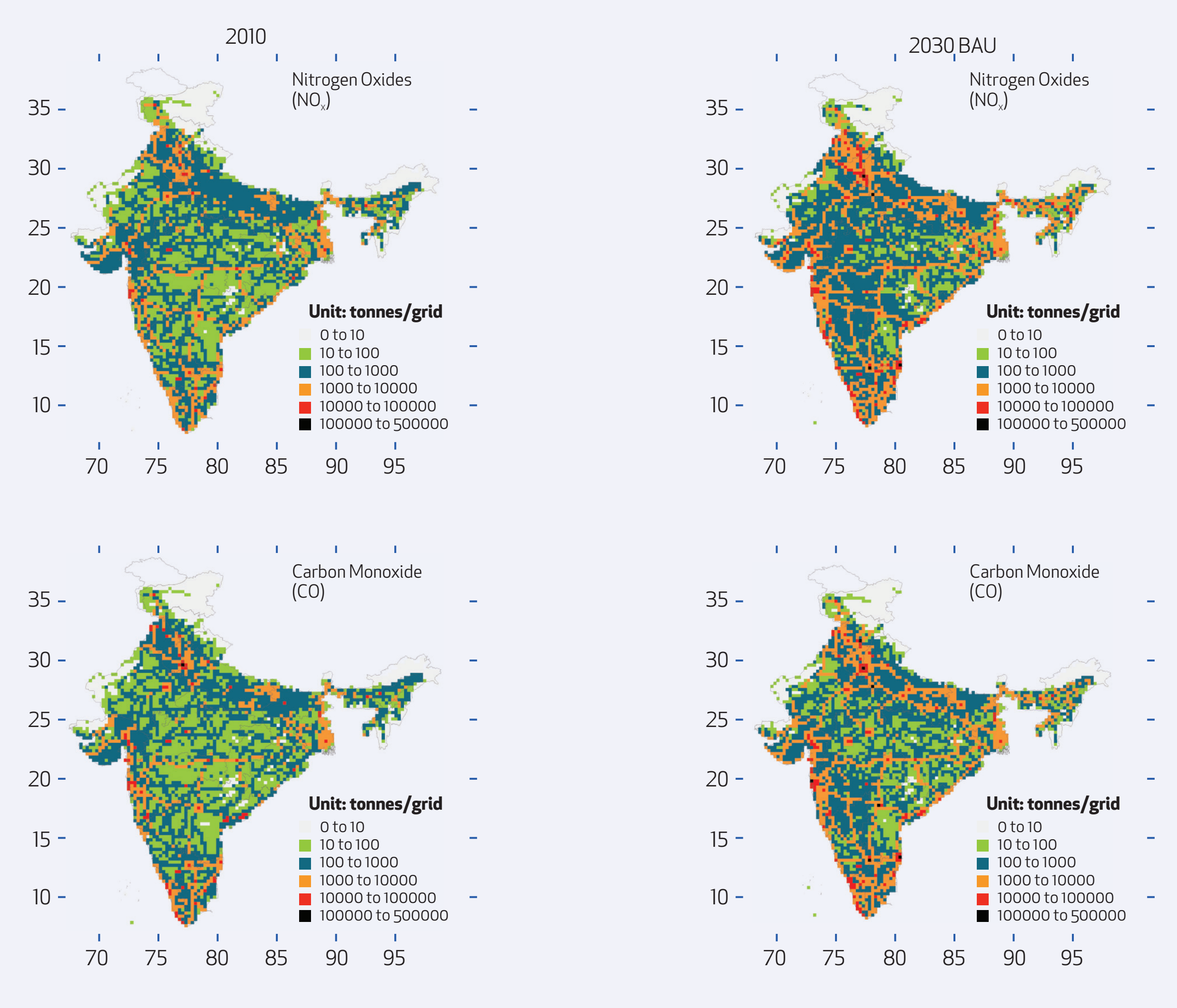
Box 7.2
Gridded Emission Inventory at Spatial Resolution of 0.25° Resolution

Total emissions by state and by city for 2010 and 2030, under the business-as-usual scenarios are spatially gridded to a resolution of 0.25° (approximately 25 km), covering an area between 67°E and 99°E in longitude and 7°N and 39°N in latitude. While the total emission fields provide information and distinguish between high and low emitting states and cities, a gridded emission field is useful in distinguishing between hotspots such as cities and green spots such as agricultural, forest, and desert areas. The intensity of the emissions in 2030 and beyond is expected to increase around urban centres, due to growing passenger travel demand, and along highways, due to growing freight movement between cities. Compared to PM and SO_2, NO_X and CO are emitted in larger quantities by vehicles.

The layers of information utilised for modelling these emissions include (a) gridded population, (b) gridded road density maps for highways, trunk roads, and arterial roads (inter and intra city), (c) activity maps like ports and airports, which are hot spots of freight movement, (d) urban centre locations, which are hot spots for passenger travel, (e) land use maps to distinguish between populated, agricultural, mining, and forest areas.

Gridded Emission Inventory at Spatial Resolution of 0.25° Resolution





Source: Guttikunda and Jawahar (2012).

In addition to the regulatory measures envisioned by the Alternate Scenario, reductions in NOx and PM emission can be enhanced by strong urban planning interventions. Aggressive urban public transport and non-motorised transport (NMT) policies can be disincentives for using personal vehicles (Figure 7.11, Guttikunda and Jawahar, 2012).

HEALTH EFFECTS

The reductions in emissions, especially those of PM, will have tangible effects on public health. A study by Guttikunda and Jawahar estimate that premature mortality can be reduced by almost half in the most aggressive scenario that envisages stringent regulations, that takes advantage of improvements in vehicle technology and fuel quality, in addition to promoting sustainable urban public transport policies[4] (Figure 7.12). Annex 1 to this chapter explains the methodology adopted by Guttikunda and Jawahar (2012) to estimate the health impact of vehicular pollution under two scenarios, as illustrated in Figure 7.12.

Another health impact assessment model developed by ICCT (model based on WHO health impact studies) estimates avoided premature deaths in cities from reduced vehicular $PM_{2.5}$ emission in cities, and the resulting economic benefits. Figure 7.13 shows annual avoided premature deaths in India's 337 largest cities from 2010 to 2030, as per ICCT's model. This is based on vehicle $PM_{2.5}$ emission reduction under the Alternate Scenario compared to the BAU scenario. It is estimated that from now through 2030, a total of almost 280,000 premature deaths can be avoided in India from reducing urban vehicle $PM_{2.5}$ emission alone. There would be further benefits of reduced NO_X and HC emission, as well as benefits in extra-urban areas not quantified here.

COSTS & BENEFITS

COSTS

The costs and benefits of implementing clean vehicle and clean fuel policies can be weighed against each other. Costs include investments needed to upgrade refineries to produce cleaner fuel, increased operating costs required to lower fuel sulphur levels, and

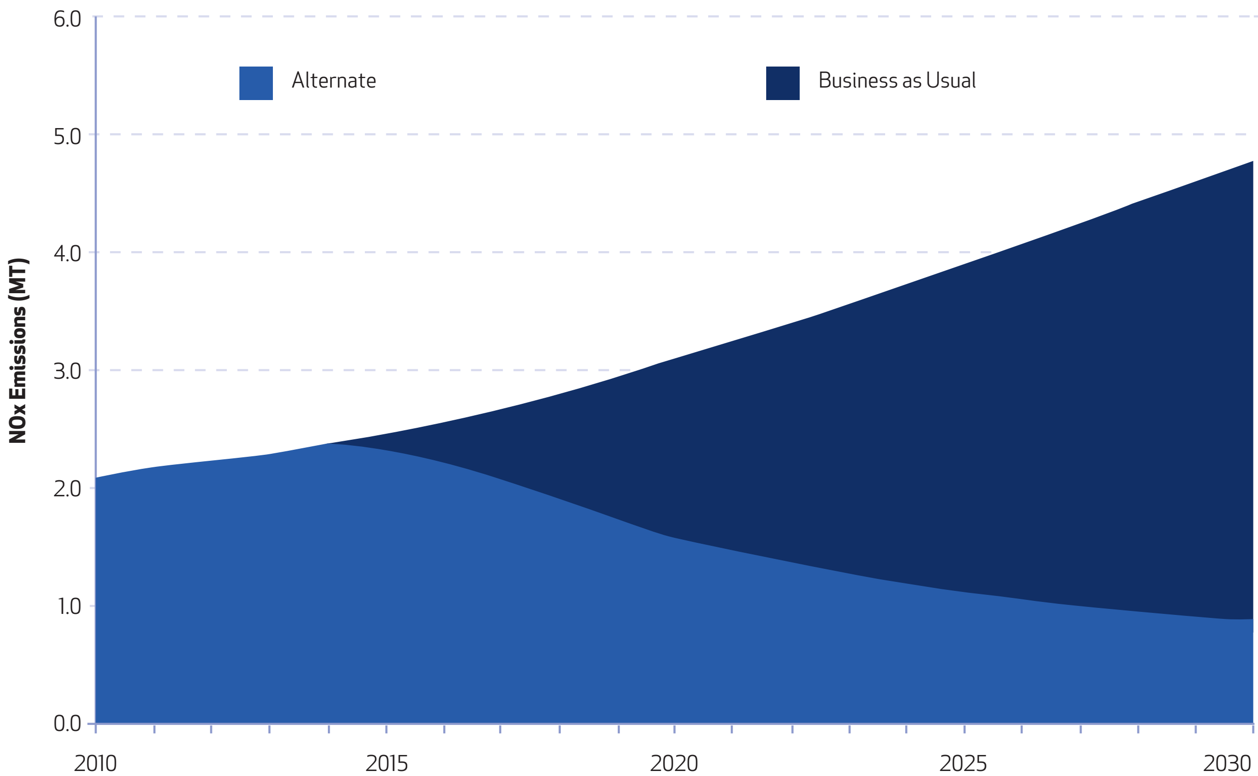
4. Gittikunda and Jawahar (2012).

Table 7.2
Assumptions Under the BAU and Alternate Scenarios in ICCT (2012)

SCENARIO	EMISSION STANDARDS	FUEL STANDARDS	ENFORCEMENT & COMPLIANCE[a]	CHANGE IN FUEL TYPE[b]
BAU	Bharat IV in 13 cities, Bharat III in rest of India	Bharat IV in 26 cities (50 ppm sulfur), Bharat III in rest of India (350 ppm sulfur)	15 per cent of vehicle fleet are gross emitters	50 per cent of new passenger car sales diesel by 2020; 60% by 2030
ALTERNATE	Bharat V by 2015, Bharat VI by 2017, and Tier 3 by 2020 for all vehicles	Low-sulfur fuel (50 ppm) nationwide by 2015; ultra-low sulfur fuel (10 ppm) nationwide by 2017	By 2020, only 3 per cent of vehicle fleet are gross emitters	15 per cent of LDV sales are CNG and 10 per cent LPG by 2030; 75 per cent of bus sales are CNG by 2030; 50per cent of 3-wheeler sales are CNG by 2030

Source: ICCT (2012).
Note: a – Gross polluters are defined as vehicles where emission controls are non-functional
b – CNG and LPG fuel share assumed to come at the expense of diesel
BAU-Business as Usual

Figure 7. 9
Annual NO_x Emission Between 2010 and 2030



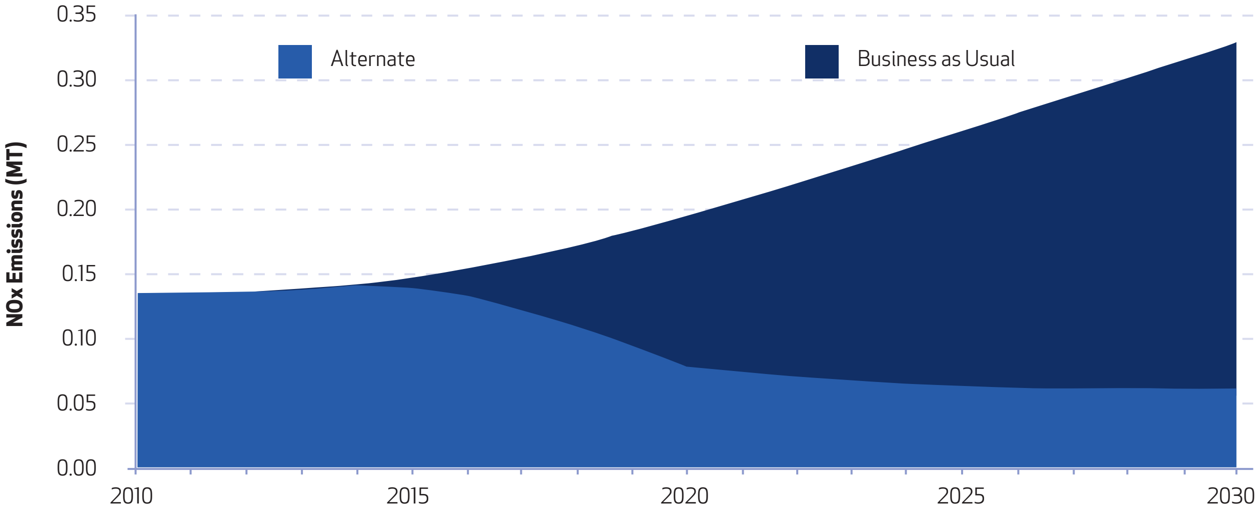
Source: ICCT (2012).

vehicle technology costs needed to reduce emissions from vehicles. Benefits are measured by monetising avoided premature deaths.

The first important study looking at costs to produce ultra-low sulphur fuels (ULSF–fuels with <10 ppm sulphur) in India was carried out by Enstrat International for the Asian Development Bank (ADB). The 2003 study concluded it would take about $445 million (Rs 22,250 million) in capital investments to produce ULSF. The increase in per litre fuel cost was estimated to be 2.80-3.15¢ (Rs 1.40-1.58). This was at a time when gasoline and diesel sulphur content were above 1000 ppm and 2500 ppm, respectively.

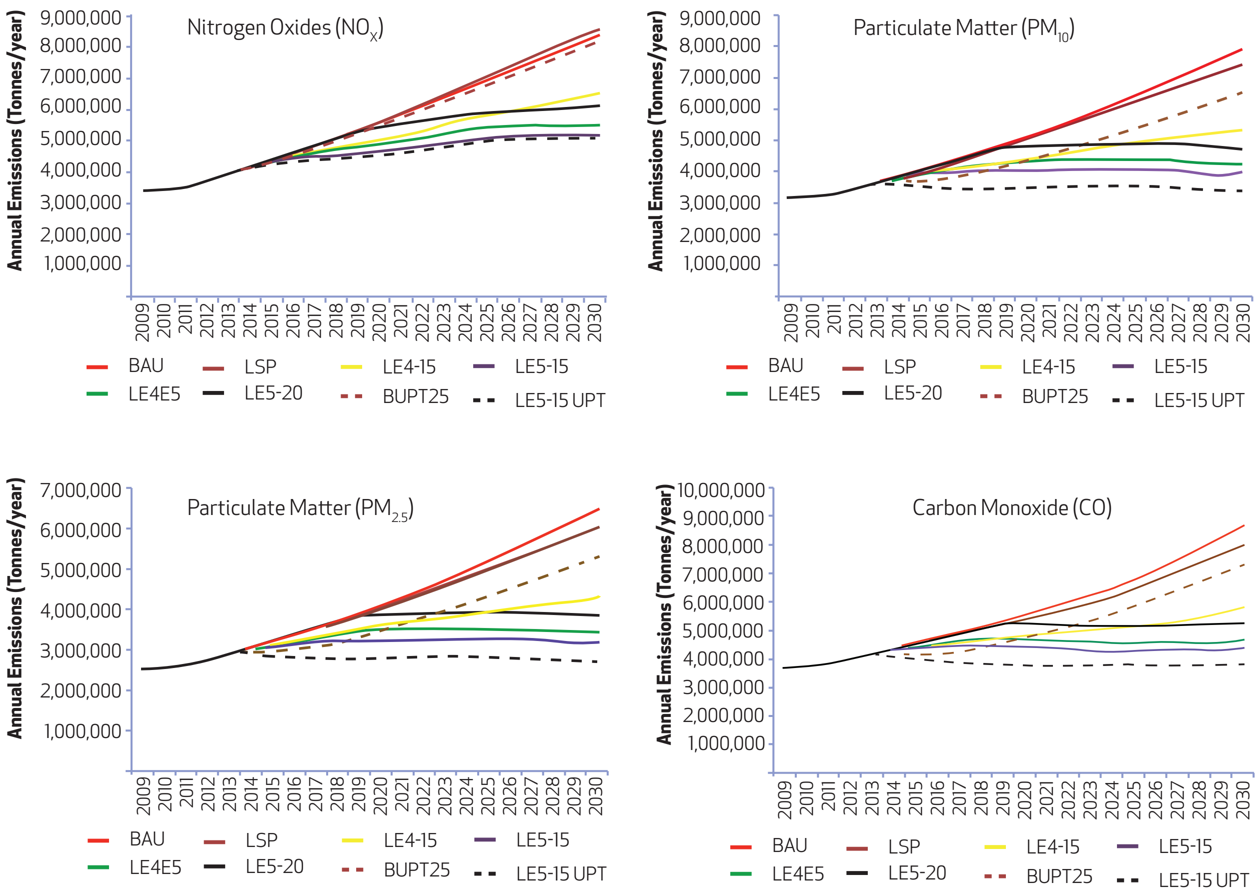
A more recent study by Hart Energy and Math Pro looked at what these costs would be today. This study took into account new refineries not accounted for in the Enstrat study, new technologies not well understood a decade ago, and updated estimates of fuel production and consumption in India. Total investments to produce ULSF in India were estimated to be $4.16 billion (Rs 208 Billion, assuming $1=Rs 50). Combining this with increased operating costs and annualising investments, the extra per litre cost of producing ultra-low

Figure 7.10
Annual PM Emission Between 2010 and 2030



Source: ICCT (2012).

