India-California Air Pollution Mitigation Program (ICAMP)

Initiative for Mitigating Air Pollution from the Transportation Sector

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A joint initiative by the University of California at San Diego (UCSD), The Energy Resources Institute (TERI), India, and the California Air Resources Board (CARB)

Sponsor: The World Bank

Inception Note: Full Text
October 15, 2013
FIRST DRAFT

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A Guide to the Inception Note

The Executive Summary for Policy Makers prepared for this report can be obtained at the following e-mail address: rharnish@ucsd.edu

The Los Angeles basin of California experienced severe air quality problems in the early 1940s. The California Air Resources Board was created in 1967. The government of California instituted a number of measures over the intervening years to reduce ground level ozone, particulate matter (PM) and black carbon (BC). California has a goal of reducing diesel PM by 85 percent by 2020. This is being achieved with new emission standards, cleaner fuels, retrofits of existing engines, and enforcement programs.

A detailed analysis of technology based emission inventories and fuel use in California indicates that although the total consumption in diesel fuel has increased, the emissions of BC from diesel fuel combustion have decreased significantly. The reduction in emissions is due to a number of factors, including the introduction of low sulfur fuel, tighter emission standards, cleaner burning engines, and other improvements in technology mandated by statewide regulations. The control of BC from diesel is an effective means of mitigating near-term global climate change.

India's air quality is impacted by transport emissions that also have health impacts. With exponential growth in vehicles focused in rapidly growing urban centers, the air quality has suffered. Air pollution is a serious concern, especially in the urban centers of the country. The main air pollutants are particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide (CO), hydrocarbons (HC/VOC) and sulfur di-oxide (SO_2), which impact human health in different ways. While many of these are directly related to respiratory disorders, some of them have shown evidence of linkages with cardio-vascular diseases and cancer.

India's transport emissions could be reduced by policies and investments promoting a systemic shift of passengers and freight to more efficient, lower-emissions forms of transport as well as by more direct regulatory and policy approaches aimed at encouraging more efficient, lower-emitting vehicles. The gains from a shift in modes of transport are difficult to estimate, but clearly significant. A series of initiatives including stricter vehicle emissions standards, durability requirements and in use vehicle testing could reduce emissions by 85% of where they otherwise might be through 2030 and reduce premature deaths to 230,000 by 2030. However, India's institutional and policy knots must be untied to achieve these emissions reductions. Policies to promote shifts in mode of transport – e.g. from road to rail for freight or private vehicles to public transport in cities – are intertwined with broader public investment and governance challenges. Regulations on fuel efficiency and emissions are tightening, but still contentious. Enforcement must be strengthened, which in turn requires streamlining responsibility and building capacity to enforce existing rules.

Current Initiative

Air pollution is now globally perceived as an important issue. Emissions of various air pollutant species (particulate matter, oxides of sulphur, oxides of nitrogen, carbon monoxide, and volatile organic compounds) released from multiple sources mix, disperse and react in atmosphere to form pollutant concentrations. The receptors (humans, vegetation, materials etc) of these concentrations show negative effects once they cross certain threshold limits (WHO guidelines). Air pollutants not only impact the receptor due to their toxicities but now also known to have effects over the global climate. A typical diagram of air pollutants classifications and their impacts is shown in Figure I.

While, emissions from different sources include gases like SO2, NOx, CO, and VOCs, they also include particles of fractions less than 10 and 2.5 µm. The constituents of PM vary based on the source characteristics and may include carbon (black or organic), ions (sulfates, nitrates etc.), heavy metals, and other crustal elements. Other than these, there are secondary pollutants formed (like Ozone) due to the chemical reactions between the primary pollutants in the atmosphere. Brief descriptions of black carbon (which is a constituent of PM) and tropospheric Ozone are presented in Box –I and II.

Transport-related emissions of particulate matter and tropospheric (ground level) ozone precursors are damaging to the environment, health, crop yields and climate. Their mitigation could lead to three major benefits globally:

1. Avoided premature deaths and morbidity that result from both direct and indirect effects of these pollutants. Ambient air pollution contributes to 3.2 million premature deaths globally.
2. Monetary savings of crops lost annually to air pollution damages. Crop losses globally range from $11-18 billion annually for rice, maize, wheat, and other staples of global food security.

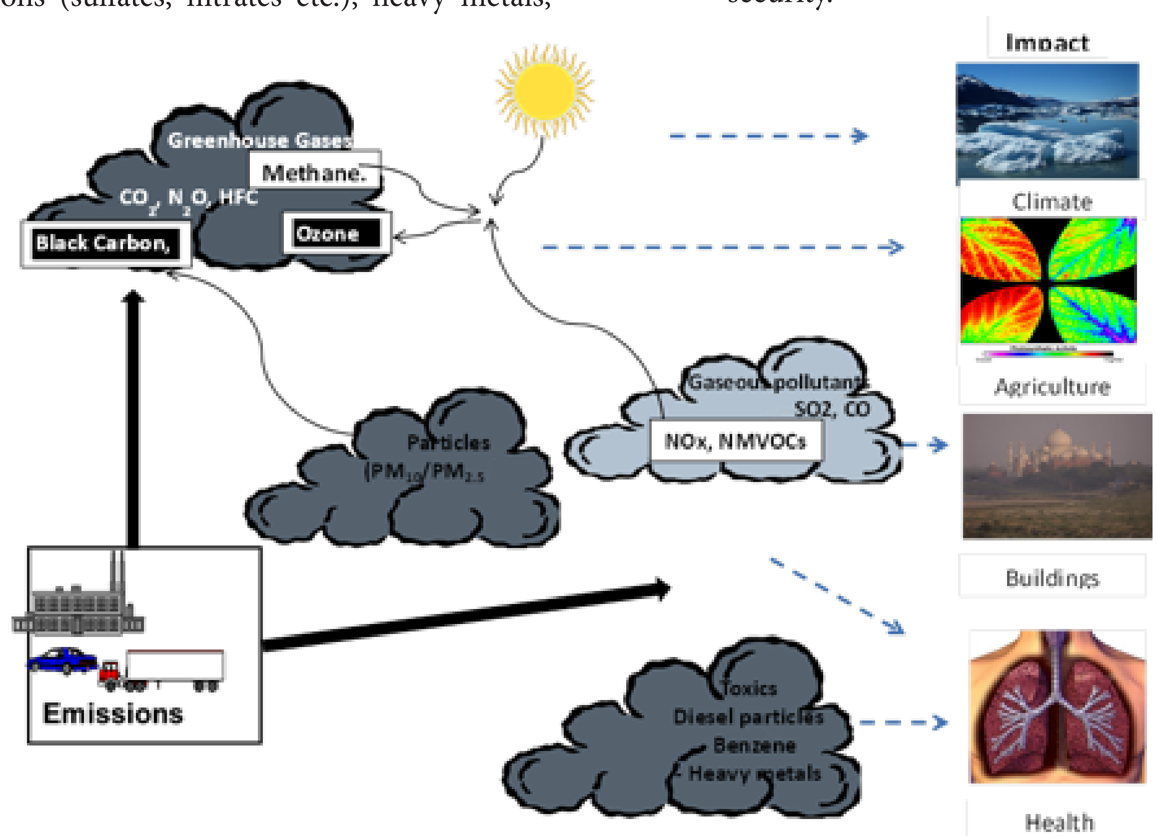

Figure I : Air pollutants classification and their major impacts

Box 1: What is black carbon?

Black carbon is a component of particulate matter formed by the incomplete combustion of fossil fuels, biofuels, and biomass. A complete combustion process should convert all the carbon in the fuel into carbon dioxide (CO_2), however due to inefficiencies in combustion processes, other substances like carbon monoxide (CO), volatile organic compounds (VOCs), organic carbon (OC) particles and BC particles are formed, along with CO_2.
While, it has the potential to cause severe health impacts, it is now also known to warm the atmosphere by intercepting the sunlight and absorbing it. It is also now linked with darkening of snow after its deposition and influencing the cloud formation. Over a period of 100 years, BC has 100-2000 times higher potential (depending on the sources) to warm the planet in comparison to CO_2, however in longer terms the effect of CO_2 dominates. BC has significant regional consequences to the monsoon, Himalayan glaciers, and Arctic sea ice. The shorter life of BC particles suggests more immediate climate benefits due to its mitigation. The ratio of BC (warming) to other particles (cooling) defines the contribution of a source in climatic impacts. Other than the climate effects, it contributes to significant health impacts by affecting the respiratory system and causing cardiovascular problems. Particulate matter emitted from diesel driven vehicles constitutes higher fractions of BC along with other harmful components, and hence has been identified as a cause of lung cancer by the California Air Resources Board (ARB) and the World Health Organization. Adverse health impacts from black carbon emissions are experienced to be higher in urban areas congested with vehicles and near highways with many heavy-duty vehicles based on diesel.

Box 2: What is tropospheric Ozone?

While there is a Ozone layer in stratosphere which protects us from UV fractions of the sunlight, there is Ozone formed in troposphere (near to the ground) which is known to have severe impacts over human health, agricultural productivities and material. It is not merely a major component of urban smog but also has a significant radiative forcing* and hence acts as an important greenhouse gas. Ozone is primarily formed by the reaction of NOx and VOCs in presence of sunlight. With rise in precursor emissions of NOx and VOCs in the last 100 years there is a threefold increase in the O_3 concentration has ben observed in the northern hemisphere. After, CO_2 and methane, it was known as third most important contributor to human-enhanced greenhouse effect. It is only recently, the research has shown to that black carbon has surpassed the radiative forcing of gases like methane and Ozone.
The effects of Ozone on human health are known to be lesser than those of PM, although still significant. However, its impacts over the agricultural productivities of important crop species like wheat, maize , cotton etc are extremely detrimental. Studies have shown to have highest Ozone concentrations in the most fertile Indo-gangetic plains in India. Impact of ground level Ozone on agricultural productivities is not only damaging to the economy of the country but also has grave implications over the issue of food security in future.

*Radiative forcing : Ramaswamy et al. (2001) define it as 'the change in net (down minus up) irradiance (solar plus longwave; in W m–2) at the tropopause after allowing for stratospheric temperatures to readjust to radiative equilibrium, but with surface and tropospheric temperatures and state held fixed at the unperturbed values'.

3. Reductions in black carbon (BC) and ozone precursor emissions could reduce the anticipated increase in global temperature over the coming decades by about half. Reducing CO_2 emissions is essential for avoiding climate change over the longer run.

India's air pollution is a known public health and environmental challenge. Many of the potential remedies are also reasonably well known, even if their costs and distributional impacts are a matter for some debate. The factors that produce emissions, however, are embedded in a complex political and institutional environment that hampers rapid change in spite of signs of increasing pressure and appetite for air pollution reduction. More rapid progress is urgently needed. Air pollution in India remains a deadly problem, especially in urban areas. The Global burden of disease estimates for 2010 show that over 620,000 people die each year in India as a result of ambient particulate matter pollution, making PM2.5 emissions the fifth largest killer in the region. Eighty percent of Indian cities violate the National Ambient Air Quality Standards (NAAQS) for PM.

The California Air Resources Board (CARB) has successfully implemented a variety of emissions control measures that have led to declining emissions even as the overall fleet size has increased. This experience offers valuable lessons for other regulators and policymakers about policy design and implementation. This project envisages knowledge transfer among the participants to highlight potential approaches, understand key factors in adapting them to India, and, in the end, accelerate integration of air pollutant reduction measures with ongoing transport development initiatives In India. This could later lead to robust frameworks for similar knowledge-to-action dialogues in other issue areas and countries. Hence, the aim of the current initiative is:

"To Convene stakeholders and experts concerned with public health, environmental damage and climate change, environmental justice, economic development, and transport industry competitiveness to develop an action agenda of scientific research, technology development, and innovative pilot programs to reduce black carbon and ozone precursor emissions from the transportation sector in India."

Our primary objective is to develop concrete, practical pathways for reducing health, agriculture, and climate-damaging particulates and ozone precursor emissions from the transportation sector in India. We propose to organize a joint program of knowledge exchange and stakeholder dialogue between world-renowned scientists; policymakers; air quality regulators from India and California; and stakeholders in India's air quality management.

For this we plan to use three steps to generate an action agenda for scientific research, technology development, and specific, feasible interventions to promote a low-emission development path for India's transport sector:

- In-person interaction among scientists, policymakers, and transport stakeholders with deep knowledge about determinants emissions as well as control options, in a neutral setting to generate an initial set of ideas for intervention. The meeting is being organized in Oakland, CA, jointly hosted by UCSD and CARB, in October 2013. A delegation of 15 persons from India representing different stakeholder groups will visit California to attend two and half days of meetings.
- Research to refine this agenda into more concrete, detailed proposals.
- High-level policy consultation to disseminate the ideas and build partnerships for further research and policy pilots. The meeting is intended to be organized in February 2014.

The exchange of in-depth knowledge on the socio-economic ecosystems underlying transport emissions, the lessons from regulatory and non-regulatory experience in both countries, and the perspectives of influential stakeholders in emission mitigation will contribute to four main results:

- Broader sensitization of policymakers/ stakeholder groups on the issues of BC and other emissions from transport sector as well as the range of emissions reductions tactics.
- Formation of new issue-based professional networks for continuing dialogue on emissions mitigation as the state of science, technologies, and monitoring evolves.
- Social innovation: adaptation of existing experience and success into specific proposals for contextually appropriate, regulatory and non-regulatory instruments for rapid results in an important global economy.
- Development and testing of a format for science-policy-development dialogue that could be replicated for other aspects of SLCP mitigation as well as in other policy areas where solutions rely on local, contextualized knowledge in addition to global science, innovation, and resource

PART I: California Actions to Reduce Ozone, PM and Black Carbon

History

The first recognized episodes of smog in Los Angeles occurred in the summer of 1943. Visibility was limited to only three blocks and residents suffered from smarting eyes, respiratory discomfort, nausea, and vomiting. The phenomenon was termed a "gas attack" and blamed on a nearby butadiene plant, but the situation did not improve when the plant was shut down. Smog events continued to plague Los Angeles throughout the 1940s (Figure 1.0).

FIGURE 1.0: View of part of the Los Angeles Civic Center masked by smog in 1948
SOURCE: Los Angeles Times photographic archive, UCLA Library

During the economic boom after World War II, Los Angeles developed severe air quality problems. The City of Los Angeles began its air pollution control program in 1945, establishing the Bureau of Smoke Control in its health department. On June 10, 1947, California Governor Earl Warren signed into law the Air Pollution Control Act, authorizing the creation of an Air Pollution Control District in every county of the state. The Los Angeles County Air Pollution Control District (APCD) was then established, the first of its kind in the U.S. During the 1940s and 1950s, air pollution control focused on obvious sources, such as backyard burning and incinerators, open burning at garbage dumps, and smoke emissions from factories (South Coast Air Quality Management District, 1997). In 1953, the Los Angeles County Air Pollution Control District started requiring controls to reduce hydrocarbon emissions from industrial gasoline storage tanks, gasoline tank trucks, and underground storage tanks at service stations. California officially adopted the Ringelmann System, which measures the opacity of smoke arising from stacks and other sources.

In 1967, California's Legislature passed the Mulford-Carrell Act, which combined two Department of Health bureaus – the Bureau of Air Sanitation and the Motor Vehicle Pollution Control Board – to establish the California Air Resources Board (CARB). Since its first meeting on February 8, 1968 in Sacramento, CARB has worked with the public, the business sector, and local governments to find solutions to California's air pollution problem. The resulting state emission standards set by CARB continue to outpace the rest of the nation and have prompted the development of new control technologies for industrial facilities and motor vehicles.

Starting in 1970, the federal government phased out lead in gasoline. In 1975, the first oxidizing catalytic converters to reduce CO and hydrocarbon tailpipe emissions came into use as part of CARB's Motor Vehicle Emission Control Program. This is the state's first example of "technology forcing" regulations, compelling industry to develop a new pollution control capability by a set deadline. In 1977, the first three-way catalytic converter to control hydrocarbons, nitrogen oxides, and CO was introduced. During the late 1970s, Los Angeles and later the entire state required vehicle inspections for measuring emissions and inspecting emission control equipment, which in 1984 evolved into the California Smog Check Program administered by the state Bureau of Automotive Repair (BAR). CARB has pioneered a motor fuels specification enforcement program since 1977 in response to adoption of a state Reid Vapor Pressure (RVP) standard. Other regulations were adopted to further control the chemical properties of gasoline by limiting lead, sulfur, phosphorus, and manganese, and to control the sulfur content of vehicular diesel fuel in Los Angeles.