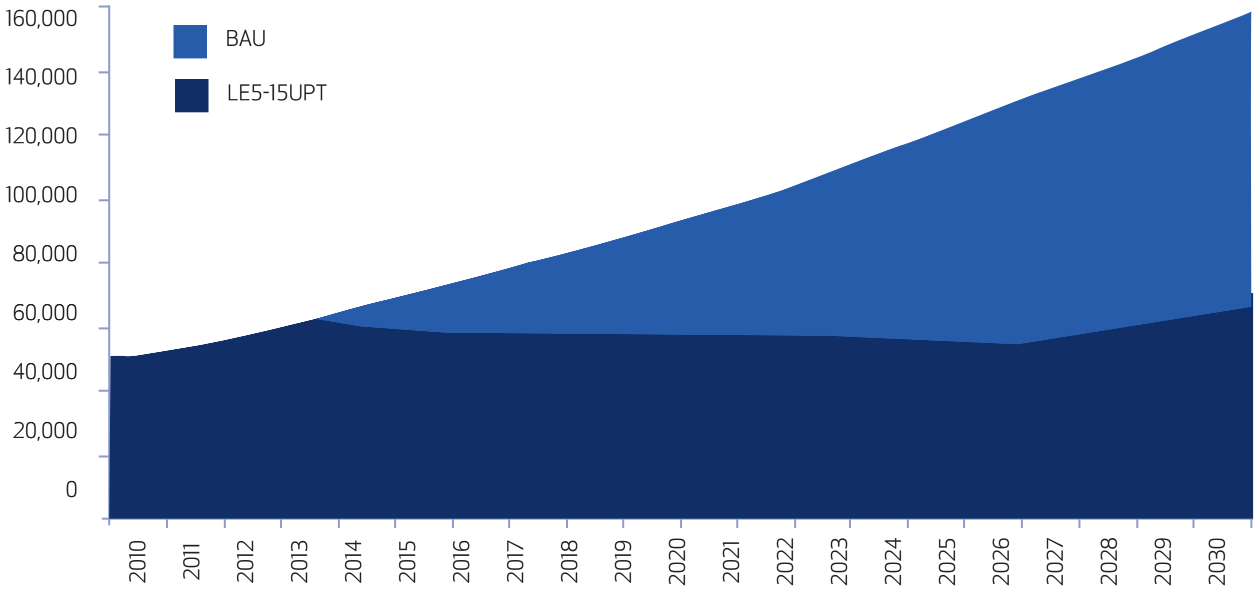
Figure 7.11
Estimated Energy and Emission Outlook for Road Transport



Scenarios in the figure:
BAU = business as usual growth rate and no change in the emission standards
LSP = lower sales projection and no change in the emission standards
LE4-15 = lower sales projection with Bharat IV standards for all vehicles by 2015 for all states
LE5-15 = lower sales projection with Bharat V standards for all vehicles by 2015 for all states
LE5-20 = lower sales projection with Bharat V standards for all vehicles by 2020 for all states (a delayed introduction of the standards)
LE4E5 = lower sales projection with Bharat IV enforced in 2015 and Bharat V standards introduced in 2020 for all vehicles and for all states
BUPT25 = business as usual with no change in emission standards, with an aggressive urban passenger transport policy to promote public transport and NMT, in order to reduce 25 per cent of the vehicle km travelled from passenger vehicles
LE5-15UPT = lower sales projections with introduction of Bharat V standards by 2015 and an aggressive urban passenger transport policy.

Source: Guttikunda and Jawahar (2012).

Figure 7.12
Premature Mortality per Year Attributable to Road Transport Emissions Under the BAU and LE5-15UPT Scenario



Source: Guttikunda and Jawahar (2012).
Note: BAU: Business as Usual Scenario; LES-15UPT: Scenario with lower sales projections, introduction of Bharat V standards by 2015 and an aggressive urban passenger transport policy

sulphur gasoline and diesel was estimated to be about 0.70-0.87¢ (Rs 0.35-0.44) and 0.64-0.88¢ (Rs 0.30-0.44) respectively.

Costs for clean vehicle technologies have not been studied in India as in the US and Europe. A 2003 study by the German Federal Environmental Agency estimated the cost increase per diesel LDV and HDV for Euro 5 over Euro 4 to be €200-400 (Rs 14,000-28,000) (assuming €1=Rs 70) and €1500-3000 (Rs 0.1.1-0.21 million) respectively. Studies by the European Commission found the cost of upgrading to Euro 6 from Euro 5 to be €200-600 (Rs 14,000-42,000) for LDVs and €825-2000 (Rs 58,000-1,40,000) for HDVs.

ICCT estimated clean vehicle costs in India as well as in Europe, and found costs to be lower than what was reported in European studies.[5] Figures 7.14 and 7.15 show ICCT estimates for per vehicle upgrade costs for various four-wheelers, and two- and three-wheelers, respectively, in India.

The increased costs of cleaner vehicle and fuel production will be passed on to customers. Customers can expect to see an increase in fuel prices of less than Rs 0.50 per litre. With the current programme of adjustment in diesel prices, a half rupee increase that is required for improving the quality of fuel would not be significant for consumers. In fact, public sector refineries can add a few paise to monthly diesel price hikes already being implemented to build capital to invest in ULSF production.

Passenger car customers will see modest increases in gasoline car prices, while diesel cars prices will increase significantly. This will incentivise the production and sale of gasoline cars, which emit less PM and NOx and do not take advantage of government subsidies for diesel fuel. HDV buyers will most likely see the largest cost increase, up to 15 per cent of vehicle cost for diesel HDVs and 10 per cent for CNG HDVs.

BENEFITS

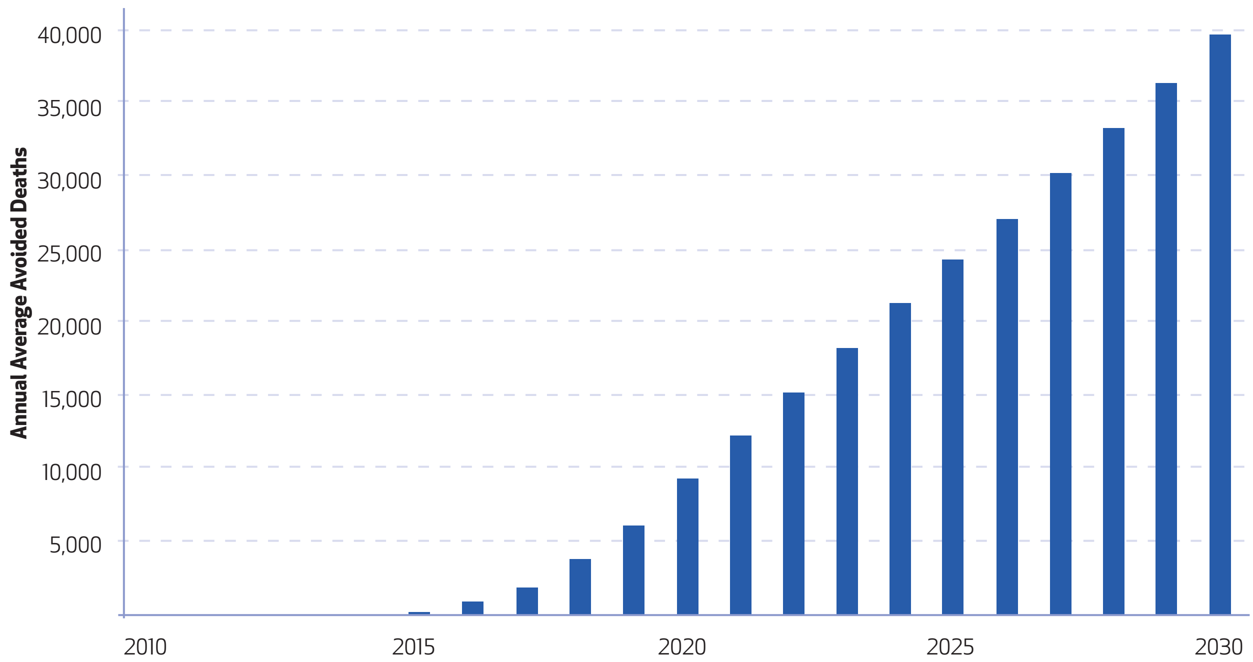
Benefits are often monetised using Value of Statistical Life (VSL) analysis. VSL is multiplied by the number of avoided deaths to arrive at a cost estimate for benefits. Relatively few VSL studies have been conducted in India, but a 2006 study estimated VSL to be about $1.5 million (Rs 75 million).

Figure 7.16 shows the ICCT's cost-benefit analysis of the Alternate Scenario versus the BAU Scenario. Through 2030, total monetised benefits of avoided deaths would come out to about $500 billion (Rs 25,000 billion), whereas costs would come out to around $200 billion (Rs 10,000 billion). Annual benefits would undoubtedly continue to rise beyond the year 2030, while annual costs would stabilise, even decrease, as economies of scale and production experience allow the same products to be produced more cheaply. This emphasises that, while there is a cost attached to cleaner fuels and vehicles, the benefits far outweigh the costs in the long term

5. ICCT (2012).

Figure 7.13

Annual Avoided Premature Deaths as a Result of Lower $PM_{2.5}$ Emission Under the Alternate Scenario



Source: ICCT (2012).

The Alternate Scenario in the ICCT study envisions actions India can feasibly take over the coming decade. Many of the policy changes outlined in the Alternate Scenario have already been put into place in a number of countries. Their experiences provide a starting point for India to move in that direction.

INTERNATIONAL EXPERIENCES

INSTITUTIONAL MECHANISMS

In India, the general process to set new vehicle emission and fuel quality standards is to establish a committee to engage stakeholders and analyse related issues. Working groups within the committee recommend standards and reforms for matters within their purview, for over the next decade or so. The committee's recommendations can then be accepted, modified or rejected by government institutions over time.

Committees that recommend future standards are not permanent. Their composition is not predetermined either, which means they often have to rely on data provided by outside sources, particularly the automobile and oil industries, to make informed decisions. This can lead to a conflict of interest, in which the regulated parties may strongly influence policymaking in their favour rather than in the national interest.

The institutions and mechanisms established in India differ from those in other countries. This section takes a look at institutional mechanisms in the US, Europe, and China.

THE UNITED STATES

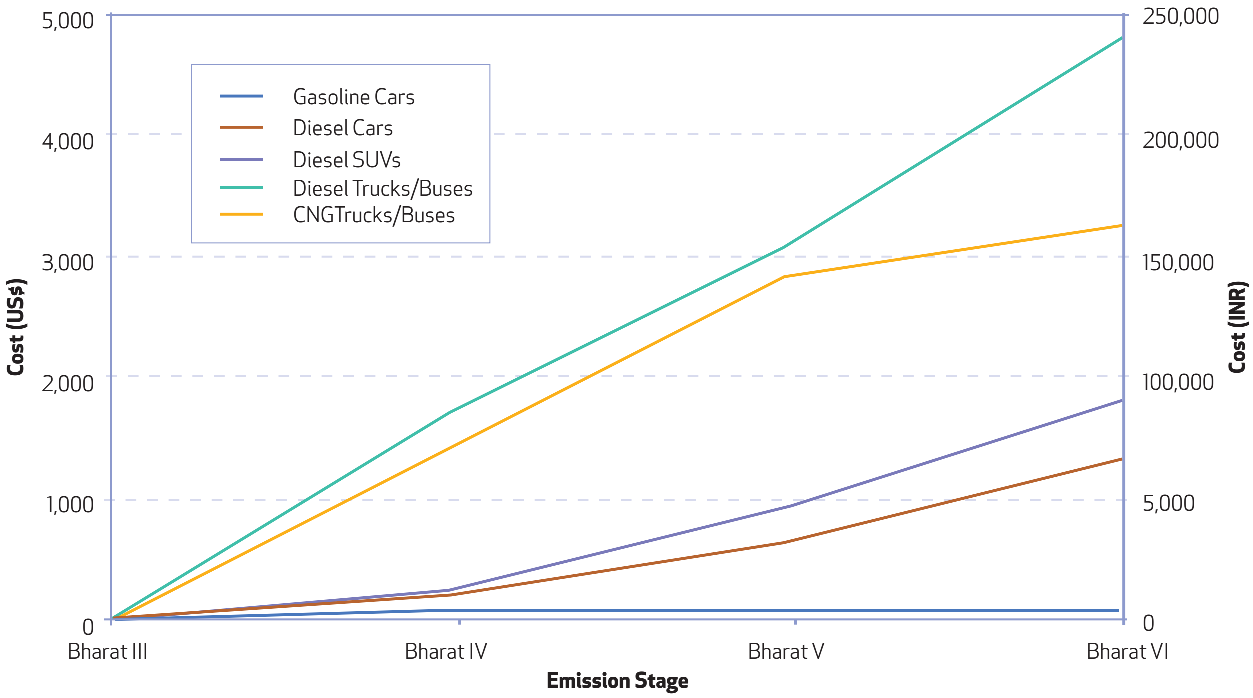
In the US, the Clean Air Act (CAA) of 1970 authorises the Environmental Protection Agency (EPA) to establish and enforce vehicle emission and fuel quality standards. Within the EPA, the Office of Transportation and Air Quality (OTAQ) is responsible for these standards. OTAQ consults various stakeholders in the standards development process.

Due to historical air quality needs, the US also allows the state of California to set vehicle emission and fuel quality standards stricter than those mandated by the EPA. Other states can choose to adopt California regulations, and so far 13 states have done so.

In California, the California Air Resources Board (CARB) establishes and enforces vehicle emission standards, in consultation with various stakeholders. CARB is a department within the California Environmental Protection Agency (Cal/EPA).

Both CARB and EPA are well-equipped and funded to thoroughly study issues before generating new standards. They have numerous laboratories and modelling programmes to test and simulate vehicle emissions. As a result, they do not have to rely on data and claims provided by the automobile and oil industries. This is in stark contrast to India, where committees set up to recommend future standards often lack time, and independent expertise, resources and funding.

Figure 7.14
Per Vehicle 4-Wheeler Upgrade Costs Progressing to Bharat VI Standards over Bharat III



Source: ICCT (2012).

EUROPE
In the European Union (EU), three institutions jointly establish vehicle emission and fuel quality regulations. The Directorate General (DG) of Enterprise within the European Commission first drafts the next stage of regulations in consultation with stakeholders and other DGs. The draft is then sent to the European Parliament and the European Council where it is further discussed.

In Parliament, the Environment Committee reviews the draft and may discuss it with other committees and stakeholders. Once negotiations are finalised and a compromise is reached, a recommendation is made to Parliament, which then votes on the regulation. A simple majority is needed to approve it. In the Council, ministers from the EU's member countries discuss the draft regulations. A qualified majority (74 per cent) is required for the draft to be approved by the Council.

If there are differences between regulations passed by Parliament and the Council, those two institutions negotiate a compromise. Regulations become law after this process is completed.

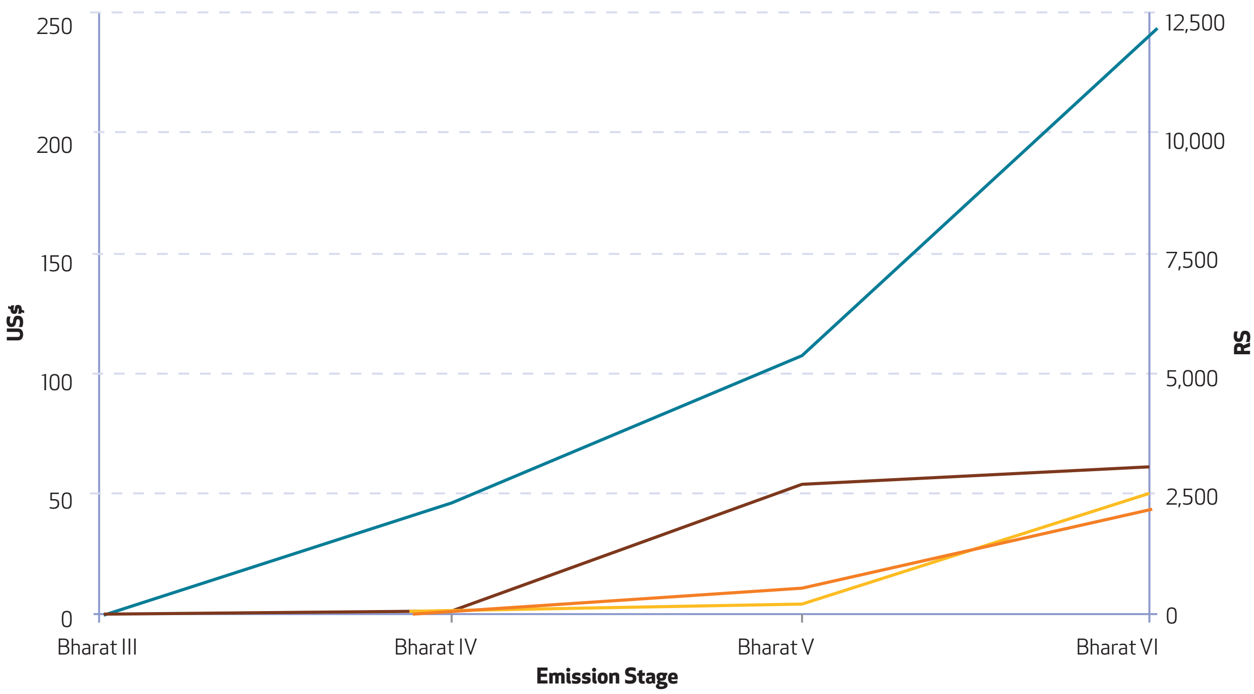
CHINA
China's Air Pollution Prevention and Control Law assigns responsibility for establishing and implementing vehicle emission standards to the country's environmental protection authorities. The relevant national-level body is the Ministry of Environmental Protection (MEP). MEP officials oversee the development, finalisation, and notification of environmental standards, though they do not typically engage in the actual drafting of the standards themselves.

In practice, the MEP assigns a third-party non-governmental institution to research and draft environmental standards. The institution assigned is usually one of several dozen government-affiliated research institutions that play a supporting role to the MEP. These institutions conduct basic research to support environmental policymaking, develop scenario analyses and emission inventories, draft and revise standards, and even participate in environmental policy implementation. Since Chinese law does not mandate that the MEP designate a government-affiliated research institution to draft standards, it is not uncommon for private companies or laboratories to be appointed for this purpose.

China's Air Pollution Prevention and Control Law does not specify clearly which government body should issue fuel quality standards. In practice, the authority to issue the standards lies solely with the Standardisation Administration of China (SAC), which itself has technical committees heavily stacked with oil industry representatives.

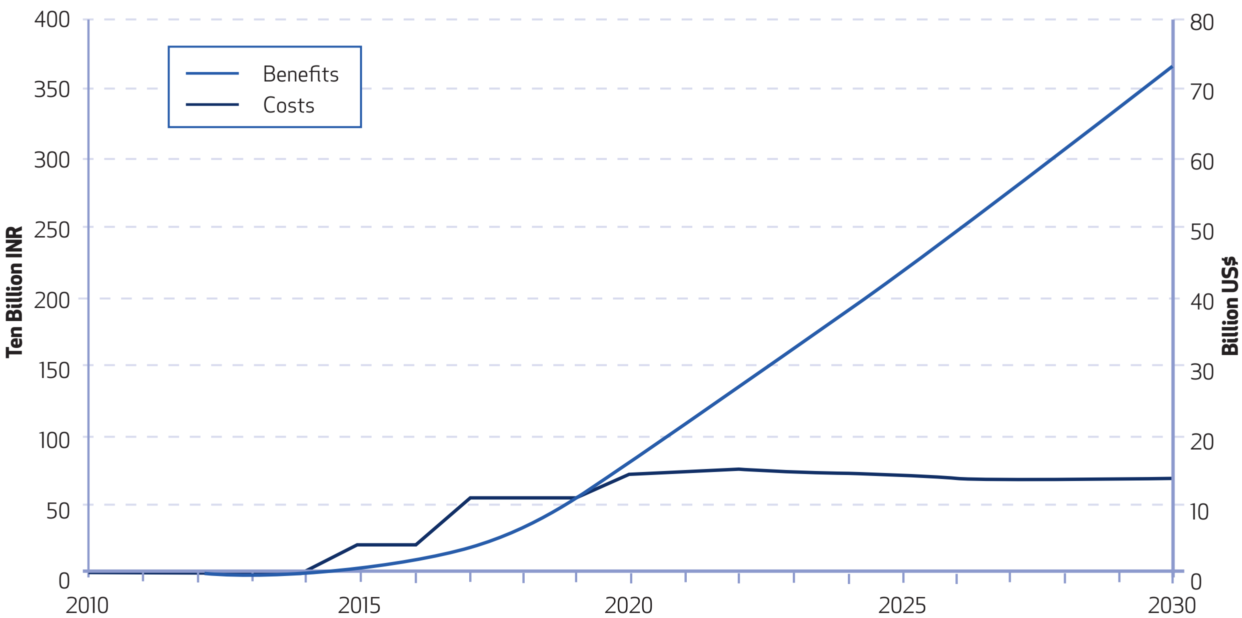
Unlike in India, the US and Europe, China does not link fuel quality and vehicle emission standards, which poses a significant problem for the country. China does not set or seek to set long-term vehicle

Figure 7.15
Per Vehicle 2- and 3-Wheeler Upgrade Costs Progressing to Bharat VI Standards over Bharat III



Source: ICCT (2012).

Figure 7.16
A Comparison of Costs and Benefits for the Alternate Scenario from 2010 through 2030



Source: ICCT (2012).

emission and fuel quality standards. This means that regulations are reviewed more frequently. This means new technologies and developments can be taken into account more often.

VEHICLE EMISSIONS AND FUEL QUALITY STANDARDS

The US has been at the forefront of vehicle emission regulations for almost half a century now. The country has some of the most stringent emission stand-

In India, certain cities have more stringent new vehicle emission standards than the rest of the country, but it has not moved to state- or region-wide implementation of different standards.

ards, as well as well-established compliance and enforcement programmes. The US has also built in much flexibility in its policies, which gives the auto and oil industry wiggle room to comply with regulations. India can learn from the vast experience of the US in setting and enforcing vehicle emission and fuel standards. Apart from the US, Europe and Japan have notable achievements in rapidly cleaning up their fuels and vehicle fleets. Europe has plans to further tighten its standards in the coming years. Both Europe and Japan have some of the cleanest fuels in the world, with the strictest low sulphur compliance. The achievements of China, Brazil, and Mexico also stand out, as all of them are large developing nations like India.

China is in the process of implementing Euro IV equivalent standards nationwide. Brazil began implementing Euro V standards for HDVs in 2012. It also has a ban on diesel powered LDVs. Mexico is one of the few developing countries to have 15 ppm sulphur diesel available in much of the country, with plans to expand the supply of this fuel nationwide in the near future. It also has plans to implement vehicle emission standards roughly equivalent to Euro 5 over the next few years.

The focus of this chapter, however, is on the US, which is the world leader for vehicular air pollution regulations. Japan is also looked at in detail regarding fuel quality compliance, since it has a successful advanced programme that differs considerably from that of the US.

THE UNITED STATES

VEHICLE EMISSIONS

The US emission standards are based on a 'tier' system with multiple 'bins', each with its own emission limits for regulated pollutants. A vehicle manufacturer may certify a vehicle model to any of the bins, provided that the sales-weighted average for all vehicles produced by that manufacturer meets specific fleet-average emission targets. This provides flexibility in meeting standards, while still assuring environmental targets are met. Furthermore, new standards in the US are not implemented at a single point in time. Instead, they are phased in, which allows for more flexibility with compliance.

The US system also establishes much longer durability requirements than Europe and India for HDVs and LDVs. Most LDVs must meet emission requirements for up to 10 years or 120,000 miles (193,200 km), whichever comes first. By contrast, LDVs in India must meet requirements for up to 100,000 km.

US emission standards do not discriminate on the fuel used. This suggests that establishing separate emission standards for diesel and gasoline engines, as is done in Europe, China, and India, is not necessary.

US law also allows states to adopt more stringent emission standards if they choose. A number of states have done so. India has a similar process in that certain cities have more stringent new vehicle emission standards than the rest of the country, but it has not moved to a state- or region-wide implementation of different standards. Nor can cities or states choose to have more stringent standards on their own. Tighter standards across a region are more effective than across a city for a number of reasons, a primary one being that higher-emitting vehicles from outside a city often operate within its limits. In the case of state-wide standards, most vehicles plying the roads of cities within that state would meet the tighter emission standards.

FUEL QUALITY

The US currently has separate sulphur content requirements for gasoline and diesel. Since 2006, diesel has been required to have no more than 15 ppm sulphur content. This level is sufficient for the most advanced after-treatment clean vehicle technologies to function well. Emissions from gasoline-operated vehicles are not as sensitive to fuel sulphur content, though sulphur in gasoline does increase PM and NO_x emissions as well. Sulphur content in gasoline in the US ranges between 30 and 80 ppm.

VEHICLE EMISSION COMPLIANCE AND ENFORCEMENT

Vehicle emission standards are only useful if they are enforced. Countries have various mechanisms to ensure manufacturers produce vehicles that comply with set standards. TA and COP are the most common practices for new vehicles in most countries with vehicle standards. Additionally, countries have differing programmes to test in-use vehicle emissions.

While Europe establishes uniform emission standards for the whole of the EU, compliance and enforcement are the responsibility of individual member states. This splinters this responsibility, and therefore analysing the successes and shortcomings of vehicle emission compliance in Europe is difficult.

China, like India, conducts TA and COP testing for new vehicles in government authorised laboratories. For in-use testing, the national government establishes emission standards and testing procedures, but local governing bodies are responsible for setting up and operating inspection and maintenance (I/M) programmes. This is similar to PUC programmes in

India. A key new aspect of China's COP programme is the gradual implementation of COP testing without prior notice to manufacturers. While this is still in its early stages, a number of problems have already been identified. This suggests that similar problems in India may come to light if India were to adopt similar procedures.

THE UNITED STATES

Compliance and enforcement in the US is carried out entirely by the Environmental Protection Agency (EPA), as authorised by the Clean Air Act (CAA) of 1970. Many individual states and municipalities have separate in-use emission compliance programmes that may assist the EPA's work. States with more stringent emission limits than federal standards have separate in-state compliance programmes that function parallel to the EPA programme.

The EPA compliance programme looks at emissions throughout the useful life of a vehicle. New vehicles are first tested by at the pre-production stage, and certified by the EPA, if they pass. The EPA then conducts confirmatory testing on certain vehicles. Unlike in India, manufacturers are not given prior notice regarding the timeframe of confirmatory testing, nor are they told from where the test vehicles will be selected.

After confirmatory testing, the EPA relies on a number of in-use compliance programmes to ensure vehicles meet emission standards throughout their useful life. One such programme is the Selective Enforcement Audit (SEA). The SEA came into being in the 1970s, when the EPA found manufacturers were occasionally producing vehicles that did not comply with standards, even though prototypes had been certified. Under the SEA, the EPA can require manufacturers to pull vehicles off the assembly line and test them, at their own expense, in a lab of the EPA's choosing.

As other in-use compliance programmes developed, the SEA programme was phased out for LDVs, though the EPA reserves the right to reinstate it if need be. For HDVs, it is still conducted.

Emissions from in-use vehicles are tested by manufacturers and the EPA. Manufacturers pay vehicle owners to test their vehicles. If vehicles fail an initial test, the manufacturer is required to conduct more rigorous testing. All test data is sent to the EPA. If a vehicle model continues to fail tests, a mandatory recall can be ordered to fix the problem.

The EPA also conducts in-use surveillance testing of its own. Like manufacturer in-use testing, the EPA selects in-use vehicles either at random or because of reasonable belief that further testing is needed. The agency usually pays owners to test their vehicles. In-use surveillance testing verifies manufacturer testing.

The US has the most comprehensive fuel quality compliance programme in the world, which has evolved over time. In Asia, Japan has set up an effective programme, successfully conducting random testing of fuel at all its retail outlets each year.

Much of the US compliance and enforcement approach is based on cooperation between the EPA and vehicle manufacturers. Manufacturers are often invited to see how EPA testing is conducted, and there is considerable communication between the two before important decisions are made. This saves the US government money, as the EPA does not have to test every single vehicle. At the same time, it ensures compliance.

Important aspects of compliance in the US are well-established recall procedures and non-compliance penalties. These incentivise manufacturers to design and test vehicles so they meet emission standards throughout their life. Not doing so means facing stiff fines and expensive recalls or production halts.

Figures 7.17 and 7.18 diagrammatically represent compliance programmes for LDVs and HDVs in the US.

FUEL QUALITY COMPLIANCE & ENFORCEMENT

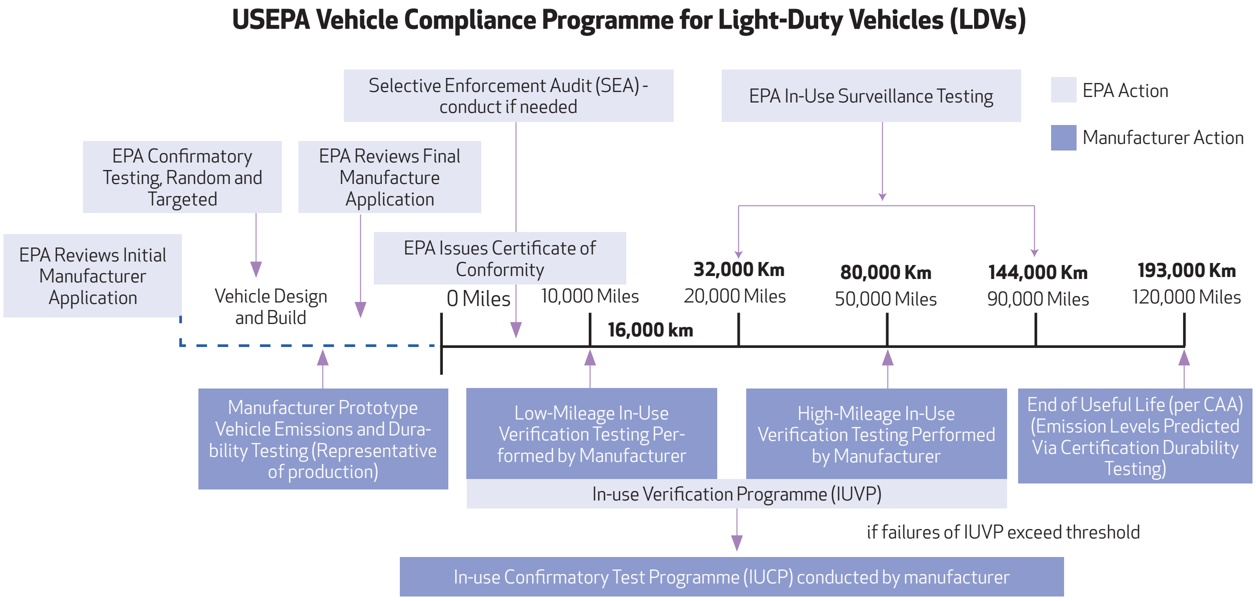
As with vehicle emission compliance, the US has the most comprehensive fuel quality compliance programme in the world. It also has many years of experience in this area, and its programme has evolved with time. In Asia, Japan has set up an effective fuel quality compliance programme. The country successfully conducts random testing of fuel at all its retail outlets each year.

THE UNITED STATES

The CAA of 1970 authorises the EPA to prohibit the manufacture or sale of fuels and fuel additives if there is reason to believe they endanger public health. This is the basis of fuel quality regulations in the country.

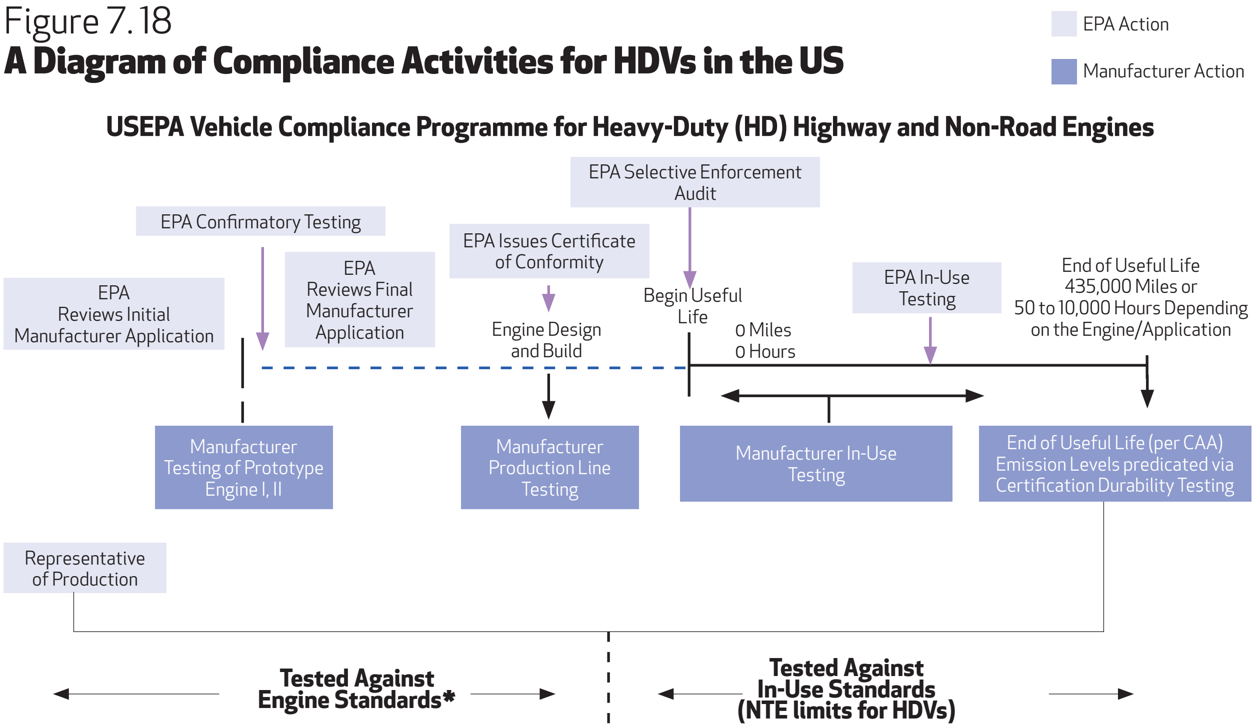
The US fuel quality compliance approach seeks to ensure that fuel quality meets set standards throughout the supply chain. At the top of the chain, fuel refiners and importers must first register fuels and fuel additives with the EPA, and conduct tests on their potential evaporative and combustion emission, prior to marketing them. After production, refiners are required to test every batch of fuel four times a year and submit results to the EPA. In addition to this, oil companies are required to hire independent laboratories to conduct fuel testing at refineries and retail outlets. Independent laboratory test

Figure 7.17
A Diagram of Compliance Activities for LDVs in the US



Source: EPA. 2007 Progress Report-Vehicle and Engine Compliance Activities Oct., 2008

Figure 7.18
A Diagram of Compliance Activities for HDVs in the US



* Except HDVs Certified using chassis dynamo meter
Source: EPA. 2007 Progress Report-Vehicle and Engine Compliance Activities Oct., 2008

results are submitted to the EPA and compared with industry test results.

EPA enforcement officials also conduct their own field tests of fuel quality at various points in the distribution system. They also selectively audit the industry and independent laboratories. If laboratories do not meet standards or if documents are found to be falsified, the EPA can levy fines and shut down facilities.

Because of such comprehensive testing throughout the supply chain, the onus of complying with fuel quality standards falls on all parties in the chain. Costly penalties for non-compliance, such as fines and criminal charges against violators, create a strong incentive for oil companies to meet fuel quality standards at all times.

JAPAN
Japan's current fuel quality compliance programme grew out of the removal of a ban on imported refined fuel in 1996. As more companies started selling fuel

in Japan, and as fuel came from more diverse places, the country recognised the need to ensure the quality of these products. The Fuel Quality Control Law was then passed, which put the Ministry of Economy, Trade and Industry (METI) in charge of doing this.

Japan's approach to fuel quality compliance is based on testing fuels at the point of sale. All fuel retail outlets must be registered with METI, and fuel samples are selected at random, without prior notice, from each and every outlet. METI contracts the National Petroleum Association (NPA), an independent public corporation, to test samples from every retail outlet at least once a year.

In addition, oil companies are required to conduct their own testing. This must be done prior to distribution and sale, as well as at retail outlets. Industry test results are checked with NPA test results for consistency.

Testing fuel at the point of sale incentivises oil companies to maintain fuel quality throughout the supply chain. Retail outlets selling non-compliant fuels can be shut down and fined heavily, which is costly for the oil companies.

RETROFIT PROGRAMMES

Retrofitting high-emission vehicles, usually older vehicles, can have a strong and positive impact on air quality. Unlike stricter standards for new vehicles, the benefits of which are seen over time as the vehicle fleet turns over, retrofits allow for immediate reduction in emissions since they target vehicles already on the road.

In order to fully harness the benefits of vehicle retrofits and minimise the economic impact, retrofit programmes must be designed and implemented appropriately, and use appropriate technologies. In some instances, retrofitting vehicles may not lead to any reduction in emissions, while costing companies, individuals, and the government large sums of money. For example, studies have found that converting gasoline vehicles to CNG may only have benefits if engines are optimised and after-treatment systems are correctly installed. In some cases, retrofitting vehicles with CNG led to an increase in emissions. This is particularly relevant to India, where there is, and has been, a strong push for CNG vehicles.

At the same time, retrofit programmes that install additional after-treatment technologies on vehicles can significantly reduce emissions, provided that the requisite fuels and supporting infrastructure are available. Two successful retrofit programmes for HDVs, one in the US and one in Japan, are analysed in more detail below. The experiences of each can be a starting point for what is possible in India.

Retrofitting high-emission vehicles, usually older ones, can have a strong and positive impact on air quality. Unlike stricter standards for new vehicles, the benefits of which are seen over time as the fleet turns over, retrofits allow for immediate reduction in emissions since they target vehicles already on the road.

UNITED STATES

In 1993, the EPA developed an Urban Bus Retrofit and Rebuild (UBRR) programme for model year 1993 and earlier urban buses operating in cities with a 1980 population of 750,000 or more. The programme was set to be implemented in 1995.

The programme sought to reduce bus PM emissions by 25 per cent. It allowed cities to choose whichever technologies they felt would be most appropriate, provided that they were certified by the EPA. This allowed flexibility at the local level, while ensuring no cities used technologies that were outdated or unreliable. A later study of the UBRR programme found the cost per tonne of PM reduced to be $31,500 (Rs 1.6 million). The same analysis estimated the cost of new HDV emission standards- that went into effect in 2007- to be $14,200 (Rs 0.7 million) per tonne of PM reduced.

Cost-effectiveness studies for other retrofit programmes in the US found the cost per tonne to be less. An assessment by the Texas Commission on Environmental Quality (TCEQ) found the costs of retrofit programmes in its state to be lower than the costs of new HDV emission standards.

JAPAN

The Tokyo Metropolitan Government (TMG) adopted an ordinance on environmental preservation in December 2000 that included an array of measures targeted at cleaning air, water, soil, and noise pollution. To reduce air pollution, the ordinance included a variety of directives aimed at reducing vehicle emissions, including the retrofitting of diesel-powered HDVs.

The retrofit programme had a two-tier structure, each targeting vehicles of different ages. The programme generally sought more reduction in PM emissions from older vehicles than from newer vehicles.

Emission control equipment manufacturers were required to submit data on the reliability, safety, and durability of retrofit equipment, though there were no specific regulations on minimum standards for these, as there were in US retrofit programmes.

While India focuses on certifying emissions for new vehicles, the US devotes more resources ensuring in-use vehicles meet emission standards throughout their useful lives.

Once a vehicle was retrofitted, it was issued a TMG sticker, which allowed it to operate within TMG city limits. Vehicles operating within TMG city limits in violation of retrofit requirements were subject to a fine of up to 5,00,000 yen ($5000 or Rs 250,000).

SUMMARY & CONCLUSIONS

The institutional mechanisms to set vehicle emission and fuel quality standards differ in different regions. In India, a committee usually recommends standards for the following decade. Government ministries and agencies then choose whether to implement the recommendations over time or not.

In the US, the EPA alone develops and implements new standards, in consultation with stakeholders, based on its authority under the CAA. In Europe, regulations are developed and have to be passed by the European Commission, the European Parliament, and the European Council. Only then they become law.