In 1988, CARB adopted regulations effective on 1994 model cars requiring that they be equipped with "on board diagnostic" (OBD) computer systems to monitor emission performance and emission control equipment. Owners are alerted when there is a problem. All 1996 and newer vehicles less than 14,000 lbs. (e.g., passenger cars, pickup trucks, sport utility vehicles) throughout the United States are equipped with OBD II systems, the second generation of OBD requirements. In 1990, CARB adopted standards for Cleaner Burning Fuels (also called Phase I Reformulated Gasoline) resulting in gasoline composition changes that reduced vehicle emissions and enabled advances in catalytic converter technology. This consisted of lowering previously regulated components (RVP and sulfur); requiring the use of oxygenates year round; and regulating additional components (benzene, total aromatics and olefins). This was followed by the introduction of Phase II Reformulated Gasoline (also known as Cleaner Burning Gasoline, CBG) in 1996. In 1999, the Board amended and adopted Low-Emission Vehicle regulations, known as LEVII, which set stringent emission standards for most mini vans, pickup trucks, and sport utility vehicles (SUVs) to reduce emissions of these vehicles to the level of emissions from passenger cars by 2007.

Air Quality

The Los Angeles metropolitan area is the second-most populated urban area in the United States, after the New York Metropolitan Area. California's population grew rapidly following World War II, growing from under 7 million in 1940 to over 38 million today. Los Angeles has a diverse economy of many heavy and light industries, including two major ports, oil production and refining, and natural gas-fired power plants. The combined ports of Los Angeles and Long Beach make up the largest container complex in the U.S. Due in part to its "invention" of the suburb and freeway, it now has the greatest number of cars, trucks, and miles of roadways of any city in the world, altogether 27 intertwining freeways handle roughly 214 million vehicle-miles traveled (344 km) daily.

These mobile and stationary sources of air pollution, emitted into the Los Angeles air basin surrounded by 3000-meter mountains with prevailing oceanic winds, and capped by a persistent thermal inversion under sunny skies, created the highest levels of photochemical air pollution ever recorded. But no city has ever made greater progress toward air quality goals, with air pollution levels now less than one fourth of those in the past, during a period when population doubled and vehicle miles traveled quadrupled. The California economy has grown into the 8th largest in the world, with a gross state product of $2 trillion dollars.

Los Angles historically experienced the most severe smog in the U.S., but air pollution levels have improved dramatically. The health-based standards for lead, CO, NO_2, SO_2, and sulfates have all been attained, and peak ozone levels have dropped 75 percent relative to levels in the mid-1960s. California has also had success with PM_{10} and air toxics. Prior to the implementation of emission reduction measures beginning in the early 1960s, hourly averaged ozone mixing ratios approaching 0.70 ppm were reported in the South Coast Air Basin (SoCAB), and Stage III episodes (ozone exceeding 0.50 ppm) were relatively frequent events. Four decades of progressively more stringent controls on emissions of NOx and VOC have significantly reduced the frequency and intensity of excessive ozone levels in the SoCAB. The Basin recorded 167 days exceeding the National Ambient Air Quality Standard (NAAQS) of 0.12 ppm maximum hourly average in 1980, 158 days in 1985, 131 days in 1990, 98 days in 1995 and 33 days in 2000 (CARB, 2002). The number of days exceeding the more stringent California Ambient Air Quality Standard (CAAQS) of 0.09 ppm for a maximum hourly average declined from 210 in 1980 to 115 in 2000. The maximum hourly average mixing ratios of ozone in the SoCAB declined during this twenty-year period from 0.49 ppm to 0.18 ppm. Since 1989, when a permanent particulate monitoring network was deployed, PM_{10} concentrations have declined about 5 percent per year in the SoCAB (Dolislager and Motallebi, 1999).

The air quality improvement was achieved through significant emission reductions (CARB, 2002).

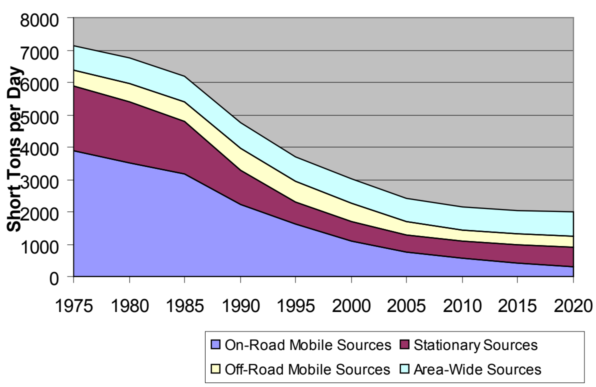

FIGURE 1.1: Statewide Reactive Organic Gases (ROG) Emission Trend

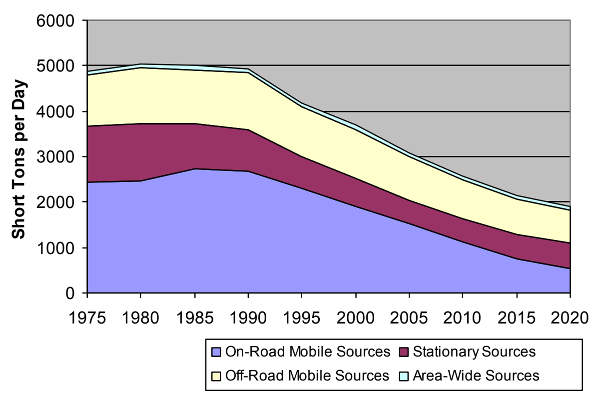

FIGURE 1.2: Statewide NOx Emission Trend

Emissions of CO and VOC (and to a lesser extent NO_x) from new passenger vehicles are reduced by a factor of a hundred in comparison to pre-control vehicles in 1963, and the standards are now applicable for 100,000 miles. Stationary source NO_x emissions have been reduced by a factor of ten since 1980 using low-NO_x burners, selective catalytic reduction, cleaner fuels (i.e., natural gas), vapor recovery, and low-VOC coatings and solvents. From 1980 to 2000, statewide emissions from passenger vehicles (NO_x+VOC) decreased from 5,500 to 2,400 tons/day and CO from 31,000 to 12,000 tons/day, and stationary sources (NOx+VOC) from 2,800 to 1,200 tons/day (Figures 4 and 5).

Approach to Air Quality Management

California has adopted many emission standards that are more stringent than the U.S. standards. These include those for light- and medium-duty vehicles – exhaust and evaporative standards, for handheld and non-handheld small off-road equipment, personal watercraft, in-board motors for boats, and portable engines. Although Los Angeles has made significant progress by attaining health-based air quality standards for lead, SO_2, sulfates, NO_2, and CO, and reducing peak ozone levels and PM, there are still many days of unacceptable ozone and particle levels.

The governor of California, with the consent of the State Senate, appoints the 12 members of CARB. It is an independent board when making regulatory decisions. Six of the members are experts in fields such as medicine, chemistry, physics, meteorology, engineering, business and law. Six others are elected officials who represent regional air pollution control agencies – one each from the Los Angeles region, the San Francisco Bay area, San Diego, the San Joaquin Valley, Sacramento, and another to represent other, more rural areas of the state. The first chairman was Professor Arie Haagen-Smit, who discovered how urban smog was created and the latest, Ms. Mary Nichols, is an environmental lawyer with extensive experience in leadership positions at non-governmental, state and federal organizations.

Except for the Chairman, the Board only works once per month and relies on its staff for technical input. The Board oversees a $150 million budget and a staff of over 1,100 employees located in Northern and Southern California. CARB oversees the activities of 35 local and regional air pollution control districts. These districts regulate industrial pollution sources. They also issue permits, develop local plans to attain healthy air quality and ensure that the industries in their area adhere to air quality mandates. CARB provides financial and technical support to the 35 local districts. It is funded by vehicle registration fees and fees on stationary sources and consumer products. It also receives up to $166 million per year in incentive funds from fees on vehicle registration and new tire sales. This goes to diesel engine retrofits, car scrappage, and agricultural, port and locomotive projects.

The South Coast Air Quality Management District (SCAQMD), the district regulatory agency in charge of the SoCAB, is authorized to develop stationary source regulations and to set fines for violators. Thus, the biggest polluters pay the most toward funding the air pollution control effort. Also, businesses must pay annual fees for their operating permits. However, since motor vehicles account for more than half of this region's pollution, a surcharge was added in 1991 to the vehicle registration fee. Part of the surcharge goes to the SCAQMD to be used for air quality improvements involving mobile sources such as those promoting ridesharing, developing clean fuels, and as grants for programs intended to reduce vehicle emissions.