In China, vehicle emission and fuel quality regulations are developed separately. The MEP and quasi-government organisations develop vehicle emission standards, while the SAC alone usually sets new fuel quality standards. This separation of regulatory authority has led to problems implementing vehicle emission standards due to poor fuel quality.

A number of countries have implemented stricter vehicle emission controls than India. In recent years, some fast-developing countries at similar economic levels as India, such as China, Thailand, Brazil, and Mexico, have surpassed India in-tightening vehicle emission and fuel quality standards. Their experience is proof that strict vehicle emission standards do not hurt economic development. The US has been at the forefront of vehicle emission control for over forty years. The US EPA has been the sole authority in charge of regulating vehicular pollution and fuel quality parameters. Its vast experience and reforms the US has adopted, provide optimal guidance for what is possible in India.

Whereas India focuses on certifying vehicle emissions for new vehicles, the US devotes more time and resources ensuring in-use vehicles meet emission standards throughout their useful life. Clear and strict punitive measures and recall policies also incentivise manufacturers to test their in-use vehicles regularly. This reduces the resource burden on the EPA.

The same holds true for fuel quality testing. While in India the MoPNG and state governments are officially required to test and certify fuels, there is little evidence that this is done and fuel adulteration persists. In contrast to this, the US EPA contracts independent laboratories to test fuels at various points in the distribution system. The EPA audits these laboratories and conducts some tests itself to verify test results. If any fraud or noncompliant fuels are found, stiff fines are implemented. This places the onus on oil companies and fuel distributers to ensure fuel quality on their own.

Japan also has a successful, comprehensive fuel quality testing programme. Japan's METI and NPA annually test fuel from all retail outlets in the country at random, without prior notice. If any outlet has non-compliant fuels, stiff fines are levied and the outlet may be shut down.

Besides ensuring vehicles and fuels meet set standards at all times, there are other actions that can reduce vehicle emissions. Retrofitting old vehicles is one such action. An urban bus retrofit programme in the US in the 1990s reduced bus PM emissions by 25 per cent in many cities. Another retrofit programme in Tokyo, Japan successfully reduced vehicle emissions there. The cost-effectiveness of retrofits to meet strict emission standards varies. Some studies show retrofits as more expensive while others say they are cheaper.

RECOMMENDATIONS

India has come a long way over the last two decades to establish vehicle emission and fuel quality standards, and to develop compliance mechanisms for them. The country has also caught up with international best practices in certain aspects. Still, there are a number of areas in which it needs to improve. Some require looking more closely at the experiences of other countries and adopting successful programmes for India. Others involve adopting the recommendations of Indian government committees themselves, particularly those of the 2003 Mashelkar Auto Fuel Policy Committee. All these recommendations are discussed here. A new Auto Fuel Policy Committee under Dr. Saumitra Chaudhury of the Planning Commission was formed in January 2013. This new committee has the authority to recommend new standards and reforms through 2025. The recommendations discussed here set an agenda for the new Auto Fuel Policy Committee to consider as they develop specific reforms and targets for India.

RECOMMENDATIONS FOR VEHICLE EMISSION & FUEL QUALITY STANDARDS

TIGHTER FUEL QUALITY STANDARDS

<50 ppm sulphur fuels should be made mandatory nationwide by 2015, and <10 ppm sulphur fuels should

be available nationwide by 2020. Reforms in diesel pricing currently being implemented should at least partially be used to pay for refinery investments needed to produce these cleaner fuels.

TIGHTER NEW VEHICLE EMISSION STANDARDS

India should implement Bharat VI standards nationwide by 2020 for four-wheelers, thus reaching Europe's fuel quality standards. For two- and three-wheelers, India should develop Bharat IV, V, and VI standards based on Europe's actions and implement them by 2020. The technologies to implement these standards are already available in India. Mandating cleaner vehicles will have positive long-term impact.

EVAPORATIVE EMISSION STANDARDS

By 2015, India should mandate:
Stage I controls for refuelling emissions which capture vapours emitted when tankers supply fuel to retail outlets- and return them to fuel tankers and

Stage II controls- which capture vapours during vehicle refuelling and return them to the storage tanks at retail outlets.

India should also mandate all new vehicles to have on-board refuelling vapour recovery (ORVR) systems at the same time that Stage II controls are implemented. These systems return vapours to a vehicle's fuel tank rather than to retail outlets. ORVR systems are generally cheaper to maintain than Stage II controls. The majority of India's fleet will have them in place about ten years after implementation begins. Once ORVR-fitted vehicles become prevalent, regulations for Stage II controls can be lifted.

WORLD-HARMONISED TEST CYCLES

India has participated in the development of world-harmonised test cycles along with other countries. However, it is yet to adopt any of them. Replacing current test cycles with world-harmonised ones will make it less likely that certain vehicles 'beat' emission testing by passing the test cycle while actually emitting much more under real-world conditions. India should make world-harmonised test cycles optional when Bharat IV regulations come into place nationwide. They should become mandatory when Bharat V regulations come into place.

REVIEW AUTO FUEL POLICY EVERY FIVE YEARS

As new technologies are developed and experiences evaluated, there is a need to review current and future standards accordingly to ensure that the country does not head in the wrong direction or fall behind the world's latest developments. In 2003, the Mashelkar Auto Fuel Policy committee had recommended a review of the auto fuel policy every five years. Yet a new Auto Fuel Policy Committee was not formed until 2013, ten years later, despite the fact that the Mashelkar Committee's mandate was through the year 2010.

India has participated in the development of world-harmonised test cycles, but is yet to adopt any of them. Replacing current test cycles with world-harmonised ones will make it less likely that vehicles 'beat' emission testing.

Even with the formation of the current Auto Fuel Policy Committee to look at regulations through 2025, a new Auto Fuel Policy Committee should be formed five years after the current one completes its task to review progress and to make recommendations in the light of future technologies and international best practices. Provisions for a new Auto Fuel Policy Committee every five years should be made in the MoPNG's five-year plans.

RECOMMENDATIONS FOR COMPLIANCE & ENFORCEMENT

SINGLE AGENCY FOR VEHICLE EMISSION AND FUEL QUALITY REGULATIONS

In 2003, the Mashelkar Auto Fuel Policy Committee had recommended the formation of a National Automobile Pollution and Fuel Authority (NAPFA) responsible for setting and enforcing vehicle emission and fuel quality standards in India. This recommendation was not adopted. Currently there are a number of ministries and agencies responsible for compliance and enforcement in India, which allows blame to be passed onto others if there are problems. Therefore, the government should establish a permanent NAPFA and ensure that it is fully funded.

NATIONAL IN-USE VEHICLE TESTING PROGRAMME

A robust Inspection and Certification (I&C) regime should be established in the country to ensure safety, road worthiness and emission performance of in-use vehicles. All motor vehicle categories should be covered under the I&C regime, which should address both safety and emissions. Presently, only commercial vehicles are required to undergo fitness test for road worthiness. Private vehicles are required to undergo pollution under control checks at periodic intervals as per the Central Motor Vehicle Rules under the Motor Vehicles Act, 1988. The parameters, for which the PUC testing is done, are not related to the parameters for which vehicles are tested for emission during the. Type Approval and Conformity of Production (CoP) tests. On the line of the practice in the United States, India should, in addition to emission standards which should be adhered to by new vehicles, lay down deterioration standards for each year to test in-use vehicles

Given the history of fuel adulteration in India, it is especially important that the Government develops a national plan to test fuel at retail outlets, along the lines of the US and Japan.

for emissions. There should also be a recall policy to recall models which, on testing, do not adhere to the emission standards derived from the applications of deterioration factors.

A modern I&C regime with minimum manual interference needs to be established in a phased manner. In the beginning, I&C regime should prioritise transport (commercial) vehicles and then move to non-transport (private) vehicles. Phasing the implementation of I&C regime would enhance the probability of success as commercial vehicles are much smaller in number and would be easier to target in the initial phase. Also, the investment requirements will be less and distributed if a phased approach is adopted. The phasing should target bringing older vehicles under the I&C regime earlier, as compared to the newer vehicles. Also, cities with higher vehicular pollution should be targeted first. Periodic fitness tests for commercial vehicles are included under the Motor Vehicles Act and can be initiated under the new I&C regime. I&C of private vehicles will require changes in the Motor Vehicles Act as the law does not currently call for periodic fitness certification; after the initial registration, private vehicles are required to re-register only at the end of 15 years.

A dense network of modern I&C centres should be established with the required capacity for testing commercial and private vehicles. The frequency of testing should be based on the principle that commercial vehicles and older vehicles are tested more frequently, preferably annually. Private vehicles need not require I&C for the first three years, after which they should be subjected to fitness tests biennially till they complete nine years. After nine years, private vehicles should also be subjected to annual tests. In case of two-wheelers, however, the biennial tests should begin after two years till eight years of age, after which they should also have annual fitness tests.

The I&C centres should be established on a public-private partnership (PPP) basis. The central government should lay down the policy and regulatory framework for tests, equipment, manpower requirements based on the advice of an independent agency like a National Accreditation Board (NAB) that could also monitor implementation of I&C by state governments. The state governments should fix the inspection fee after analysing the cost of, each centre and the expected reasonable return on investment from it. State governments could subsidise centres that have lesser volumes of fitness tests. State governments should ensure the implementation of the I&C regime by private testing agencies, independent agencies or empanelled auditors.

CLEAR RECALL POLICIES AND PUNITIVE MEASURES

Indian law clearly authorises the government to fine violators and recall noncompliant vehicles, but there are no well-defined legal procedures for this. Until NAPFA is set up, the MoRTH should establish clear punitive measures and recall processes for noncompliant vehicles and the MoPNG should establish clear punitive measures for noncompliant fuels.

TEST FUEL QUALITY AT RETAIL OUTLETS

Oil companies are responsible for fuel compliance activities while the fuel is in their possession. While they may do this, there is little, if any, verification of their activities by the government, despite legal procedures requiring this. Furthermore, there is hardly any testing of fuels at retail outlets, where consumers ultimately get fuel for their vehicles. Given the history of fuel adulteration in India, it is especially important to test fuel at retail outlets. The MoPNG should develop a national plan to test fuel at retail outlets, along the lines of what is done by the US EPA or Japan's METI and NPA.

ENERGY SECURITY & TRANSPORT ATTRIBUTABLE GREENHOUSE GAS (GHG) EMISSIONS

Increasing energy consumption levels and emission of greenhouse gases (GHG) like CO_2, is another important challenge.

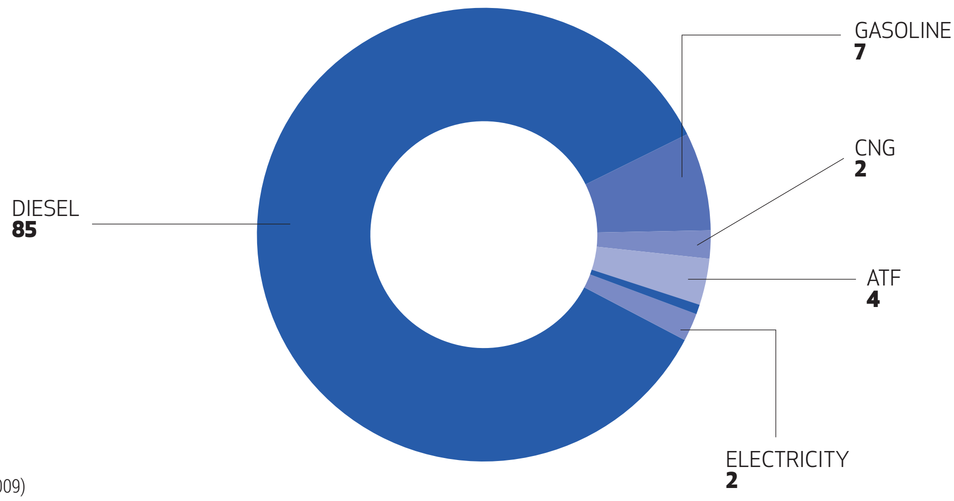
Increasing energy demand by the transport sector raises concerns about energy security and economic growth. GHG emissions from this sector also exacerbate the problem of global warming which can have long-term effects on everyday life and India's economy. Rising temperatures and changing weather patterns for instance will undoubtedly impact agriculture, which employs over half the country. Rising temperatures can also lead to higher sea levels which could inundate coastal areas permanently displacing populations.

According to TERI, in a BAU scenario, the total energy consumption by the transport sector is expected to increase from 81.3 million tonne of oil equivalent (Mtoe) in 2010 to 266.8 Mtoe in 2030, a more than threefold increase[7]. Road transport will be responsible for more than 90 per cent (244.5 Mtoe) of the energy requirements in 2030. Petroleum will continue to be the largest fossil fuel used. Diesel will account for 85 per cent of fuel used. it, as shown in

7. TERI (2009).

Figure 7.19

Fuel Mix for the Transport Sector in 2030 Under the BAU Scenario (per cent)



Source: TERI (2009)

Figures 7.19 and 7.20. Some estimates predict 2030 requirements to be even higher at 318 Mtoe[8]. The International Energy Agency (IEA) gives a more conservative estimate of 164 Mtoe in 2030 if current policies continue. Petroleum consumption will be 91 per cent of that[9].

THE CHALLENGE OF ENERGY SECURITY

The current trend of growing fossil fuel use is not favourable for India's energy security or economy. Domestic petroleum production has not kept up with growing demand, making the country increasingly dependent on imported crude oil. The uncertainty of crude oil availability in the future poses a problem for India.

This upward trend is not limited to India. World oil demand for transport is estimated to increase from 4,200 Mtoe per annum in 2009 to 5,370 Mtoe per annum in 2035 if current policies continue[10]. (See Box 7.3 for detailed analysis).

The production of crude oil in the country has increased at an average annual growth rate of around 1.6 per cent from 2000-01 to 20010-11, whereas the consumption of petroleum products over this period has increased at a rate of more than 4 per cent annually[11]. The reserves to production (R/P) ratio of crude oil in India indicates enough reserves for 30 years, whereas the R/P ratio[1] worldwide indicates enough crude oil to last in the world for 46 years[12]. India has become, and will continue to be, increasingly dependent on imported crude oil (Figure 7.21) Crude oil imports now account for almost 80 per cent of India's demand[13]. If current trends continue unchecked, this will rise to 90 per cent by 2032[14].

Heavy dependence on imports is bad for India's economic growth. It exposes the domestic economy to the vagaries of international crude oil prices, thereby affecting macroeconomic variables like the country's import bill and trade balance[15]. It also sends billions of rupees abroad to purchase fuel, rather than investing the money at home.

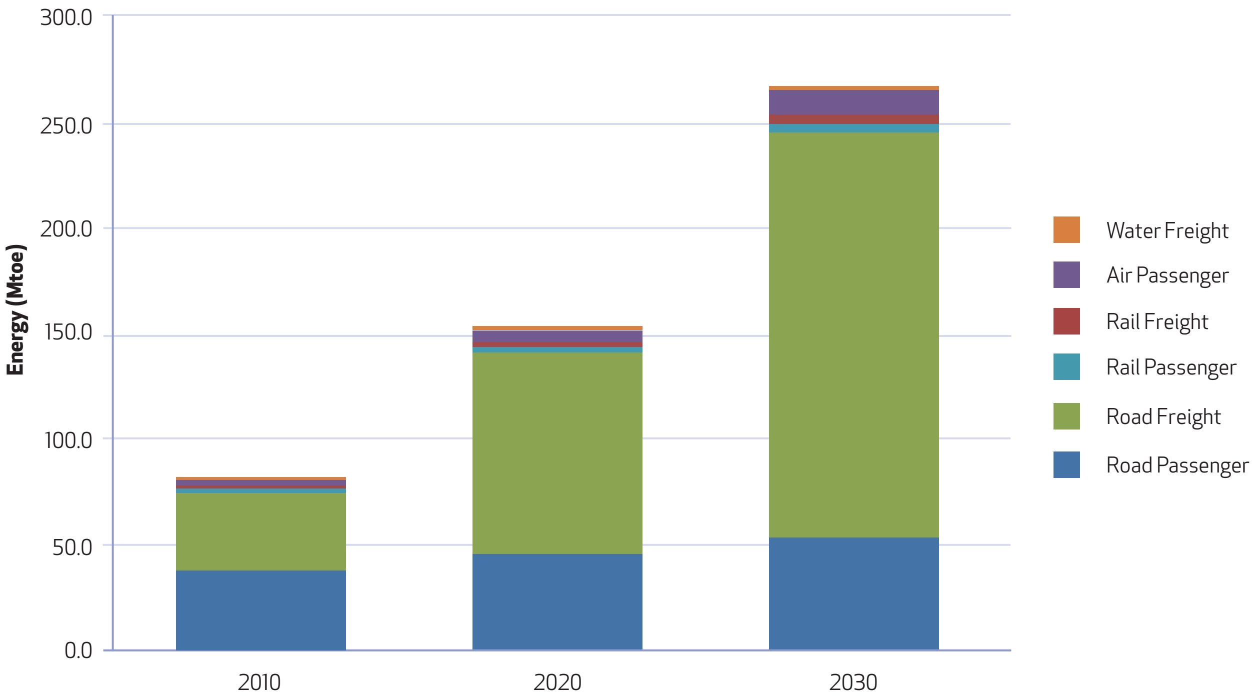
India's transport sector also uses gas and electricity in addition to petroleum products. Together, these two energy sources account for about 2.5 per cent of the energy needs of the sector. Their share is expected to go up to 3.5 per cent in 2030 under a BAU scenario[16]. The government has been making efforts to increase the use of these fuels, not only to reduce dependence on oil, but also to lower air pollutant emission.

There have especially been fairly strong initiatives to promote natural gas use. The government has a policy of allocating natural gas primarily for the transport sector and secondarily for other sectors. Many first tier cities have shifted their public transport and intermediate public transport systems (such as auto rickshaws and taxis) to CNG and other cities are following suit. According to a proposal by the Petroleum and Natural Gas Regulatory Board (PNGRB), city natural gas distribution networks may be implemented in over 200 cities, which may be used for transportation as well.

But like oil, natural gas is not an infinite resource. The R/P ratio of natural gas in India indicates sufficient domestic production for a maximum of 28.5 years[17]. Currently, the country imports more than 20 per cent of its domestic gas requirements, as shown

8. Guttikunda and Jawahar (2012).
9. IEA (2010).
10. IEA (2010).
11. MoPNG (2012).
12. TERI (2011).
13. MoPNG (2012).
14. TERI (2008).
15. TERI (2011).
16. TERI (2009).
17. TERI (2011).

Figure 7. 20
Growth in Energy Consumption in Transport Sector in BAU Scenario



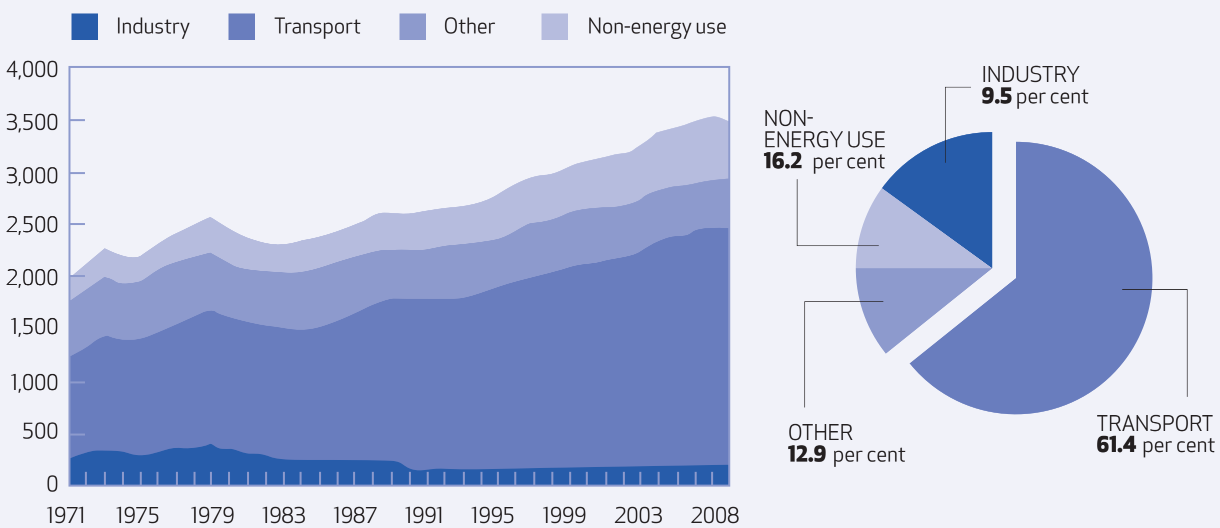
Source: TERI (2009).

Box 7.3
Share of Transportation in Global Petroleum Consumption

Worldwide, transportation accounts for a dominant share of total petroleum consumption annually. In many countries, highway vehicles consume the largest share as in the United States where they account for 61 per cent as per the US Department of Energy 2010 estimates. Clearly, any effort to enhance energy efficiency should pay particular attention to highway vehicles.

Governments worldwide are trying to improve vehicular energy efficiency for many reasons: ensuring greater energy security; enhancing economic development and competitiveness; reducing climate change impact and improving public health.

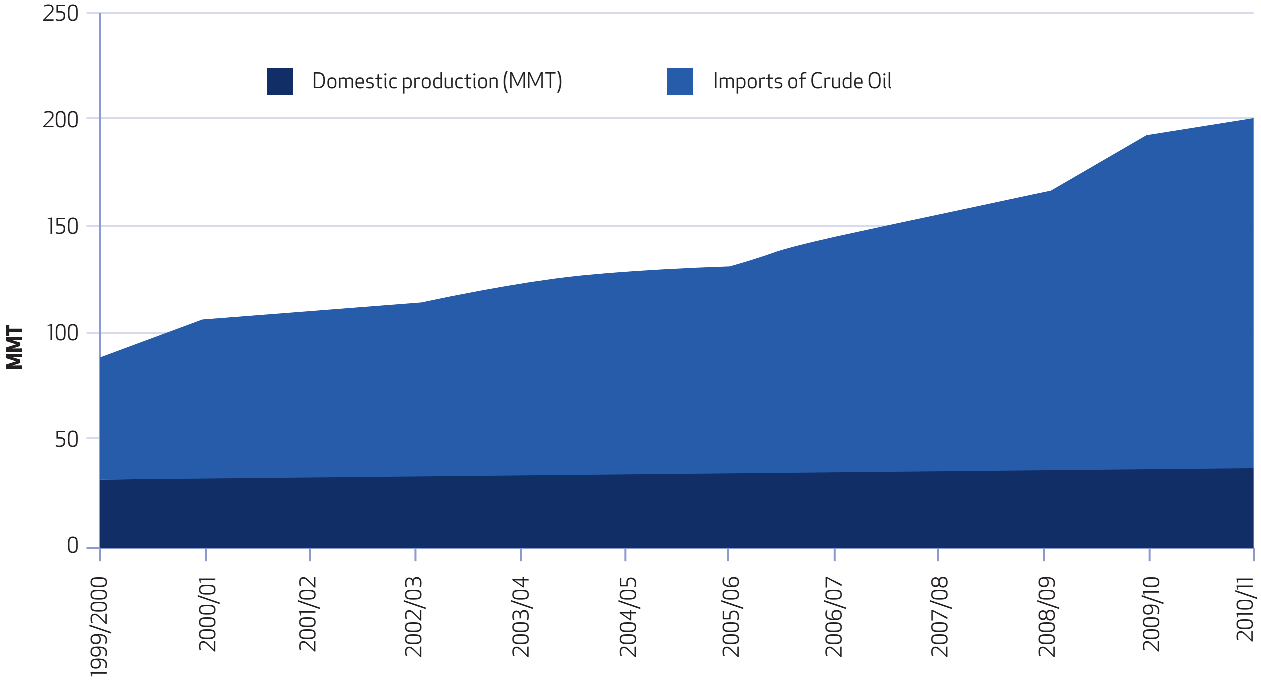
World Petroleum Consumption by End-Use (in Million Tonne of Oil Equivalent-Mtoe)



DRIVERS OF GOVERNMENT ENERGY EFFICIENCY POLICIES	
Energy security	Reduce imported energy Reduce demand increase reliability Control energy demand growth
Economic Development and Competitiveness	Reduce energy intensity Improve industrial competitiveness Reduce production costs More affordable energy customer costs
Public Health	Reduce air pollution that is attributed to vehicle emissions
Adapted from: Energy Efficiency Governance Handbook http://www.iea.org/papers/2010/gov_handbook.pdf (accessed 17 January 2013)	

Source: Government Policies to Encourage Energy Efficient Vehicles on Roads, Page 4-5, Kumares C. Sinha, Mohammad H. Arman, Samuel Labi, June 7, 2011.

Figure 7. 21
Domestic Production and Imports of Crude Oil in India, 1999-2000 to 2010-11



Source: TERI (2011).

in Figure 7.22. Increasing demand will further increase dependence on imports.

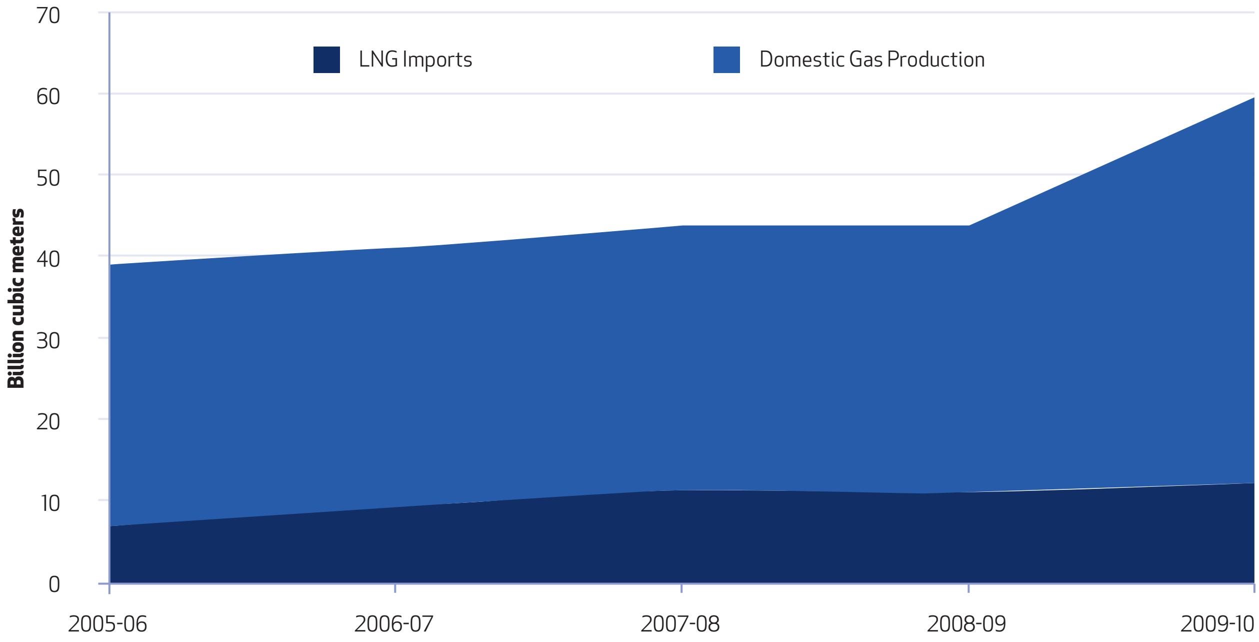
Electricity use in the transport sector has not been adequately promoted, the primary user being rail transport. Electricity use in road transport is expected to increase in the future as innovation in electric vehicles continues and they become economical to produce and use. The government has announced a National Electricity Mobility Mission Plan 2020 that targets 6-7 million new electric and hybrid electric vehicle sales by 2020. While the implementation of the Mission Plan is expected to yield liquid fuel savings of 2.2-2.5 million tonne by 2020, it will lead to an increased demand for electricity for road transport. About seven million electric vehicles will require additional power generation capacity in the range of 775-865 MW. GHG emissions and energy security concerns will be relevant if this electricity is generated from thermal power plants that depend on imports of coal and gas.

THE CHALLENGE OF INCREASING CO_2 EMISSIONS

The transport sector is a key contributor to CO_2 emission. As per a Ministry of Environment and Forests (MoEF) study[18], the sector was the second largest contributor to CO_2 equivalent emission (CO_2e) in 2007 and generated 142 MtCO_2e. Within the transport sector, road transport contributes 87 per cent of the total CO2 equivalent (CO_2e) emissions, as shown in Figure 7.23. As per studies[19] the trend of increasing CO_2 emissions from road transport is expected to continue if no action is taken. In 2030, road transport is expected to have CO2e emission in the range of 850-900 MTas shown in Figure 7.24. Total transport sector CO_2e emissions could go up to 900 million tonne in 2030[20].

18. MoEF (2010).
19. TERI (2009); Guttikunda and Jawahar (2012); ICCT (2012).
20. TERI (2009).

Figure 7. 22
Domestic Production and Imports of Natural Gas, 2005-06 to 2009-10



Source: TERI (2011).

Appropriate strategies and policies need to be put in place to lower energy consumption and GHG emission from the transport sector. These strategies should include[21]:

- Incentivise use of rail and marine transport for goods movement.
- Incentivise public transport over private vehicles for passenger transport.
- Maintain NMT options, such as biking and walking.
- Implement progressively strict vehicle fuel efficiency standards.

Improving vehicle fuel efficiency can help achieve low-energy, low-carbon growth in the transport sector. Vehicle fuel economy regulations can free up billions of rupees, currently spent on petroleum products, for other needed investments.

In recent years, many advanced countries have established fuel economy or GHG emission standards for vehicles. These regulations are relatively new and continuously changing and expanding as new technologies are developed, and successes and shortcomings are analysed. India, too, is establishing its first-ever vehicle fuel consumption regulations.

TYPES OF VEHICLE GHG EMISSION STANDARDS

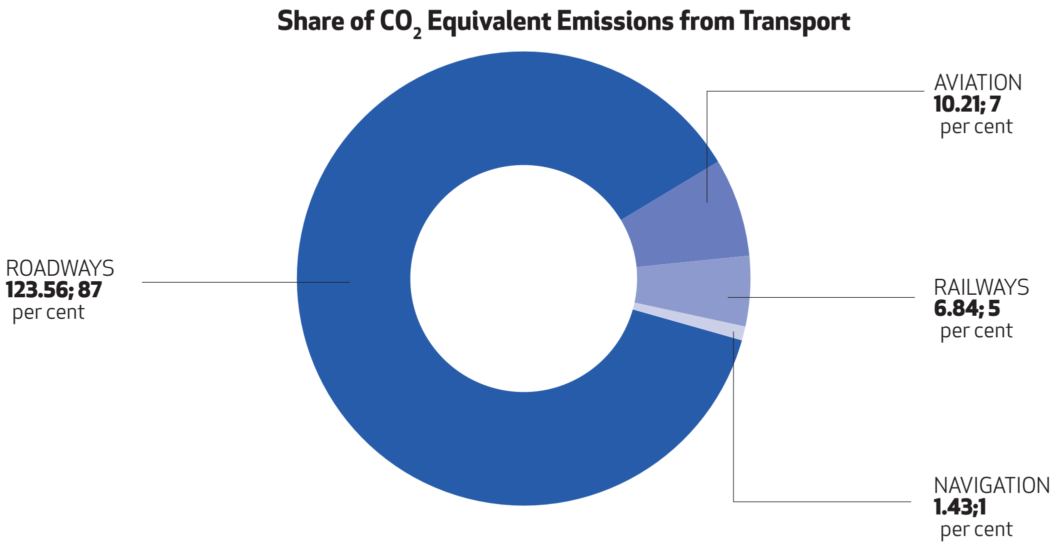
Energy consumption and GHG emissions can be reduced by setting fuel economy or fuel consumption standards, by setting vehicle CO_2 and other GHG emission standards or combination of these. Since fuel consumption correlates well with CO_2 emission for a single fuel type, limiting one, in effect, limits the other. But this does not hold true for diverse fuel types. Nor do only fuel economy or fuel consumption standards fully take into account the emission of non-CO_2 greenhouse gases, such as methane (CH_4), hydro fluorocarbons (HFCs), and nitrous oxide (N_2O). CO_2 and CO_2-equivalent GHG emission standards may be needed to regulate total vehicle GHG emissions.

If developed and implemented correctly, GHG emission standards can also provide compliance flexibility by taking into account non-engine technology improvements. For example, operating an air conditioning system places an additional load on the vehicle engine, causing additional fuel to be consumed and therefore increasing CO_2 emission. Extra emission resulting from such loads can be reduced by increasing air conditioning efficiency and using low emission refrigerants.

Standards for fuel efficiency, fuel consumption and GHG emissions can also be established based on vehicle class or weight. But, weight-based standards give manufacturers an incentive to increase vehicle weight to qualify for more lenient standards. This penalises manufacturers who use advanced technologies to reduce vehicle weight to improve fuel efficiency. It should be noted that vehicle GHG emission standards address tank to wheel (TTW) emissions, but they do not take into account well to wheel (WTW) emissions. In certain cases, as in policies promoting the use of biofuels to promote vehicle fuel efficiency, WTW emissions may increase, even with stringent TTW standards.

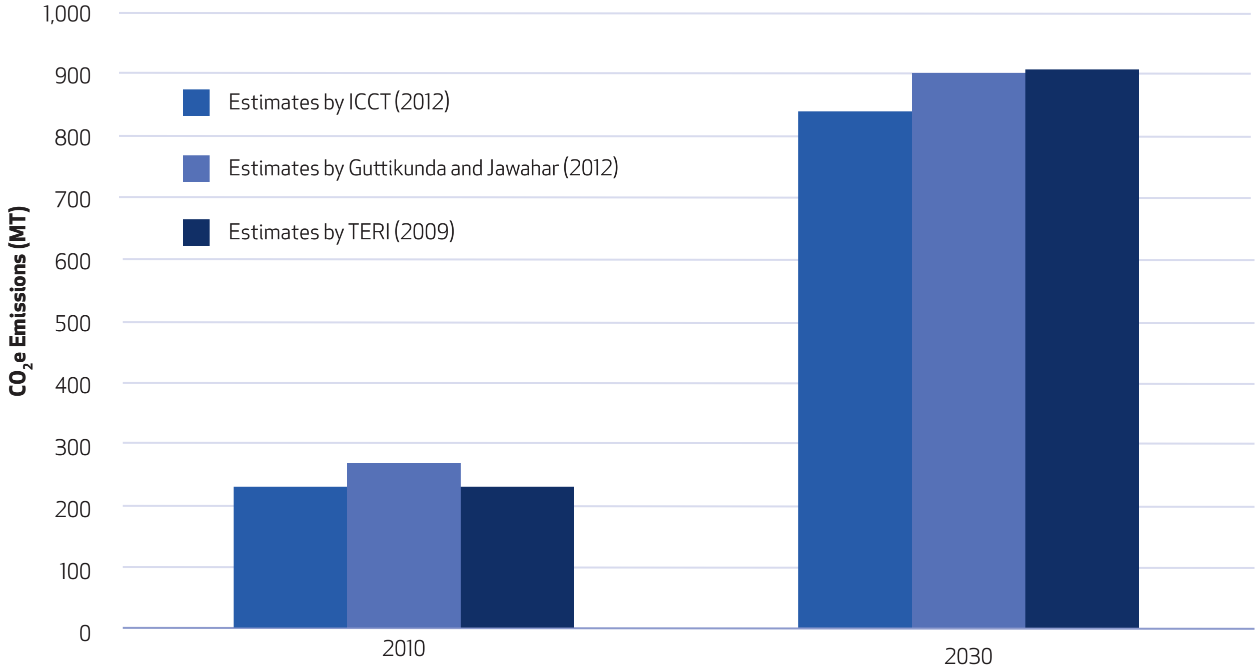
21. TERI (2011).

Figure 7. 23
CO_2 Equivalent Emissions from Transport Sector, 2007



Source: MoEF (2010).

Figure 7. 24
CO_2 Emission from Transport Sector in BAU Scenario, 2010-30



INTERNATIONAL GHG EMISSION STANDARDS

Standards have generally been established for LDVs first since improvements to reduce emission and increase fuel efficiency are best known for this class of vehicles. Recently, there has been a growing interest in standards for HDVs and two- and three-wheelers too.

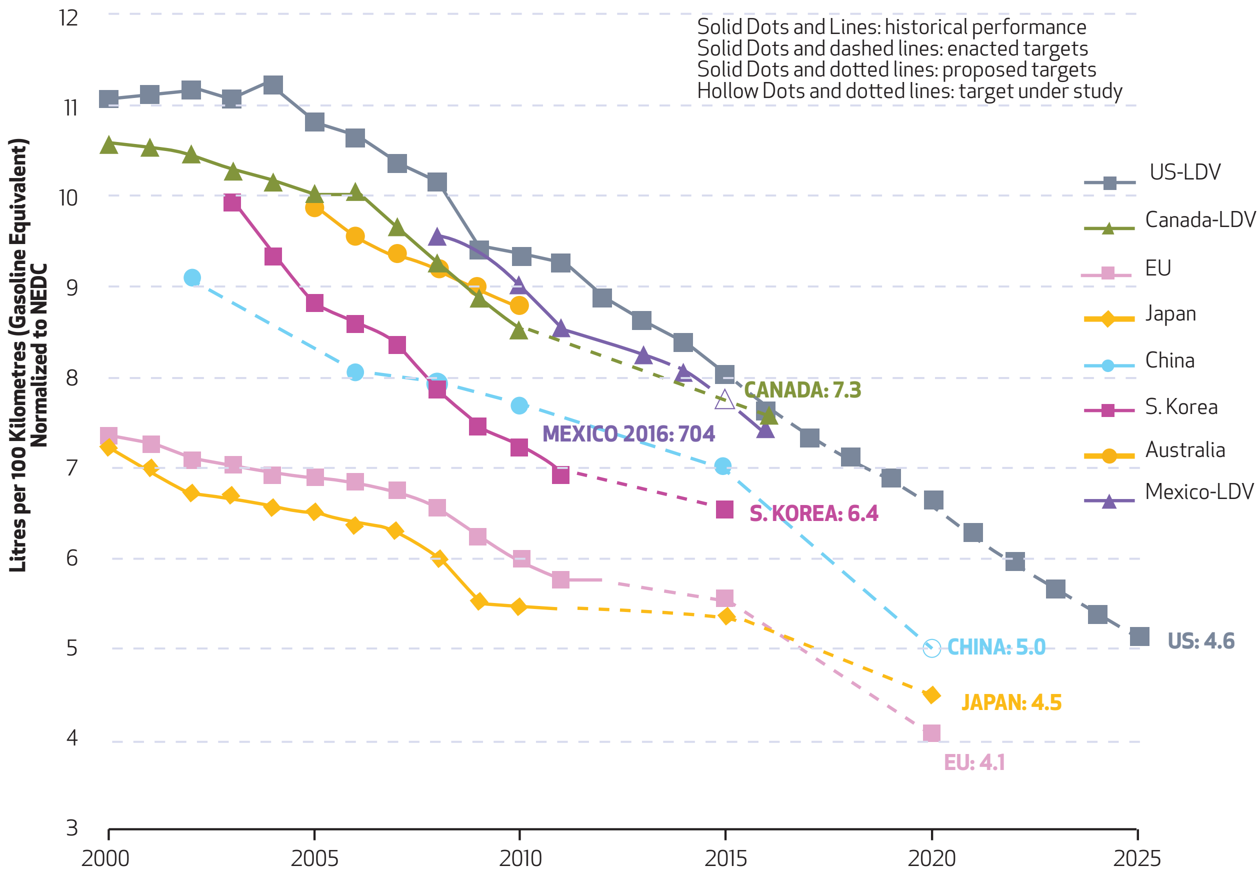
LIGHT-DUTY VEHICLE STANDARDS

GHG emissions from LDVs have steadily fallen over the last decade, and they are predicted to continue to do so as standards become more stringent. Figure 7.25 shows trends in LDV fuel consumption standards (or equivalents) in litres per 100 kilometres in various countries.