California has 4,000 air quality professionals at the State and local levels. Most of CARB's workforce comprises engineers and scientists, and about 20 percent have Ph.D.'s and Master's degrees. CARB conducts its own vehicle testing programs and funds extramural research at a level of $5 million per year, taking advantage of the strong academic community in California and other states. It also funds a technology demonstration and commercialization program, and the development of state-of-the-art emission, air quality and macroeconomic models. The technology research demonstrates how reduced emissions are feasible, but the use of performance-based standards allows industry to come up with more cost-effective approaches. Enforcement and monitoring programs ensure that the emission standards are met. CARB has a requirement that the scientific underpinnings of all its regulations undergo scientific peer review. This is normally done by the University of California. Underlying this science-based approach is the willingness to move ahead in the face of some uncertainties.

As a result of CARB's and local air district's work to limit air pollution, Californians today breathe the cleanest air since measurements have been recorded. The number of first stage smog alerts (ozone > 0.20 ppm) in the Los Angeles area has been cut from over 200 per year in the 1970s to none today. This has occurred despite massive increases in population, the number of motor vehicles and the distances they are driven.

California regulations led the way for U.S. EPA and European Union motor vehicle emission standards that are now being adopted by many developing countries, particularly in Asia. Most of the world's population benefits from the fact that over 70 percent of the vehicles worldwide must comply with cleaner emissions standards (Michael Walsh, personal communication).

Black Carbon

Black carbon is formed by the incomplete combustion of fossil fuels, biofuels, and biomass. It contributes to hospitalizations and premature death associated with fine particulate matter (PM2.5). Diesel particulate matter, which includes black carbon and other harmful components, has been identified as a cause of lung cancer by the California Air Resources Board (ARB) and the World Health Organization. Adverse health impacts from black carbon emissions are often concentrated in urban areas near roadways with many heavy-duty diesel trucks. Black carbon

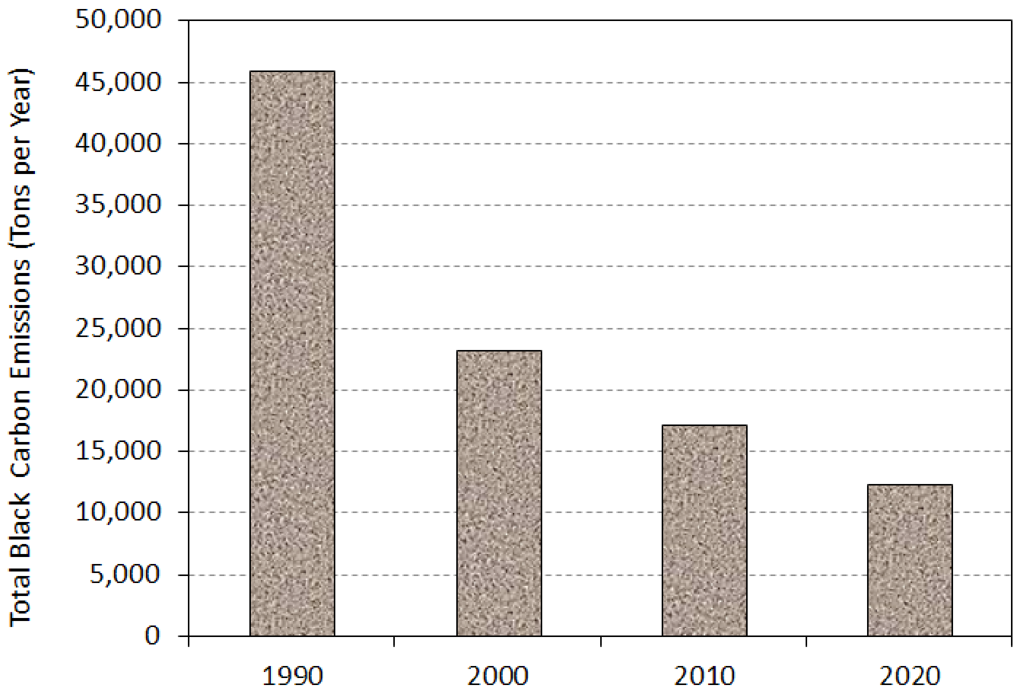

Figure 1.3: Recent ARB estimates suggest that the annual black carbon emissions in California decreased about 70 percent between 1990 and 2010 (Figure 2), in direct proportion to declining diesel particulate matter (DPM) emissions - a co-benefit of ARB's regulations on diesel engines..

contributes to climate change both directly by absorbing sunlight, and indirectly by depositing on snow and by interacting with clouds and affecting cloud formation.

California has been an international leader in reducing black carbon, with 90 percent control since the late 1960s and close to 95 percent control expected by 2020 due to existing programs that target reducing particulate matter from diesel engines and burning activities. For example, black carbon emissions have been reduced by 99 percent in heavy-duty trucks over this time period. ARB has achieved significant gains through a suite of regulations and clean fuel requirements for on- and off-road sources, as well as incentive programs to encourage and accelerate the switch to the cleaner diesel equipment.

The main anthropogenic sources of black carbon in California (excluding wildfires, which are highly intermittent but a significant source) are transportation (diesel engines), cooking, prescribed and agricultural burning, and residential wood combustion. As the on-road vehicle fleet is cleaned up between now and 2020, the remaining sources will become larger fractions of the overall emissions.

Recent ARB estimates suggest that the annual black carbon emissions in California decreased about 70 percent between 1990 and 2010, in direct proportion to declining diesel particulate matter (DPM) emissions - a co-benefit of ARB's regulations on diesel engines. Other categories of diesel engines, such as off-road diesels (e.g., agricultural and construction equipment), building equipment and diesel generators, are also projected to have major declines in DPM emissions. Efforts to manage agricultural, forest, and range land management burning operations are expected to continue reducing black carbon emissions.

How is black carbon controlled?

Due to the health concerns from PM exposures, both ARB and local air pollution control and air quality management districts (districts) have developed programs to reduce emissions from these sources, which have also concurrently resulted in significant reductions of black carbon. The main programs are listed below. The most significant reductions have come from the upgrade of the on- and off-road legacy fleet to include diesel particulate filters.

- Low Emission Vehicle Programs (LEV I, II, and III) – which have significantly reduced emissions from new light-duty vehicles.
- Heavy-Duty On-Road Engine PM Standards – which have reduced emissions from new heavy-duty on-road engines and led to the use of diesel particle filters.
- Off-Road Engine Standards – similar to the engine standards for on-road engines, these standards will accelerate the reductions of PM and black carbon from new off-road engines (e.g., construction vehicles).
- Diesel and Gasoline Fuel Specifications – required changes to diesel and gasoline fuels which reduced the formation of particulate matter and enabled the use of catalytic after-treatment on both gasoline and diesel engines.
- In-Use Fleet Rules (Drayage and Truck and Bus Rules) – which require retrofitting or engine upgrades of the current on-road diesel engines so that almost every heavy-duty diesel engine will have a diesel particulate filter by 2014.
- Fireplaces – all major air districts have adopted rules limiting wood-burning in residential fireplaces and heaters as part of their efforts to meet State and federal air quality standards for PM2.5. In some districts, new wood-burning fireplaces are not allowed (new natural gas is allowed).
- Prescribed and Agricultural Burning – California's longstanding smoke management programs minimize the impacts of agricultural, forest and range land management burning operations. State law combined with programs to reduce health impacts have phased out the vast majority of burning.
- Diesel Clean-up Incentive Programs – ARB incentive programs -- the Carl Moyer Memorial Air Quality Standards Attainment Program, the AB 118 Air Quality Improvement Program, and Proposition 1B funding -- have provided approximately $1.6 billion over the past 15 years to clean up diesel engines and simultaneously reduce black carbon.
- Cooking – A number of districts have adopted rules to reduce $PM_{2.5}$ emissions from commercial charbroiling operations. Emission reductions resulting from these regulations have reduced $PM_{2.5}$ emissions by more than 80 percent.

The overall effect of these programs has been a 90 percent reduction in ambient levels of black carbon in California since the early 1960s. This occurred during a time when diesel fuel consumption increased by about a factor of four.

Lessons Learned

Two of the keys to CARB's success are the technical evaluations that go into its regulation development and the very open public process. CARB develops new emission test methods, and in some cases, proves that more stringent emission standards are achievable by funding or conducting technology demonstrations. It encourages participation by all stakeholders, including the public, industry and communities that may be impacted by air pollution disproportionately from others. CARB meets with many stakeholders to hear concerns and to provide a mechanism for addressing their issues. It holds workshops that solicit suggestions and comments on initial issues. The technical data and assumptions are published in advance of the workshops.