UNITED STATES

For decades, the motivation for the US fuel economy regulations was energy security. In recent years, climate change has become a factor as well. In 2010, the EPA and the US Department of Transportation (DOT) finalised a new joint regulation

Figure 7. 25
Past and Proposed LDV Fuel Consumption Standards in Various Countries



Source: NTDPC Research.
Note: [1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be higher.
[2] US and Canada light-duty vehicles include light-commercial vehicles.

covering GHG emissions and fuel economy for model years 2012-2016 passenger cars and light trucks.

According to the new standards, the corporate average LDV GHG emission rate will be reduced from an average of 342 gCO_2e/mile in 2008 to 250 gCO_2e/mile in 2016. Fuel economy will increase from an average of 26 miles per gallon (11.05 km/L) to 34.1 miles per gallon (14.5 km/L) during this period.

Additionally, the US is planning to extend LDV CAFE standards to 2025. Passenger cars and light trucks will be required to meet a fleet average fuel economy standard of 54.5 miles per gallon (23.17 km/L) by that year. Some leniency in that standard will be allowed through credits for enhancements in air conditioning technology and other areas that reduce GHG emissions. Box 7.4 discusses some incentives in the US to increase vehicle fuel efficiency.

EUROPE
In 2009, Europe set its first mandatory CO_2 emission target for 2015 at 130 gCO_2e/km for the fleet average for all manufacturers combined. A similar standard for light commercial vehicles (vans) was set in 2011 at 175 gCO_2e/km for the year 2017.

These targets are to be met with vehicle efficiency improvements alone, with additional cuts achieved through measures such as changes in tire pressure, gearshift indicators, air conditioning as well as an increased use of biofuels.

In 2011, a more far-reaching 2020 target of 95 gCO_2e/km was announced for LDVs. The European Commission has until early 2013 to consider the technical and economic analysis to achieve this.
The European standard for CO_2 emissions is a weight-based corporate average, while US fuel efficiency regulations are class-based. This means vehicle manufacturers in Europe do not necessarily have an incentive to decrease vehicle weight in order to increase fuel efficiency.

There are some flexibility and incentives built into the European system. For example, cars emitting less than 35 gCO_2e/km will count as 1.3 cars for up to 20,000 new car registrations per manufacturer. Addi-

Box 7. 4
Improving Fuel Efficiency for Existing Vehicles: Examples of Rebates and Penalties

The United States government allows tax credits for the purchase of energy efficient vehicles. Tax credit is calculated on the basis of the vehicle's fuel economy and energy savings. After a vehicle meets the eligibility criteria, the automaker applies to the Internal Revenue Service for official certification of the incentive. Above a certain level, the tax credit amount decreases until it eventually phases out (Onoda, 2008).

The state of California developed a 'feebate' system (fee as penalty and rebate as reward). Such a system could be designed to be revenue neutral or to yield a certain pre-specified ratio of total fees to total rebates. For this policy, issues to be considered include (i) the effect of gradual reduction in energy efficiency of vehicles over time. So scheme parameters pivot point(s) and rate- need to be adjusted periodically to maintain overall revenue neutrality. (ii) there can be significant administrative cost, depending on the complexity of the scheme. The purchase of old vehicles which tend to be fuel inefficient and the production of fuel inefficient cars are penalised in certain countries. At the federal level in the US, the Gas Guzzler Tax is a disincentive established by the 1978 Energy Tax Act to discourage the production and purchase of fuel inefficient vehicles (Onoda, 2008).

The Car Allowance Rebate System (CARS), colloquially known as "Cash for Clunkers", a $3 billion U.S. federal programme, established in 2009, provides economic incentives to residents to purchase a new, more fuel-efficient vehicle when trading in a less fuel-efficient vehicle. The programme was promoted as providing stimulus to the economy by boosting auto sales, while putting safer, cleaner and more fuel-efficient vehicles on the roadways (USDOT, 2009).

In Canada, the ecoAUTO programme provides rebates for purchase or long-term lease of efficient cars and light trucks, and Green Levy-an excise tax- penalises those who purchase certain types of energy-inefficient cars (APEC, 2009).

Source: Government Policies to Encourage Energy Efficient Vehicles on Roads, Page 8-9, Kumares C. Sinha, Mohammad H. Arman, Samuel Labi, June 7, 2011.

tionally, manufacturers that develop 'innovative technologies' that are not covered by the test cycle can apply for a maximum credit of 7 gCO^2e/km.

CHINA

China regulates vehicle fuel consumption rather than fuel economy. It introduced its first national fuel consumption standards for new passenger vehicles in 2005 (Phase I). Phase I sets fuel consumption standards on vehicle weight. It was successful in reducing fuel consumption to 8.1 L/100km for model year 2008 vehicles, over an average of 9.1 L/100km for model year 2002 vehicles. Phase I standards were tightened by 10 per cent in 2008 (Phase II) for all model year 2009 vehicles and beyond. In 2009 and even more stringent standards were proposed (Phase III), which aims at a nationwide LDV fleet average fuel consumption rate of 7 L/100km by 2015.

The first two phases of the Chinese standards were per-vehicle certificate standards. Every new vehicle had to meet a maximum fuel consumption set for its weight class before it could enter the market. Such a compliance scheme, though useful in phasing out vehicles with out-dated technologies, does not encourage manufacturers to adopt state-of-the-art fuel efficiency technologies over time.

But the 2015 target may not be met as vehicles are generally getting heavierand hence will have less stringent fuel consumption standards.China is therefore considering a combined per-vehicle certificate standard and corporate average fuel consumption (CAFC) system for Phase III regulations, details of which have yet to be released.

Additionally, China also provides incentives for the production and sale of fuel-efficient vehicles as detailed in Box 7.5.

HEAVY-DUTY VEHICLE STANDARDS

Since the use of HDVs is linked with growth in freight activity, stakeholders in the HDV sector extend beyond vehicle manufacturers and owners to include those who contract services as well.

There are many well-known technical improvements to reduce HDV fuel consumption.

Box 7. 5

Enhancing Highway Vehicle Energy Efficiency: China's Case

Worried about heavy reliance on imported oil and faced with increasing hazy smog conditions in Beijing and other Chinese cities, China is seeking ways to impose greater fuel efficiency. Chinese officials have drafted automotive fuel economy standards that require automakers in China to improve fuel economy by an additional 18 per cent by 2015. The Chinese government has been active in adopting policies and programmes to encourage energy-efficient vehicles on roads:

Economic incentives & disincentives are used to reduce greenhouse gas emissions, and are implemented through subsidies to individuals for purchasing new fuel-efficient or alternative-fuel vehicles or increasing the fuel efficiency of existing vehicles. Some of these economic incentives are:

- A subsidy of $455 to each consumer who buys selected vehicles with engines not exceeding 1.6 liters;
- Subsidies of up to $9,100 for the purchase of an electric car, and up to $7,580 for the purchase of a gasoline-electric hybrid vehicle, in the cities of Shanghai, Hangshou, Changchun, Shenshen and Hefei, under a trial programme, started June 2010.
- Procurement of energy-efficient vehicles for the government
- China is actively supporting research and development of new vehicle technologies. Its largest automobile company, the SAIC group, and other local and foreign auto makers are investing in R&D centres to develop alternative energy and environmentally-friendly technologies. In addition, China enforces mandatory vehicle emission inspection and retirement of old vehicles.

Hence we see that standards of new vehicles have been controlled through i) Establishment of mandatory fuel-efficiency standards for light duty vehicles. ii) Automotive industry agreements on fuel efficiency and adaptation of efficient and innovative vehicle technology. iii) Mandatory fuel-efficiency standards for passenger cars based on vehicle weight and transmission type (manual or automatic).

The Chinese Government actively promotes public outreach to enhance awareness of the need to reduce energy consumption, how it can be achieved by individual contribution as individuals monitor their energy use. For this purpose, information on vehicle performance is provided to car purchasers and vehicles are labelled with fuel consumption rates at the time of purchase.

Source: Government Policies to Encourage Energy Efficient Vehicles on Roads, Page 22, Kumares C. Sinha, Mohammad H. Arman, Samuel Labi, June 7, 2011.

Setting fuel economy or GHG emission standards for HDVs is a more recent regulatory endeavour than for LDVs. Until the mid-2000s, the focus was on voluntary best practice programmes which connected fleets with resources to improve their in-use efficiency.

Recently, several countries have begun to develop and implement mandatory fuel economy or GHG emission standards for HDVs. Japan implemented the first mandatory HDV fuel economy standards in 2005, followed by the US in 2011. China has implemented a voluntary industry standard on certain vehicle types and is developing a mandatory fuel consumption standard. In Europe, HDV GHG emission standards for the 2013-14 timeframe are under consideration. Table 7.3 shows the development of HDV fuel economy and GHG emission standards in assorted countries and regions.

JAPAN

Japan was the first country to implement mandatory fuel economy standards for HDVs. In 2006, the Japanese government introduced the first fuel economy standards for new HDVs, which were estimated to be responsible for approximately one-third of all CO_2 emission from motor vehicles in 2008. Fleet average fuel economy targets were set to be 7.09 km/L (369.6 gCO_2e/km) for heavy-duty trucks and 6.30 km/L (416 gCO_2e/km) for buses by 2015. Both targets represent a 12 per cent increase in fuel economy over fleet average fuel economy for both vehicle types in 2002.

Japanese standards are corporate average, weight-based standards. Specific targets are set for different types of vehicles and also depend on vehicle weight. Vehicles are tested on a chassis dynamometer over the urban JE 05 test. Fuel economy is then calculated based on a computer simulation that takes into account, testing and various vehicle factors.

THE UNITED STATES

In 2011, the US passed its first GHG emissions and fuel economy requirements for HDVs through model year 2018. The new requirements require up to a 20 per cent decrease in fuel consumption for tractors, a 10 per cent decrease for delivery trucks, garbage trucks, buses, and vocational vehicles, and a 17 per cent

Table 7.3
The Development of HDV Fuel Economy and GHG Emission Standards in Various Countries

COUNTRY/ REGION	REGULATION TYPE	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Japan	Fuel Economy						Phase 1 Regulation Implemented Starting MY 2015					
				Phase 2 Development								Phase 2
United States	GHG/Fuel Efficiency	Standard proposal	Final rule			Regulation Implemented Starting MY 2014 (mandatory DOT program starts MY 2016)						
					Trailer Rule?		Phase 2 Final Rule					Phase 2
Canada	GHG/Fuel Efficiency			Standard Proposal and Final Rule		Regulation Implemented Starting MY 2014					Phase 2 Implementation?	
Mexico	Fuel Efficiency			Standard Proposal				Regulation Implemented Starting MY 2016			Phase 2 Implementation?	
China	Fuel Consumption	Test Procedure Finalised	Industry Standard Proposal	Standard Proposal	Final Rule		Regulation Implemented Starting MY 2015					
European Union	GHG	Technical Studies			Test procedure Finalised	Mandatory Efficiency Reporting and Policy Development				Policy Implementation?		
California	End-user Purchase Requirements	Requirements for new Tractors and Trailers (MY 2011+)			Additional Requirements for Existing Tractors and Trailers (<MY 2010)				Additional Requirements for Existing Trailers and Reefers (<MY 2010)			

Source: NTDPC Research.

decrease for heavy-duty pickups and vans by 2018 over 2010 year levels.

While the Japanese approach was largely based on engine improvements, the US took a comprehensive look at improving HDV fuel economy. The US programme includes separate engine-only standards as well as also aerodynamics, tires, and weight reduction in its approach.. This gives manufacturers flexibility while complying with regulations.

OTHER COUNTRIES
No other country currently has plans to implement HDV fuel efficiency or GHG emission standards in the near future. Europe and China are currently assessing their capability to set GHG emission standards for HDVs, but neither has yet announced anything definitive.

TWO- AND THREE-WHEELERS
Currently, there are only two countries in the world with two and three-wheeler fuel economy standards: China and Taiwan. China first implemented its two- and three-wheeler fuel consumption standards in 2008. It is expected to implement its second phase of motorcycle fuel consumption standards in the near future.

INDIAN GHG EMISSION STANDARDS

As a part of its low-carbon growth strategy, India has announced it will reduce its GHG emission intensity by 20-25 per cent over 2005 levels, by 2020. An expert group has been set up to develop a strategy to reduce the emission intensity for each of the critical sectors of the economy. After the power generation sector, the transportation sector is currently the second largest contributor of GHG emission in India. Its share is increasing as vehicles on Indian roads increase. Box 7. 6 for the recommendations of the expert group for the transport sector.

In India, the Bureau of Energy Efficiency (BEE) and the MoRTH are responsible for establishing and enforcing fuel economy and GHG emission standards. The BEE will set the standards and MoRTH will be responsible for their enforcement.

LIGHT-DUTY VEHICLES
India is currently developing its first ever fuel economy standards for passenger vehicles. These standards will be applicable to new cars, but will not include light commercial vehicles (LCVs). Including LCVs or establishing separate standards for them would be a good opportunity to reduce diesel consumption, and in turn, lower diesel subsidies the Indian government doles out every year.

New passenger car fuel economy standards were expected to be finalised in 2012, but have been delayed inexplicably. The new standards envision a continuous reduction in fuel consumption over a ten-year period. To give manufacturers adequate lead-time, they are expected to go into effect from 2015-2016. They will be implemented on a CAFC model.

India has developed its first ever fuel economy label for new cars sold in fiscal year 2011-2012. The label is

Box 7.6

Recommendations on the Transport Sector by the Expert Group on Low Carbon Strategies for Inclusive Growth

As a reflection of its intent to be a responsible member of the community of nations in the efforts to contain climate change, in December 2009, India announced that it would aim to reduce the GHG emission intensity of its GDP by 20-25 per cent by 2020 from its level in 2005. The fulfilment of this commitment requires sector-specific actions. An Expert Group on Low Carbon Strategies for Inclusive Growth was set up to develop recommendations for such actions. The Expert Group submitted an interim report providing a menu of options to reduce GHG emissions intensity in critical sectors of the economy. One of the critical sectors examined by the group was transport.

The strategy for reducing emissions intensity in the transport sector laid out by the Expert Group consists of three elements: avoid; shift; and improve.

1. **Avoid:** This element involves adopting a systems approach and reducing the need for transport through appropriate choices for locating industries and other businesses and through better urban planning to minimise commuting needs.
2. **Shift:** This element focuses on use of more carbon efficient modes of transport.
3. **Improve:** This element emphasises the use of the most carbon efficient technologies for any mode of transport.

The Expert Group focused on three specific interventions that follow from this strategy:

1. Increasing the share of rail in freight transport. This is a "shift" intervention. Chapter I in Volume III of this report which deals with Railways discusses this issue in greater detail.
2. Increasing or retaining the current modal shares of public and non-motorised transport in urban passenger transport. This is an "avoid" and "shift" intervention. It is covered in more detail in Chapter 5 of Volume III of this report on Urban Transport.
3. Improving the efficiency of the vehicle fleet. This is an "improve" intervention and is one of the subjects covered in this chapter.

For improving the fuel efficiency of the vehicle fleet, the Expert Group recommended:

1. Introduce vehicle labelling/rating systems.
2. Introduce minimum efficiency standards.
3. Introduce corporate fleet efficiency standards.

These recommendations are similar to those made on improving fuel efficiency in this chapter.

Source: 'Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth,' Planning Commission, Government of India, May 2011.

shown and described in Figure 7.26. Apart from displaying the combined fuel economy of the vehicles, the label ranks fuel efficiency on a five star system. The current rankings are based on fleet average fuel consumption by kerb weight for fiscal year 2009-2010. This means that vehicles with the highest fuel efficiency may not have the highest number of stars. Conversely, vehicles with the lowest fuel efficiency may get more than one or two stars. Despite the BEE label in Figure 7.26 having been finalised, it has not yet been made mandatory.

HEAVY-DUTY VEHICLES

HDV fuel consumption standards have not yet been considered in India, though there is much potential to reduce fuel consumption from HDVs. Probably, they will follow once LDV standards have been put in place.

TWO- AND THREE-WHEELERS

Two and three-wheeler fuel economy or fuel consumption standards may follow after LDV and HDV standards get finalised. Since sales of two- and three-wheelers are high in India, fuel consumption standards for this class of vehicles will be important in curbing overall fuel use and GHG emission. There is also much room for improvement in two- and three-wheeler fuel efficiency in India.

IMPACT OF GHG STANDARDS

According to analysis by the ICCT, fuel use and CO_2 emission in India will decrease significantly with implementation of vehicle fuel consumption standards. Figure 7.27 shows results of the ICCT's Alternate scenario over the BAU scenario[22]. The Alternate scenario assumes the following annual reduction in GHG emission between 2015 and 2025: 3 per cent for LDVs; 2 per cent for HDVs; 1 per cent for two- and three-wheelers.

From Figure 7.27, it can be seen that over 1,665 million barrels of oil can be saved and 695 million tonne of CO_2e emissions can be avoided if the

22. ICCT (2012).

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Figure 7. 26
India's New Vehicle Fuel Economy Label

Source: NTDPC Research.

2030 Alternate scenario were to become reality. Certainly, reductions in CO_2 emission would continue even without further reductions in new vehicle fuel consumption, as more fuel-efficient vehicles replace old ones.

RECOMMENDATIONS TO REDUCE ENERGY CONSUMPTION AND CO_2e EMISSION

MANDATE FUEL EFFICIENCY LABEL FOR ALL NEW VEHICLES

A BEE label to clearly display a passenger vehicle's fuel efficiency has been developed, but not made mandatory. India should mandate this label for all new model year 2014 and later cars so consumers can make informed decisions when they purchase vehicles.

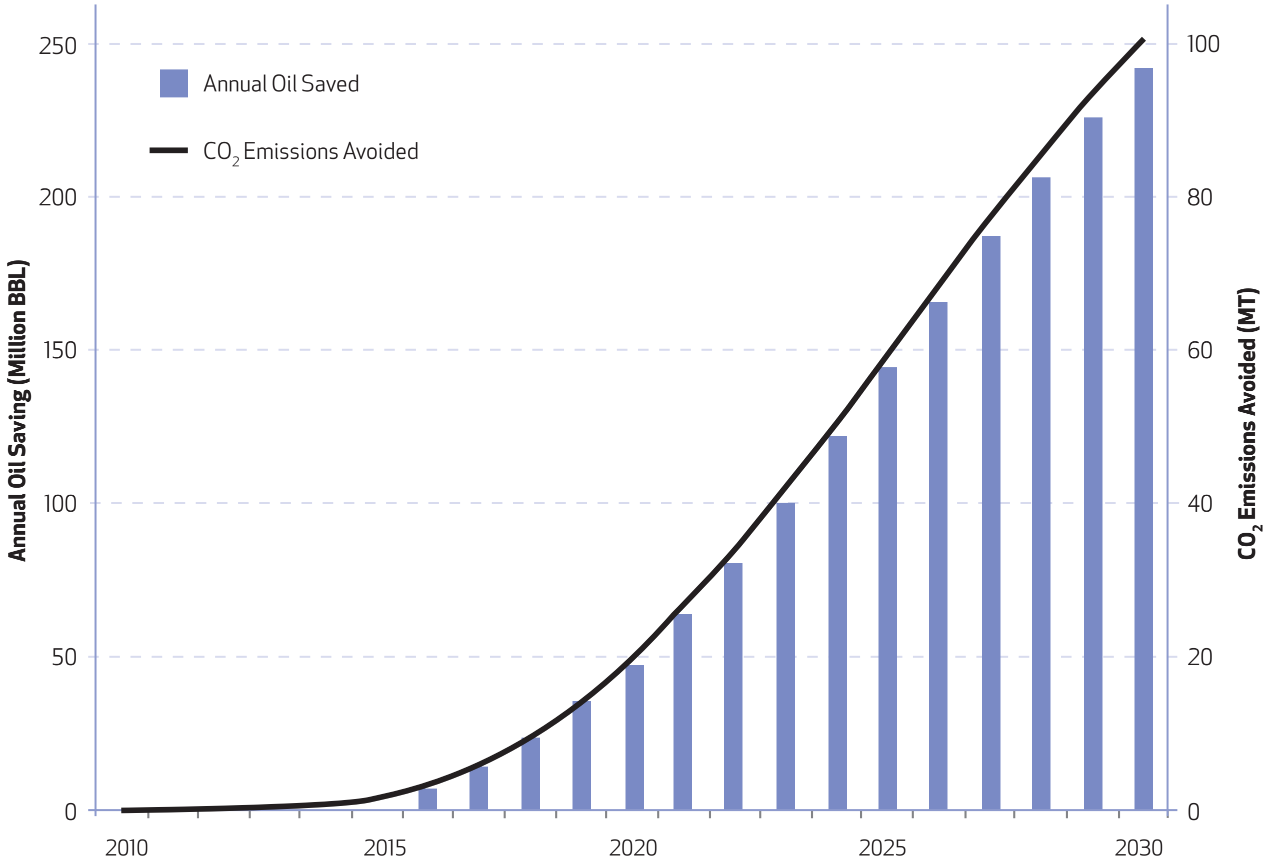
NOTIFY LDV FUEL CONSUMPTION STANDARDS

India has already developed LDV fuel consumption standards for the remainder of this decade, but their implementation has been delayed inexplicably. These standards should be notified immediately, and assessment for standards beyond 2020 should be started. Europe is targeting its LDV fleet average GHG emission to be 95 gCO_2e/km by 2020, which is far more stringent than standards proposed in India. Given that India's LDV fleet average GHG emission is roughly equivalent to those in Europe at the moment, India should aim for 95 gCO_2e/km by 2025 at the latest.

DEVELOP HDVs AND TWO- AND THREE-WHEELERS FUEL CONSUMPTION STANDARDS

The government has indicated it would begin this process once LDV standards have been finalised. There is also much that can be done to improve the fuel efficiency of HDVs and two- and three-wheelers. This is especially important in India, where motorcycles dominate new vehicle sales and are expected to do so in the future. The process to develop fuel consumption standards through the remainder of this decade for these vehicles should begin immediately. HDV standards should be in place by 2015 and two- and three-wheeler standards, by 2016. The target for both categories should be to reduce fuel consumption by 20 per cent under current levels by 2020.

Figure 7. 27
Annual CO_2 Emission Under the BAU and Alternate Scenarios



Source: ICCT (2012).

PROMOTE NMT AND PUBLIC TRANSPORT, ESPECIALLY IN URBAN AREAS

Reductions in energy consumption and GHG emissions can also come by promoting public transport and NMT, which would also stem the growth of private vehicles in most Indian cities. Adequate and quality public transport systems should be assured in all cities with populations above 500,000 and safe NMT options should be available everywhere.

SUMMARY & CONCLUSIONS

Energy use and GHG emission by the Indian transport sector are growing dramatically. This will continue unless strong action is taken. Most studies predict energy consumption by the transport sector will increase by factor of 2 to 4 over current levels, by 2030.

Increasing energy use and GHG emission means India will become even more dependent on imported fuels. This can hurt India's energy security and economy, as it sends money abroad rather than investing at home. GHG emission also exacerbates the problem of global warming, which can have dire effects on Indian agriculture and coastal populations.

To mitigate these problems India can:

i) Develop better urban development policies that incentivise public transport and NMT over private vehicle use.

ii) Implement stringent fuel consumption standards for all vehicle types. Indian vehicles are already relatively fuel-efficient, since they are typically smaller. The potential to further improve vehicle fuel efficiency over the next decade or so is also well-recognised.. Still, India risks falling behind other countries that have already implemented LDV fuel efficiency standards and are in the process of implementing HDV and two- and three-wheeler fuel efficiency standards.

India has developed LDV fuel consumption standards for the remainder of this decade, but it has inexplicably not notified them. These standards should be notified immediately, and assessment of the potential to reduce LDV fuel consumption beyond 2020 should begin immediately. India should aim for its LDV fleet average emission to be 95 gCO_2e/km by 2025.

Likewise, the development of fuel consumption standards for HDVs and two- and three-wheelers should be started immediately. Standards for HDVs should be in place by 2015, and those for two- and three-wheelers, by 2016. Both should aim to reduce fuel consumption by 20 per cent of current levels by the end of this decade.

LIFE CYCLE ANALYSIS OF TRANSPORT MODES

NEED FOR FACTORING LIFE CYCLE ENERGY AND CO_2 COSTS IN TRANSPORT DECISIONS

Environmental impact assessment exercises carried out to support decision-making in transport sector do not consider the full life cycle energy and CO_2 impact of transport modes and focus on the tail pipe impact only. It is, however, necessary that a holistic approach is adopted while analysing impact.

This is because different transport modes involve varying degrees of construction and maintenance activities; while some modes may be highly material and energy intensive, others may be comparably less energy intensive. Material and energy consumption at various stages of a transport project i.e. construction, operations and maintenance, need to be examined in order to fully understand their impact on environment.

Life cycle analyses (LCA) are typically used to assess such holistic/full-life impact of various products, systems, projects, etc. LCA is considered to be a robust decision-support tool due to the comparative character of its analysis . It helps identify life stages of a product/system having maximum impact and hence enables identification of appropriate mitigation strategies. Full life cycle impact of transport needs to be accounted for and recognised while taking policy decisions related to inter-modal choices and intra-modal greening.

ESTIMATING LIFE CYCLE ENERGY AND CO_2 IMPACTS ON SCOPE OF LCA

All stages in the life cycle of a transport mode like construction of fixed infrastructure and production of materials used in construction, manufacture of rolling stock, movement of rolling stock for transportation of people/goods, maintenance of rolling stock, maintenance of fixed infrastructure, etc require material and energy consumption and lead to CO_2 emission. The LCA should take into account all these life stages. However, certain life stages/activities can be left out in order to ensure that the LCA exercise is doable. A good LCA exercise should typically include the following life stages.

Life Cycle Analysis helps identify life stages of a product/system having maximum impact and hence enables selection of the right mitigation strategies. Full life cycle impact of transport needs to be recognised when taking decisions on inter-modal choices.

CONSTRUCTION OF THE TRANSPORT CORRIDOR/FIXED INFRASTRUCTURE

PRODUCTION OF CONSTRUCTION MATERIALS

Construction of any transport corridor requires consumption of materials. While on-site consumption of materials may not have any emission, the production of most construction materials is an energy-intensive process that also leads to CO_2 emission. The LCA framework should include this indirect energy consumption component, commonly referred as the 'embodied energy' of materials, and the resultant 'embodied CO_2' of materials.

TRANSPORTATION OF CONSTRUCTION MATERIALS

Once produced, materials are transported to construction sites by motorised modes like trucks. There are two types of energy consumption during this life stage–direct energy consumption by trucks and embodied energy of trucks. While the direct energy consumption component should be included in the LCA framework, the indirect energy consumption i.e. embodied energy of trucks need not be included because these trucks are capital assets,re-used for other construction and non-construction activities too.

ON-SITE IMPACTS: ON-SITE CONSUMPTION OF ENERGY

On-site construction processes require energy to run construction machinery, generate heat, etc. Diesel, electricity and fuel oil are the most common fuels consumed on-site. These processes and their CO_2 impact should be included in the LCA. Indirect energy consumption and CO_2 due to manufacturing of construction machinery and equipment, however, need not be included in the LCA.

ON-SITE IMPACTS: REMOVAL OF VEGETATION

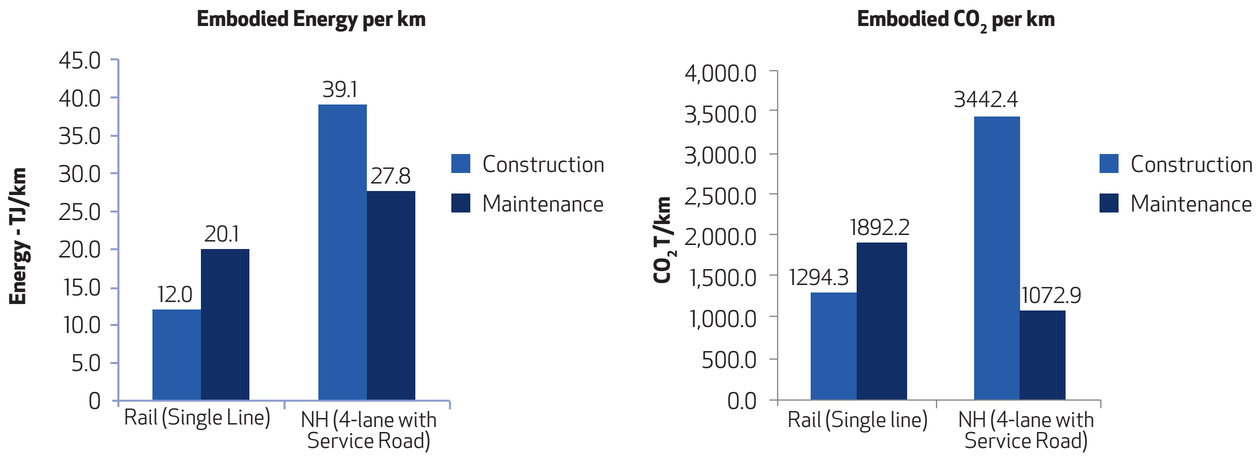
Construction of transport corridors often require removal of vegetation, which leads to loss of the carbon sequestration (CS) potential of vegetation. The LCA should include this CS potential loss.

OPERATIONS ON THE TRANSPORT CORRIDOR

Operations on transport corridors involve movement of the rolling stock. Energy consumption and CO_2 emission due to movement of rolling stock (direct) and manufacture and maintenance of rolling stock (indirect) should be included in the LCA.

Figure 7. 28

Construction of Rail and National Highways: Embodied Energy and CO_2 Emission



Source: Life cycle analysis study carried out by TERI for NTDPC

Note: It should be noted that the above analysis has been carried out for sample rail and national highways projects.

MAINTENANCE OF THE TRANSPORT CORRIDOR

Energy and CO_2 impact due to annual routine maintenance and periodic maintenance/renewal should be included in LCA as done in the construction stage.

CONSIDERING LCA FOR INTER-MODAL DECISIONS

An understanding of the life cycle energy and emission costs resulting from the above activities in the life cycle of a transport project can help make informed and objective choices of transport modes and technologies in our policies and plans. While financial and technical feasibility analyses are carried out to select the most suitable mode of transport on a corridor/in a city, there is also a need to evaluate life cycle energy and emission costs of the alternate modal options and understand their environmental costs. For e.g. while financial feasibility analysis may indicate construction of national highways as being more cost effective than rail projects, LCA indicates that national highways are more energy and CO_2 intensive during construction, in comparison. (Figure 7.28).

Metro rail projects in urban areas have highest construction costs. LCA comparison indicates that construction of metro has highest environmental costs of all alternatives for urban areas (Figure 7.29).

While cities may choose high-capacity public transport systems like the metro rail as the least carbon emission-generating technology for public transport because it generates no emission at the tail pipe, an LCA evaluation indicates that a metro system generates more CO2 emission per km on a life cycle basis compared to, say, a Bus Rapid Transport system, which can also be high-capacity (Figure 7.30).

But the same metro system, however, is more energy efficient (on a per PKM basis) for its full life period, when compared to a BRT system (Figure 7.30). Introducing life cycle impact considerations can hence bring more detailed understanding of the overall impact of a system/proposed infrastructure project that are not limited to just tailpipe or operations stages and help decision makers make informed choices based on the economic, social and environmental goals set by the national, state or city governments.

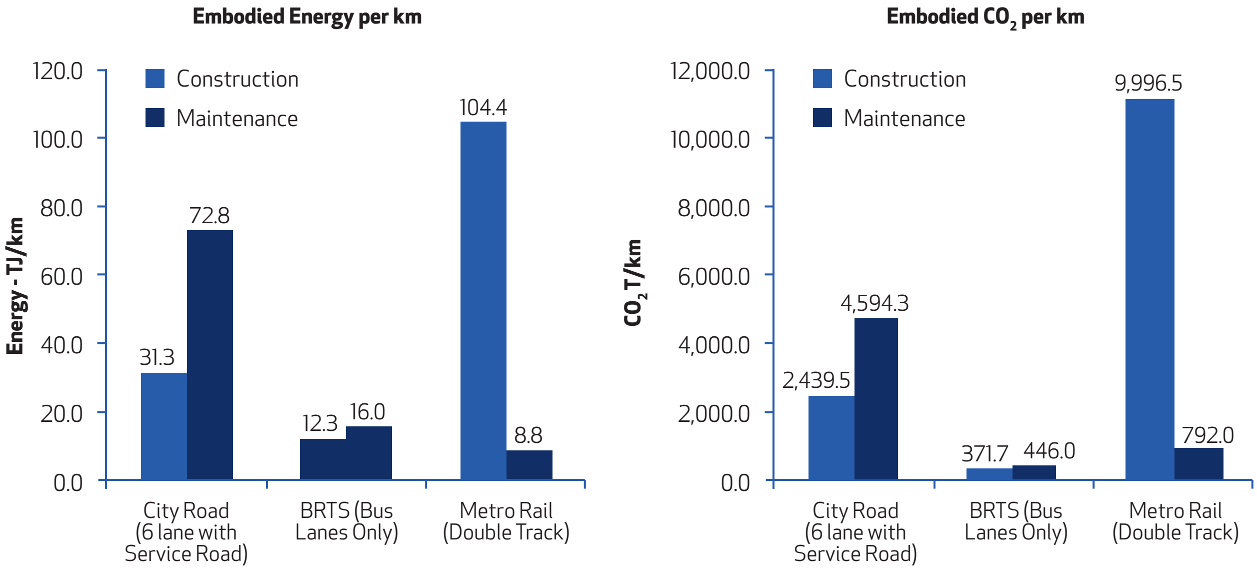
It is important to note that LCA results cannot be generalised. While in smaller cities, high-capacity systems like metro rail may not look desirable on a life cycle energy and emission impact basis (per PKM) on account of the low usage, the same systems may be highly desirable in very large cities having very high usage levels. The choice of mode hence needs to be context-specific and an economically and environmentally feasible choice.

CONSIDERING LCA FOR INTRA-MODAL GREENING

Construction and maintenance of transport infrastructure involves consumption of materials and fuels, some of which are highly energy- and carbon-intensive, significantly contributing to the life cycle energy and CO_2 impact of a particular transport mode.

LCA, if carried out, can indicate the materials and fuels that could be replaced by alternative materials and fuels that are less energy- and carbon-intensive. The LCA can also indicate the positive impact of using locally-available materials in reducing costs. Some possible areas where energy reduction can be achieved during the life of a transportation system are:

Figure 7. 29
Construction of Urban Transport Projects: Embodied Energy and CO_2 Emission



Source: Life cycle analysis study carried out by TERI for NTDPC.
Note: It should be noted that the above analysis has been carried out for sample urban transport projects.

- Reducing energy and CO_2 intensity of conventional materials used,
- Using alternative materials that are comparatively less energy- and CO_2 -intensive,
- Using locally available materials,
- Using energy-efficient processes and machinery during construction and maintenance,
- Optimising resource utilisation during construction and maintenance, especially for transportation of materials (using locally available materials, reducing idling, using rail for bulk transport of materials, etc.),
- Using alternative fuels for construction processes and for transportation of materials during construction
- Promoting inter-modal shift (towards more energy-efficient modes),
- Improving efficiency of rolling stock, and
- Reducing energy and material intensity during manufacturing and maintenance of rolling stock.

LCA also indicates that if the life of projects is enhanced, then the energy and CO_2 impact due to reconstruction can be reduced/deferred, especially in the case of road-based projects that tend to have a shorter life. Project life can be enhanced by continued maintenance. This will help reduce both monetary and environmental costs on a life cycle basis.

It is recommended that LCA exercises should be carried out at least for all capital-intensive transports projects like metro rail, BRT, national highways, etc. in order to identify intra-modal improvements in terms of material substitution, bringing about operational efficiencies, reducing logistics coss, etc.

BUILDING CAPACITY FOR LCA

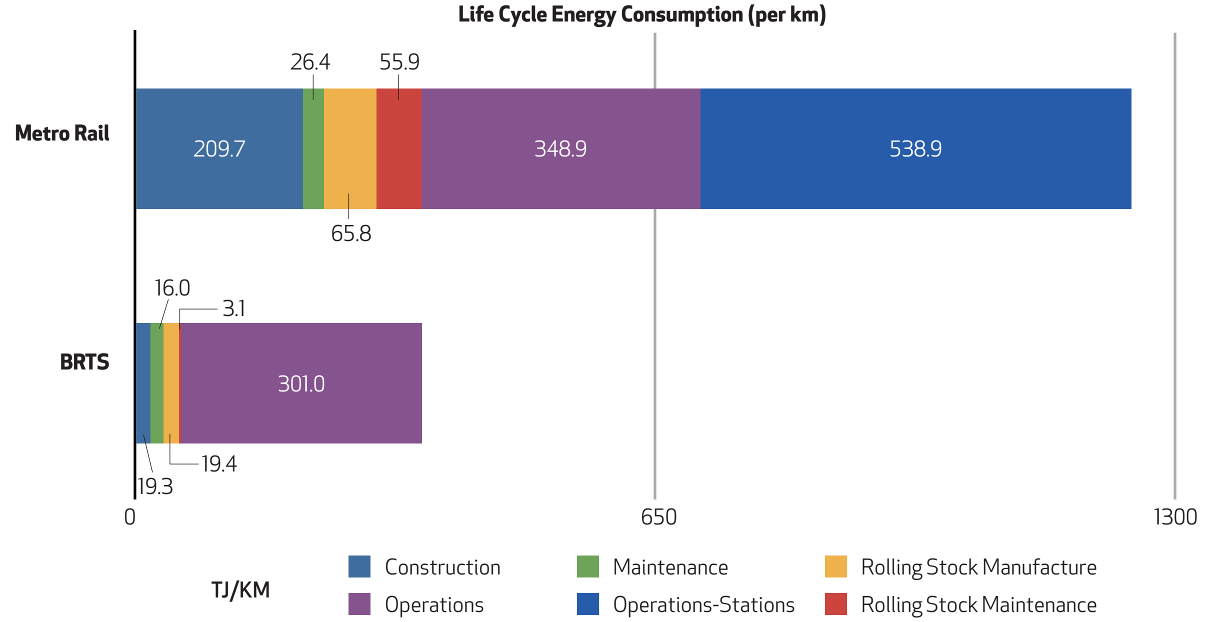
Conducting LCA calls for understanding of LCA concepts and analytical skills. These skills do not exist in ministries, government agencies and in most cities including metros. It might also be difficult and not cost-effective to build these skills in all agencies and cities. It is hence recommended that the capacity for conducting LCA should be built in key central agencies like the Planning Commission, state governments and in all metros. State governments can conduct LCA for the other cities.