Regulations are first proposed in an initial report and additional workshops are held for public comment. CARB change its proposal once significant issues are raised that warrant a revision. Once the regulation is adopted, it issues a formal response to all issues raised. The public has a chance to air their concerns directly to Board members. The Board reviews the technology and enforceability of regulations when necessary to make sure that the regulations meet the expectation held at the time of adoption. CARB considers economic impacts of its regulations on California businesses and individuals, and regulations do not advantage or disadvantage California manufactured products over products manufactured elsewhere in the U.S. or in the world.

Air pollution control also has positive economic aspects. In 2001, the air pollution control industry in California generated $6.2 billion in revenues and employed 32,000 people (EBI, 2004). The U.S. figures are $27 billion in revenues and employment of 178,000 people (Ibid).

California has a goal of reducing diesel PM by 75 percent during this decade and 85 percent by 2020. This is being achieved with new emission standards, cleaner fuels, retrofits of existing engines, and enforcement programs. CARB and the U.S. EPA have adopted new vehicle standards that reduce emissions by 90 percent beginning in 2007. CARB will require after treatment on every diesel source where it is technically feasible. Low-sulfur fuel is required, as well as cleaner fuels like CNG and measures to reduce or eliminate idling. Enforcement programs are used to minimize the effects of tampering and wear, especially in environmental justice communities.

California has made significant progress in reducing black carbon. The reduction in black carbon emissions is due to multiple ARB programs including the introduction of low-sulfur fuel, tighter emission standards (which necessitated the use of diesel particulate filters), cleaner burning engines, and other improvements in technology mandated by statewide regulations. By 2020, a significant portion of black carbon emissions remaining is expected from off-road vehicles – an indication of the reliance of the off-road sector on diesel engines. In order to reduce these emissions in the long-term, California needs to invest in advanced technology to transform our mostly diesel-based freight system to a zero or near zero-emission system using advanced technology and renewable fuels to meet our air quality and climate goals. In addition, diesel particulate retrofits and legacy fleet turnover are critical for obtaining near and mid-term reductions to continue to reduce risks associated with exposure to diesel particulate.

PART II: Co-benefits of BC Reductions to Climate Change Mitigation

Until recently, black carbon climate forcing was considered to be small in relation to CO2, methane, CFCs and ozone. Two exceptions to this construct were the Stanford model study [Jacobson (2001, 2010)] and the Scripps-Iowa observational study [Ramanathan and Carmichael, 2008]. Both concluded that black carbon is the second largest contributor to global warming, next only to CO2. In January 2013, a major modeling study by 30 co-authors (Bond et al, 2013), came to a similar conclusion that black carbon is indeed the second largest contributor to global warming. It concluded that the global atmospheric absorption attributable to black carbon should increase by a factor of 3. Based, on this they amplified the estimate of industrial-era climate forcing of black carbon through all forcing mechanisms (including clouds and cryosphere forcing) to +1.1 W m 2 and put that just next to CO2, overtaking the other green house gases. Specifically, on sources like diesel engines the study mentioned that eliminating all short-lived emissions from these sources would reduce net climate forcing (i.e., produce cooling).

CARB commissioned a multi-institutional study led by V. Ramanathan in collaboration with UCSD, UC Berkeley, Lawrence Berkeley Laboratory and DOE's PNNL laboratory to evaluate the role of black carbon in regional climate over California. The group developed a unique integrated approach between observations, data analyses, and modeling studies. The primary findings of the report were (Ramanathan et al, 2013):

- The control of BC from diesel is an effective means of mitigating near-term global climate change. However, we would like to caution that, without simultaneous reduction of CO_2 emissions, it will not be possible to limit future warming to below 2^0C as required by the Copenhagen Accord.
- BC emission reductions since the 1980s, attributed in large part to diesel engine emissions mitigation, are equivalent to *reducing CO_2 emissions by 21 million metric tons annually. This is approximately equal to 5 % of the total direct CO_2 annual emissions of 393 million metric tons*. As on-road diesel is very low in sulfur in developed regions and lowering elsewhere, and since compared to other major BC sources, diesel PM has more BC and less OC, it follows that controlling diesel BC would have a cooling effect.
- *Annual average BC concentrations measured at California remote sites have decreased by about 50% from 0.46 µg m-3 in 1989 to 0.24 µg m-3 in 2008 compared to a corresponding reductions in diesel BC emissions (also about 50%) from a peak of 0.013 Tg Yr-1 in 1990 to 0.006 Tg Yr-1 by 2008 (Figure 2(a)).*
- *A larger set of urban measurements is also used to determine BC concentrations and reveals that these urban trends are uniform across the state and persistent in several major air basins (Figure 2(b)).*
- *A corresponding trend in co-pollutants such as nitrates, sulfates, and organic carbon is not observed (Figure 2(a)).*
- *This finding is crucial, since the co-pollutants are largely cooling aerosols, through their direct and indirect effects on clouds. Since they are not showing negative trends, it implies that the decrease in BC will most likely lead to a global cooling effect from California's BC reductions.*
- *As no similar trends are observed in other chemical source tracers (such as postassium, K), for biomass burning), we therefore attribute the observed BC trends primarily to the emission reduction from transport-related PM emissions, primarily from diesel. A detailed analysis of technology based emission inventories and fuel use in California indicates that although the total consumption in diesel fuel has increased, the emissions of BC from diesel fuel combustion have decreased significantly. The reduction in emissions is due to a number of factors, including the introduction of low sulfur fuel, tighter emission standards, cleaner burning engines,*

and other improvements in technology mandated by statewide regulations. California therefore appears as a success story in mitigating the anthropogenic impact on climate. While, decreasing trends in BC have been noted in other states (of the US), we are unable to comment on their climate mitigation efficacy since data on other co-pollutants have not been analyzed in published literature.

- *Our conclusion that the reduction in diesel emissions is the primary cause of the observed BC reduction is also substantiated by a significant decrease in the ratio of BC to non-BC aerosols.*

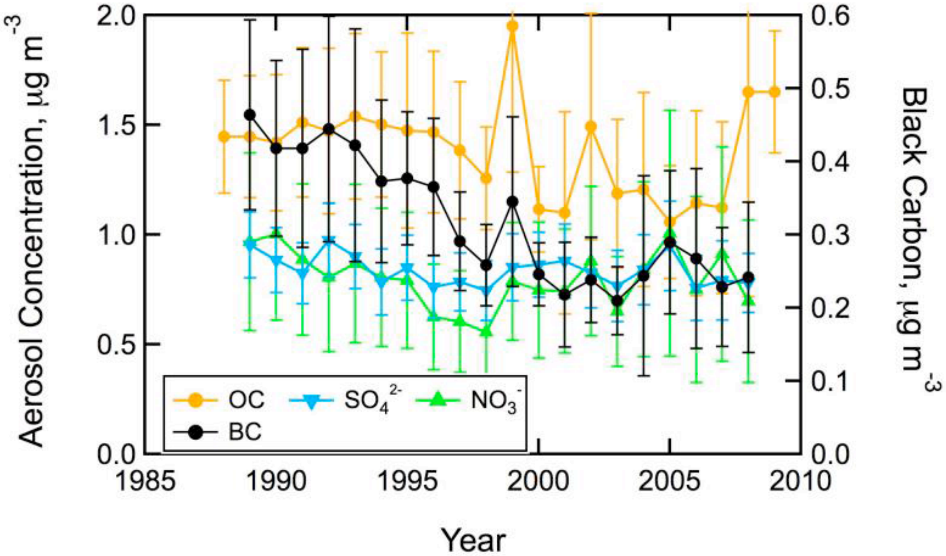

Figure 2.0 Statewide trends in concentrations of common aerosol species from the IMPROVE network