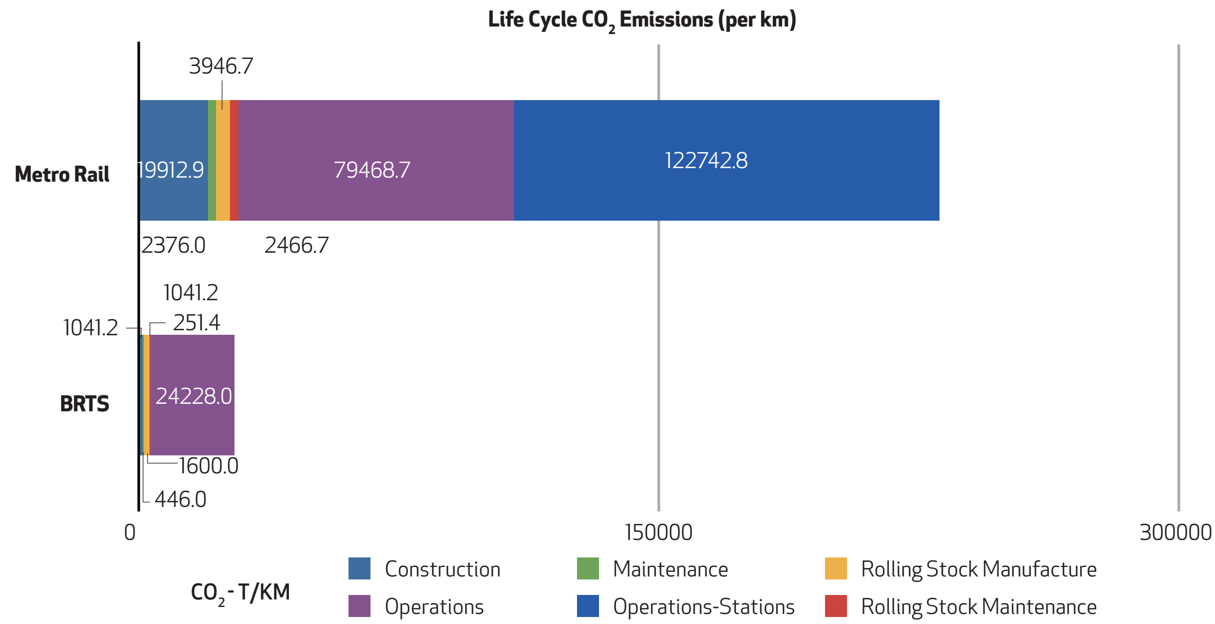
FINDINGS & RECOMMENDATIONS

India has come a long way over the last two decades in reducing vehicle emission. Still, associated poor air quality and public health problems drive the need for further emission control. Many Indian cities have been ranked among the most polluted in the world. Vehicles are responsible for the majority of urban NO_x emission and 30-50 per cent of PM emission, in addition to significant HC and CO emission. The problem is exacerbated by the preference for diesel cars in India due to diesel subsidies. Currently, new diesel cars are allowed to emit much more NO_x and PM than gasoline cars.

India also lags behind international best practices in terms of fuel quality and vehicle emission standards. Sulphur levels in fuel remain high, well above the maximum of 10 ppm required for the best clean vehicle technologies to function optimally. Nor does India have any plans of implementing 10 ppm sulphur fuels nationwide any time soon. As a result, vehicle emission standards are not where they can be. Most of

Figure 7. 30
Life Cycle Energy and CO_2 Emission from Metro and Bus Rapid Transit System (BRTS) Projects





Source: Life cycle analysis study carried out by TERI for NTDPC.
Note: It should be noted that the above analysis has been carried out for sample urban transport projects.

India is at Bharat III, with a handful of cities ahead at Bharat IV.

In contrast, the US, Europe, South Korea, and Japan have had 10 ppm sulphur fuels for many years now. Europe is in the process of moving to Euro 6/VI. Countries at similar economic levels as India, such as China, Mexico, and Brazil, are also planning to move ahead on fuel quality and vehicle emission standards shortly.

There is much room for improvement for compliance and enforcement issues in India. Standards are meaningful only if complied with. The US, in particular, has been at the forefront of compliance efforts for over 40 years. By shifting the focus of vehicle emission compliance from new vehicles to in-use testing, over time the onus has been placed on vehicle manufacturers to ensure their products function as designed throughout their useful life. And testing fuel quality at multiple points along the distribution system has incentivised oil companies and fuel handlers to ensure fuel quality is met at all times. Clear, strict recall policies and punitive measures for non-compliant vehicles and fuels compel industry to test its own products. So the US EPA save money as it does not have to allocate resources to test many vehicles or all batches of fuel.

India can learn from the vast experience of the US and other countries to enhance its own regulatory programmes. Vehicle emission testing is currently limited to new vehicles, meaning there is little data to analyse the effectiveness of emission control technologies throughout their useful life. Weak test cycles mean that while vehicles pass initial emission testing, they may emit much more in real-world situations. While the laws provide for government testing of fuel quality, there is little evidence this is actually done.

Energy use by the transport sector is increasing dramatically, led primarily by private vehicle use. Studies predict that energy use by the transport sector will increase two to fourfold over the next 20 years. Unless strong action is taken, the consequences will be dire for India's energy security, economy, air quality, and global warming.

Enhanced public transport and NMT systems that disincentivise private vehicle use are one step towards combating these problems. These are discussed in more detail in the chapter on urban transport. Establishing vehicle fuel efficiency standards also help mitigate these problems.

India has already developed progressively stricter LDV fuel consumption standards for the remainder of this decade, but they have not yet been notified. They are also significantly weaker than European standards, despite the fact that Indian and European LDV fleets are currently at similar fuel consumption levels. Processes to develop HDV and two- and three-wheeler fuel consumption standards have not even begun, while many other countries are starting to implement these standards already.

It is important to treat vehicle emission and fuel use as a system. Improvements in one often lead to improvements in the other. For example, many technologies that improve vehicle fuel efficiency not only lead to lower GHG emission and fuel consumption, which mitigate global warming and reduce India's dependence on imported fuels, but also reduce air pollutant emission, which improves air quality and public health. Therefore, this chapter looks at all these issues holistically.

With the formation of a new Auto Fuel Policy Committee in January 2013, there is a lot of potential for India to make a headway on all of the points mentioned above. The committee has the authority to recommend reforms through the year 2025. The recommendations below are a starting point for that committee to reduce long-term vehicle emission and fuel consumption in India.

TIGHTER FUEL QUALITY STANDARDS

50 ppm sulphur fuels should be mandated nationwide by the middle of this decade, and 10 ppm sulphur fuels should be mandated nationwide by 2020. Reforms in diesel pricing being implemented currently should be used to pay for refinery investments needed to produce these cleaner fuels.

Energy use by the transport sector is increasing dramatically,led primarily by private vehicle use. Unless strong action is taken, the results will be dire for India's energy security, economy, air quality, and global warming.

TIGHTER NEW VEHICLE EMISSION STANDARDS

Bharat IV fuel quality standard should be implemented nationwide by the middle of this decade, with a target to reach Bharat VI by 2020.

EVAPORATIVE EMISSION STANDARDS

By mid-decade, India should mandate Stage I controls when retail outlets are supplied with fuel, and Stage II controls for vehicle refuelling. India should also mandate all new vehicles to have on-board refuelling vapour recovery (ORVR) systems at the same time. These systems return vapours to a vehicle's fuel tank rather than to retail outlets. Stage II controls can be lifted about ten years after the implementation of ORVR systems because the majority of India's vehicle fleet will then have ORVR systems in place.

WORLD-HARMONISED TEST CYCLES

Replacing current test cycles with world-harmonised test cycles will make it less likely that certain vehicles 'beat' emission testing by passing the test cycle while emitting much more under real-world conditions. India should make world-harmonised test cycles optional when Bharat IV regulations go into force nationwide and mandatory when Bharat V regulations come into force.

REVIEW AUTO FUEL POLICY EVERY FIVE YEARS

In 2003, the Mashelkar Auto Fuel Policy committee had recommended a review of the auto fuel policy every five years. Yet a new Auto Fuel Policy Committee was not formed until 2013, ten years later, despite the fact that the Mashelkar Committee's mandate was through the year 2010. It should be made compulsory that a new Auto Fuel Policy Committee be formed five years after the previous one completes its work. Provisions should be made for this in the MoPNG's five-year plans.

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SINGLE AGENCY FOR VEHICLE EMISSION AND FUEL QUALITY REGULATIONS

In 2003, the Mashelkar Auto Fuel Policy Committee had recommended the formation of a National Automobile Pollution and Fuel Authority (NAPFA) responsible for setting and enforcing vehicle emission and fuel quality standards in India. Currently a number of ministries and agencies are responsible for compliance and enforcement in India. This allows blame to be passed onto others in case of problems. Parliament should establish a permanent NAPFA and ensure that it is fully-funded.

NATIONAL IN-USE VEHICLE TESTING PROGRAMME

India needs to establish a robust Inspection and Certification (I&C) regime to ensure safety, road worthiness and emission performance of in-use vehicles. National-level vehicle testing needs to move beyond type approval (TA) and conformity of production (COP) to include in-use testing. All motor vehicle categories should be covered under the I&C regime. There should also be a recall policy to recall models which on testing do not adhere to the emission standards. Modern I&C centres with minimum manual interference need to be established on a PPP basis in a phased manner. In the beginning, transport (commercial) vehicles could be targeted, followed by non-transport (private) vehicles. Cities with higher vehicular pollution should be targeted first. Commercial and older vehicles should be tested more frequently, preferably annually. The central government should lay down the policy and regulatory framework for tests, equipment and manpower requirements based on the advice of an independent agency like a National Accreditation Board (NAB) that could also monitor implementation of I&C by state governments.

CLEAR RECALL POLICIES AND PUNITIVE MEASURES

Until NAPFA is set up, the MoRTH should establish clear punitive measures and recall processes for non-compliant vehicles and the MoPNG should establish clear punitive measures for non-compliant fuels.

TEST FUEL QUALITY AT RETAIL OUTLETS

There is little, if any, evidence that governmental or independent fuel quality testing is done anywhere along the fuel distribution system in India. Given the history of fuel adulteration, it is especially important to test fuel at retail outlets, where consumers ultimately purchase fuels. Until NAPFA is set up, the MoPNG should develop a national plan to test fuel at retail outlets, along the lines of what is done by the US EPA or Japan's Ministry of Economy Trade and Industry (METI) and National Police Agency (NPA). Mandate fuel efficiency label for all new vehicles A BEE label to clearly display a vehicle's fuel efficiency has been developed but not made mandatory. India should mandate this label for all new model year 2014 and later vehicles so consumers can make informed purchase decisions.

NOTIFY LDV FUEL CONSUMPTION STANDARDS

India has already developed LDV fuel consumption standards for the remainder of this decade, but their implementation has been delayed inexplicably. These standards should be notified immediately and assessment for standards beyond 2020 should be started. The country should target LDV fleet average GHG emission to be 95 gCO2e/km by 2025, Europe's target for 2020.

DEVELOP HDVs AND TWO- AND THREE-WHEELERS FUEL CONSUMPTION STANDARDS

A lot can be done to improve the fuel efficiency of HDVs and two- and three-wheelers. This is especially important in India, where motorcycles dominate new vehicle sales and will continue to do so in the future. India should aim to have HDV standards in place by 2015 and two- and three-wheeler standards by 2016. The target should be to reduce fuel consumption by 20 per cent of current levels by 2020 for both categories.

PROMOTE NMT AND PUBLIC TRANSPORT, ESPECIALLY IN URBAN AREAS

Adequate and quality public transport systems should be assured in all cities with populations above 500,000 and safe NMT options should be available everywhere. Other measures, such as integrated land use planning, enhanced traffic management systems, and integrated transport modes, also help reduce the energy intensity of urban transport systems. The chapter on urban transport details these issues and makes recommendations.

LIFE CYCLE ANALYSIS APPROACH TO BE ADOPTED IN TRANSPORT DECISION MAKING

It is recommended that the capacity to conduct LCA should be built in key central agencies like the Planning Commission, state governments and all metros. State governments can conduct LCA for the other cities. These agencies should carry out LCA analysis to facilitate decisions related to inter-modal choices and intra-modal improvements which reduce environmental costs of transport projects.

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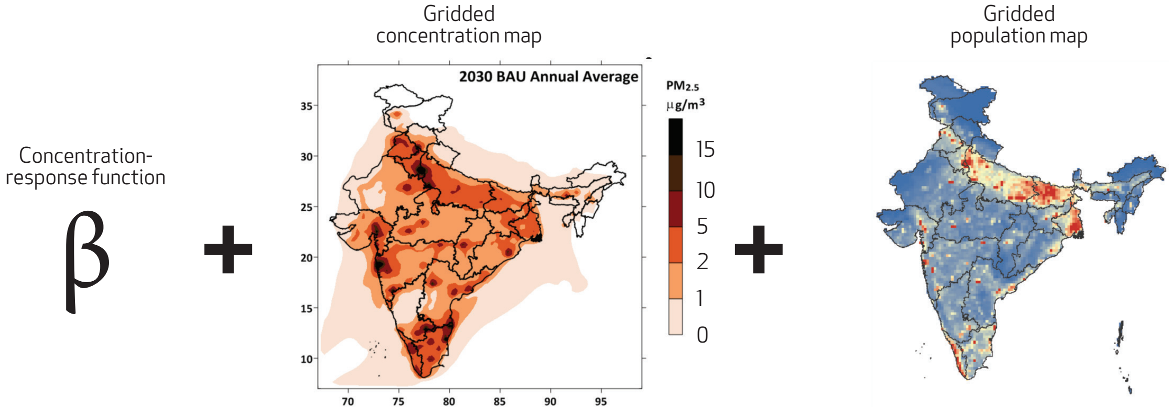
Figure 7. 31
Schematics of Health Impacts Assessment



Source: Guttikunda and Jawahar (2012).

ANNEX

METHODOLOGY FOR HEALTH IMPACT ANALYSIS IN GUTTIKUNDA AND JAWAHAR (2012)

Health impact analysis estimates premature mortality and morbidity as a result of outdoor air pollution, using concentration-response functions. However, this is not as easy to calculate and in all likelihood is a gross underestimate that captures only the direct impacts of air pollution (respiratory illness, allergies etc.). The road transport emissions account for 30 per cent of ambient pollution and isolating impacts of transport sources is tricky. The indirect impacts of exposure to pollutants are also many - an increase in inflammation, cardiac conditions, decrease in fertility, cancer, premature birth, among others.

The health impacts (mortality and morbidity) of baseline and future scenarios are estimated using the following methodology-

$$\delta E = \beta * \delta C * \delta P$$

where,

δE= number of estimated health effects (various end points for mortality and morbidity)
β= the concentration-response function; which is defined as the change in number of cases per unit change in concentrations per capita. This is established based on epidemiological studies conducted over a period of time, analysing the trends in hospital records and air pollution monitoring

δC= the change in concentrations

δP= the population exposed to an incremental concentration; defined as the vulnerable population, of age more than 17 years, which spends more time outdoors. This spatial spread of population is obtained from GRUMP (2010) and Census-India (2011).

The concentration-response function (β) (CRF) is defined as the change in the number of cases per unit change in concentrations per capita. Health effects range from minor irritation in eyes and upper respiratory system to chronic respiratory disease, heart disease, lung cancer, and lead up to premature death. In case of mortality, CRF is set to 0.225 per cent per 10 µg/m^3 increase in the PM_{10} concentrations[22] as the lower bound[23] and 0.6 per cent per 10 µg/m^3 increase in the PM_{10} concentrations (WHO, 2005) as the higher bound[24]; the total death incidence rate of 241 per 1,000 people was adjusted for the those due to lower and upper respiratory illnesses (including bronchitis and asthma) and cardio vascular diseases. Among the reported number of deaths, these causes account for 15 per cent of the annual death rate[25]. Morbidity in terms of asthma cases, chronic bronchitis, hospital admissions, and work days lost is also estimated.

The population exposed (δP) is defined as the total population exposed to the incremental concentrations (δC) in each grid cell. The grid level population is estimated using GRUMP (2010) and Census-India (2012) and presented in the figure. The population data and the concentrations of PM_{10} are available at 0.25° resolution.

Comprehensive Air Quality Model with Extensions (CAMx) is used; it is an Eulerian photochemical dispersion model that allows for integrated assessments of gaseous and particulate air pollution over many scales ranging from sub-urban to continental.

22. HEI (2010).
23. Public Health and Air Pollution in Asia (PAPA): A Multicity Study of Short-Term Effects of Air Pollution on Mortality. Health Effects Institute (2010) @ http://pubs.healtheffects.org/view.php?id=348 (accessed 27 March 2014).
24. Health effects of transport related air pollution (2005) published by WHO @ http://www.euro.who.int/en/what-we-publish/abstracts/health-effects-of-transport-related-air-pollution (accessed 27 March 2014).
25. Annual Report (2010) on "Registration of Births and Deaths in India". Directorate of Economics and Statistics, the Government of Delhi, New Delhi, India.

This model is designed to unify all of the technical features required of 'state-of-the-science' air quality models into a single open-source system that is computationally efficient, easy to use, and publicly available[26]. For the analysis of the road transport emissions in India, the CAMx model is set up to model the concentrations at 0.25° horizontal grid resolution. The vertical grid resolution extends to 12km stretched over 23 layers. The removal processes in the model include dry deposition varying with the land-use patterns and wet deposition due to predominant meteorological conditions.

The meteorological data (3D wind, temperature, and pressure, as well as surface heat flux and precipitation fields) is derived from the National Centre for Environmental Prediction (NCEP) global reanalysis[27]. The NCEP databases are available for the period of 1948 to 2012. We selected 2010 as the base year and the required data fields are processed for this year. The same meteorology for 2010 is used for all the future scenarios. The NCEP global meteorological fields are processed through the RAMS meteorological model (version 6.0)[28] and the data is available at 2 hour interval for the parameters necessary to run the CAMx dispersion model[29].

Source: Guttikunda and Jawahar (2012).

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DieselNet (2009b) Europe: Heavy-Duty Diesel Truck and Bus Engines. http://www.dieselnet.com/standards/eu/hd.php (accessed 20 October 2013).

26. The CAMx model source code, support systems, manuals, and test cases are available for download @ http://www.camx.com/about/default.aspx (accessed 10 October 2012).
27. The meteorological fields are available for free @ http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html (accessed 10 October 2012).
28. The RAMS v6.0 model source code, support systems, manuals, and test cases are available for download @ http://www.atmet.com (accessed 10 October 2012).
29. All the animations are available @ http://www.urbanemissions.info/india-meteorology (accessed 10 October 2012).

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