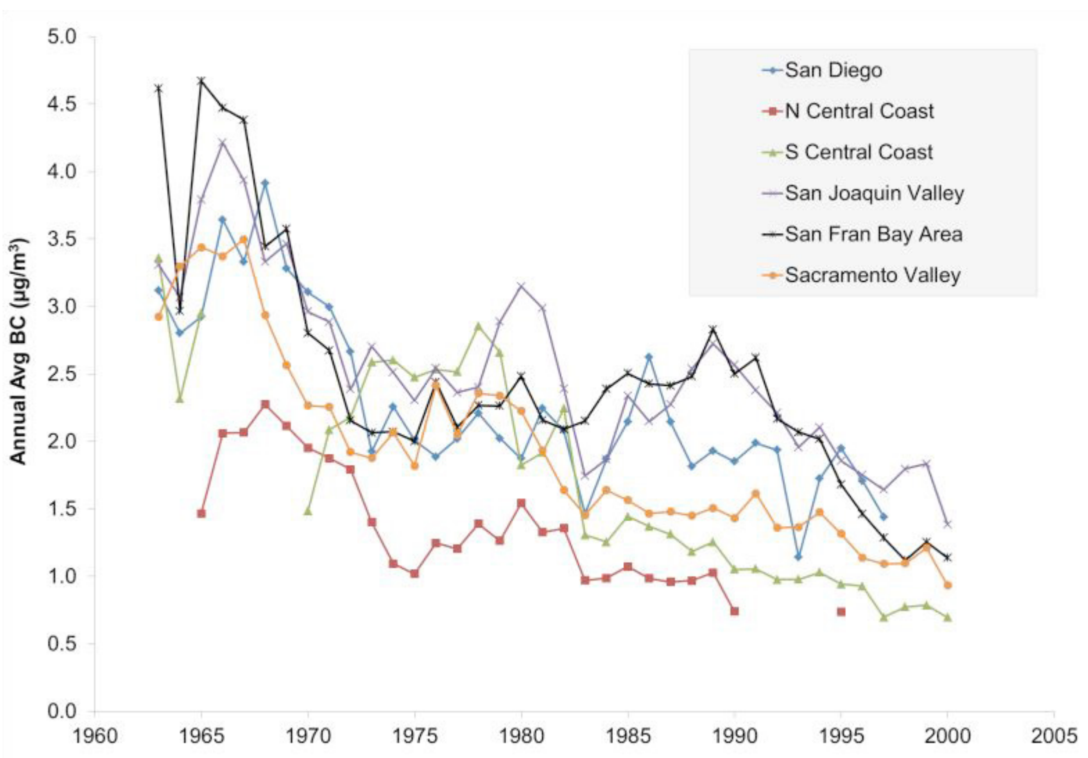

Figure 2.1 Historical URBAN BC concentrations resolved by air basin. A clear reduction in BC is observed

II. Role of brown carbon absorption

- *Organic carbon (OC) is shown to absorb strongly at visible to UV wavelengths, an effect typically not represented in climate models. The BrC absorption at 440 nm is about 40% of the EC, while at 675 nanometers (nm) it is less than 10% of EC (Figure 2).*
- *BrC emissions are likely both from biomass burning (forest fires and residential wood burning) as previously thought, and also from large aged particles indicating that secondary organics may also be absorbing and thus contributing to warming.*

What IPCC, Assessment report -5 says

a) The total anthropogenic radiative forcing (RF) for 2011 relative to 1750 is 2.29 [1.13 to 3.33] W m^{-2} and AR5 reports 43% higher RF than that reported in AR4 for the year, mainly due to continued growth in most greenhouse gas and improved estimates of RF by aerosols which now indicate a weaker net cooling effect (negative RF).

b) The RF of the total aerosol effect is reported as –0.9 [–1.9 to −0.1] W m^{-2}, which is a net results of positive forcing from black carbon absorption of solar radiation and negative from other aerosols.

c) Climate models now include more cloud and aerosol processes, and their interactions, than at the time of the AR4.

d) Observational and modelling evidences suggest that locally higher surface temperatures in polluted regions will increase peak levels of ozone and PM2.5.

e) Short term climate forcers, such as black carbon can be comparable to CO2's for short time horizons , but in the long term the effect of CO2 dominates .

f) The RF from absorbing aerosol on snow and ice is assessed separately to be +0.04 (+0.02 to +0.09) W m^{-2}

PART III: India Air Quality, Transport Emissions, and Health Effects

India is going through a major economic change. While the population in the last sixty years has grown three fold, the index of industrial production has grown more than forty times. The improved quality of life, economic capacity, and competitive markets has led to tremendous growth in the number of motor vehicles in India. Registered vehicles in India grew to 141.8 million by the year 2011. The fleet is dominated by motorcycles scooters (two-wheelers) (72%), followed by private cars (Figure 3.0).

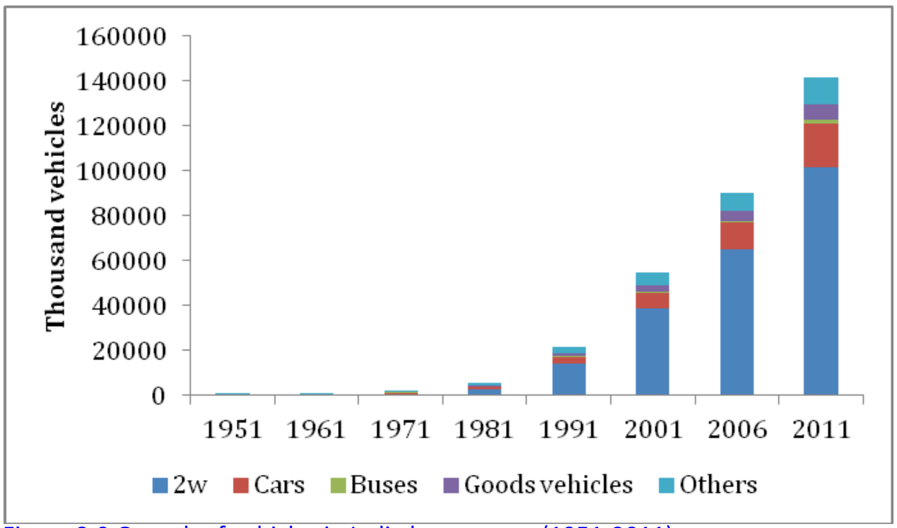

Figure 3.0 Growth of vehicles in India by category (1951-2011)

While some efforts have been made for improvement of public transport facilities in Indian cities, they have not been substantial enough to curb the demand for private vehicles in rapidly growing Indian cities. On average about 28 thousand two-wheelers and 4200 cars are added daily to the fleet of vehicles in India. Moreover, due to a price differential between diesel and gasoline, many consumers tend to prefer diesel vehicles. Sales of petrol vehicles have increased faster than those of diesel for the first time, however, over the past quarter as the price of diesel has increased.[1]

Despite past growth, vehicle numbers per thousand people in India are very low compared to the developed world. There is high probability of further growth of private vehicle demand in the country. At present, the transport sector in India accounts for 18% of the total commercial energy consumed in the country. India has one of the world's most extensive rail network, but less efficient road transport is the dominant mode for reasons discussed in subsequent sections. The demand for transport and associated fuel consumption in the sector is expected to rise two or three fold in the next two decades.

There are no reliable models of projecting overall transport demand in India, but planners and policymakers expect passenger and freight transport requirements to grow faster than the economy. The Ministry of Road Transport and Highway estimates an income elasticity[2] of freight transport (billion ton kilometers - TKM) per unit of growth of 1.2, or about 10% increase in transport demand for 8% annual growth[3]. Similarly, road passenger transport (billions of passenger-kilometers) grew at an average of 8.8 annually from 1980-2011 even as growth averaged 4.9% per year. Rail passenger and freight demand has not increased as fast as GDP (an elasticity of 0.79 over 2005-2009) as more freight and passenger trips have shifted to road transport (discussed below), but the Railway Ministry has targeted an elasticity of 1.25.[3] International evidence suggests that transport elasticity will increase over time before declining, though patterns vary widely across countries based on demography, geography, land use patterns, sources of growth (e.g. manufacturing versus services) and other factors.[4]

Most policy reports and strategies focus on increasing both capacity and access to the transport network in order to lower costs of freight transport, increase household access to national employment markets, and otherwise support a larger flow of goods and people as India grows.[5] Urban strategy documents from government, private and multilateral sources[6], for example, emphasize the importance of investment in transport networks that link fast-growing peri-urban areas and smaller cities with dense core business districts in order to de-concentrate economic activity. High land prices are already leading to rapid expansion of built-up areas in India's suburbs; policymaker and public commentators focus on transport links between these newly urban areas and existing hubs. Similarly, while there is some debate about the best strategy for growth, there is widespread consensus on the need to create more jobs for India's growing young workforce by integrating the national market – increasing goods and people flows at the same time.

The increasing number of vehicles not only points toward energy security issues for India, but also to growing air pollutant emissions from the sector. Diesel driven vehicles predominantly emit toxic particulate matter (PM) and oxides of nitrogen (NOx). Gasoline powered vehicles contribute to the pool of carbon monoxide and hydrocarbon compounds. With exponential growth in vehicles focused in rapidly growing urban centers, air quality has suffered.

State of Air Quality and Contribution of Transport Sector

Air pollution is a serious concern, especially in the urban centers of the country. The main air pollutants are particulate matter, oxides of nitrogen, carbon monoxide, hydrocarbons and sulfur dioxide, which impact human health in different ways. While many of these are directly related to respiratory disorders, some of them have shown evidence of linkages with cardio-vascular diseases and cancer. For control of air quality, ambient air quality standards introduced under the Air Act, 1981, were made more stringent in 2009, and a few new ones were added. About 80% of 167 cities (where air quality monitoring is carried out) show particulate matter concentrations higher than the prescribed standards. World Health Organization guidelines are being surpassed by a substantial margin in some cities. It is not only big cities that are exposed to the unacceptable levels of air pollutants but also the smaller ones, which have limited infrastructure to cope with it. While clean air is valuable to every citizen, unfortunately it is not available in Indian cities. Figure 3.1 shows the air quality concentrations observed at different cities in India with respect to their standards. While SO_2 levels seem to be under control, NO_x concentrations are about to violate the standards in many cities. NO_x has always been associated with growth in number of vehicles in India cities. Quite clearly, PM_{10} is a pollutant concern in India with more than 80% of cities violating the prescribed standards.

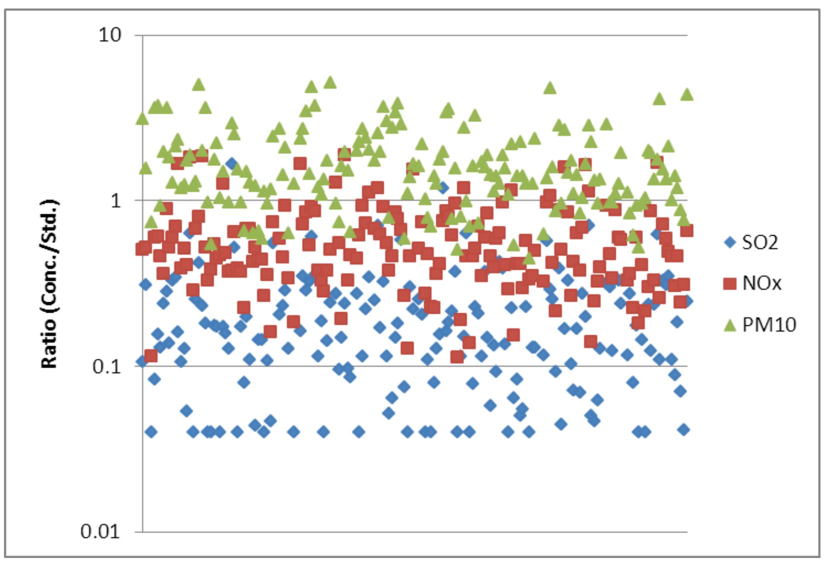

Figure 3.1 Ratio of annual averaged pollutant concentrations to prescribed standards in 172 cities of India in 2010, Data source: NAMP, CPCB

The facts observed in surface measurements in Figure 3.1 are supplemented with satellite data. Figure 3.2 shows the increase in aerosol optical depth (AOD) over India during 2001 to 2008 and from 2001 to 2013. AOD is basically a vertically averaged measure of number of PM2.5 particles.

Source apportionment studies have been carried out

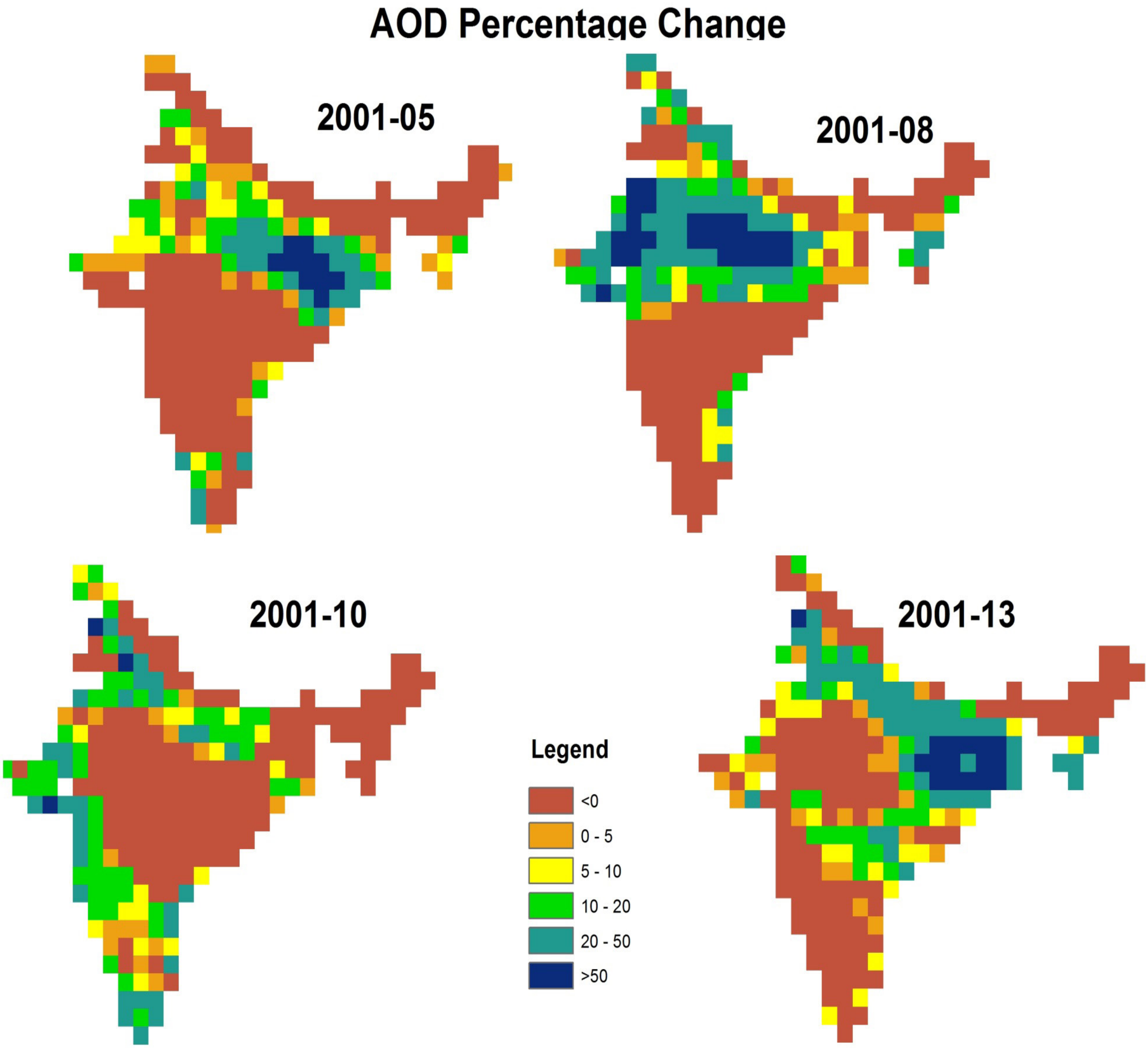

Figure 3.2 Changing AOD over India during 2001 to 2008 and 2001-2013 Data source: Moderate-Resolution Imaging Spectroradiometer (MODIS)

Source apportionment studies have been carried out in India to ascertain the share of the transport sector in the ambient PM10/PM2.5 concentrations in a few cities of the country. Figure 4a/b show the PM10 and PM2.5 results, respectively, in three major cities. While, road and soil dust has been the dominant contributor in PM10 concentrations, the transport sector is the major contributor to PM2.5 fractions. PM emissions from transport can have deeper penetration into the lungs and hence a larger health impact.

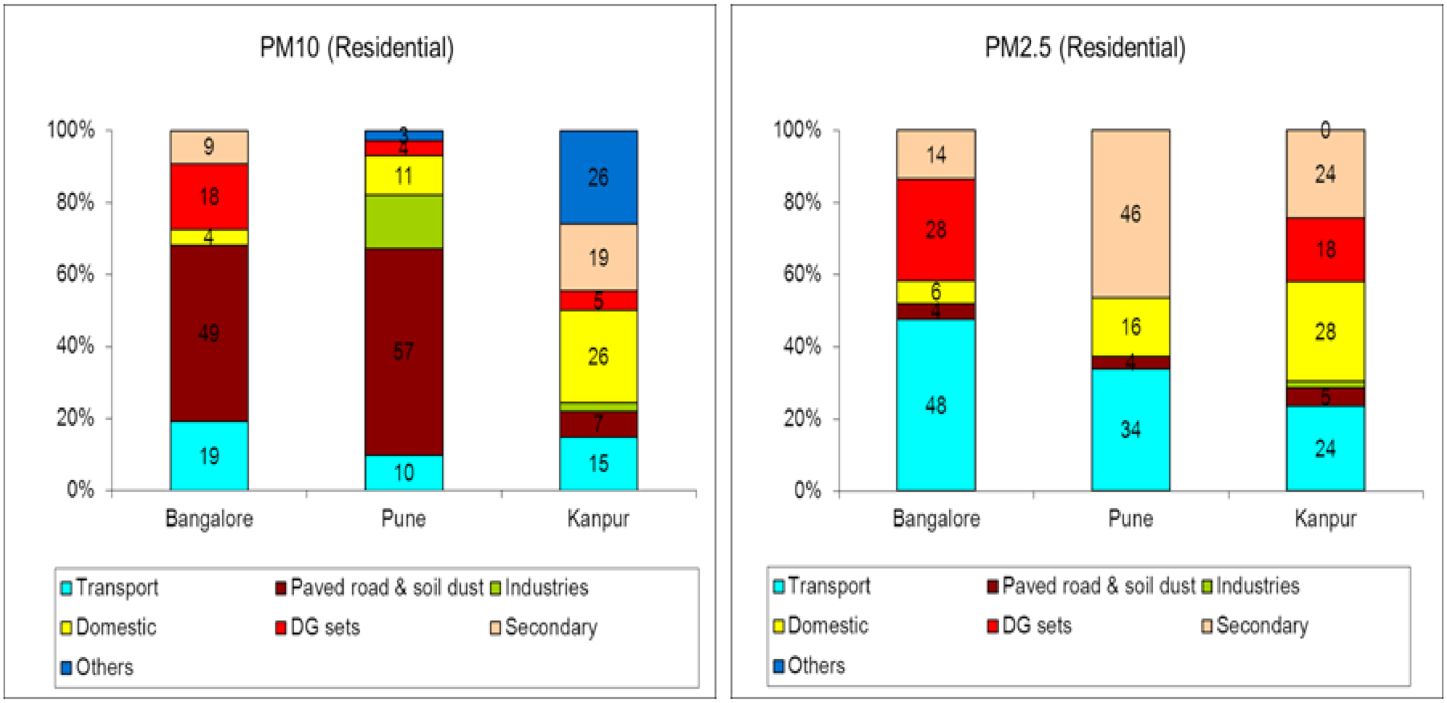

Figure 3.3 Results of source apportionment studies for PM10 (a) and PM2.5 (b) in Indian cities
Data source: CPCB, 2011

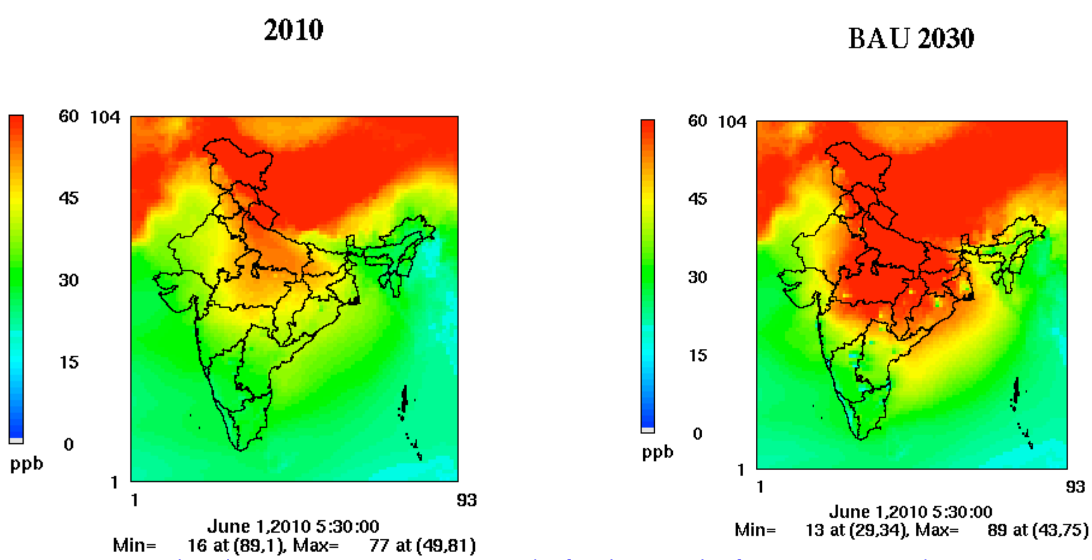

Figure 3.4: Simulated Ozone concentrations in India for the month of June in 2010 and 2030 Source: TERI, 2013

in India to ascertain the share of the transport sector in the ambient $PM_{10}/PM_{2.5}$ concentrations in a few cities of the country. Figure 4a/b show the PM_{10} and $PM_{2.5}$ results, respectively, in three major cities. While, road and soil dust has been the dominant contributor in PM_{10} concentrations, the transport sector is the major contributor to $PM_{2.5}$ fractions. PM emissions from transport can have deeper penetration into the lungs and hence a larger health impact.

Moreover, NOx emissions are found to be dominated by the transport sector in all the cities. NOx has its own health impacts but also contributes to secondary particulate formation (as nitrates), acid raid (as Nitric

Study	BC emissions	Transport Sector
Sahu et al, 2008	1343.78 Gg and 835.50 Gg for 2001 and 1991	34% and 26% in 2001 and 1991 respectively
Reddy and Venkataraman (2002)	.35 Tg in 1996-97	16.5% from diesel vehicles
GAINS (Sloss, 2012)	1.10 Tg in 2010	7%
Lu et al, 2011	1.01 Tg in 2010	10%

Table 3.0 Emission estimates of BC in India and share of transport sector

acid), and formation of ground level Ozone. TERI (2013) showed very high sensitivities of NOx towards Ozone formation in Indian conditions. Simulated ozone concentrations in India for the year 2010 and projections for 2030 are shown in Figure 3.4, which clearly show very high values in the agriculture dependent Indo-gangetic plains in India.

Emissions in India

Most of the past studies have shown that climate models (global and regional) significantly underestimate (by ~50% or more) the aerosol concentrations over the Indo-Gangetic basin (IGB), mainly during winter and pre-monsoon seasons [Ganguly et al., 2009a; Menon et al., 2010; Henriksson et al., 2011; Verma et al. 2011; Nair et al. 2012]. This is mainly due to underestimation of emissions and unreal characterization of PM constituents in the region. Using these inventories, many studies have tried to model the role of aerosols in changing the meteorological and climatic patterns in the region[Ramanathan et al., 2005; Lau et al., 2006; Chung and Ramanathan, 2006; Wang et al., 2009; Bollasina et al., 2011; Ganguly et al., 2012a, 2012b] and have concluded significant impacts over important meteorological phenomena such as monsoons. It is to be noted that with improved inventories the effect of aerosols on air quality and climate could be even more significant.

In past, emission inventories of black carbon have been developed for the region by Sahu et al, 2008 , Bond et al, 2004, Reddy and Venkataraman (2002), Streets et al. (2003), Streets et al. 2004, Venkataraman et al (2005), IIASA, 2010. Table shows the various estimates of BC emissions and the share of transport sector in India.

Although, emission inventory approach showed limited contribution of fossil fuel (transport sector) in the BC emissions, measurement based radio-carbon analysis shows much higher contributions (about 54%) from fossil fuels (Gustaffson et al, 2009). INDOEX experiments over the Indian Ocean also pointed towards higher contributions of fossil fuels in the BC concentrations. The measurements and underestimations of models have depicted the gap in emissions from sectors like transport. Under estimation of emissions from transport sector in the region could be attributed to

a) Indian driving cycles on which emission factors are developed do not account for varying real-world driving conditions (Sharma et al 2013) e.g. congestion, high accelerations which lead to higher on-road emissions despite compliance with emissions norms.

b) Emission factors are developed on limited set of vehicles which may not include high emitters

c) Over-loading of vehicles lead to increased emissions

d)Inaccurate information on on-road vehicles as very old vehicles still ply on the roads without re-registrations after 15 years

Transport Sector emissions

Trends of emission estimates of PM (PM10, PM2.5, and BC) from the transport sector in India are shown in Figure 3.5. It is evident that there had been a decrease in PM emissions in the last decade mainly due to

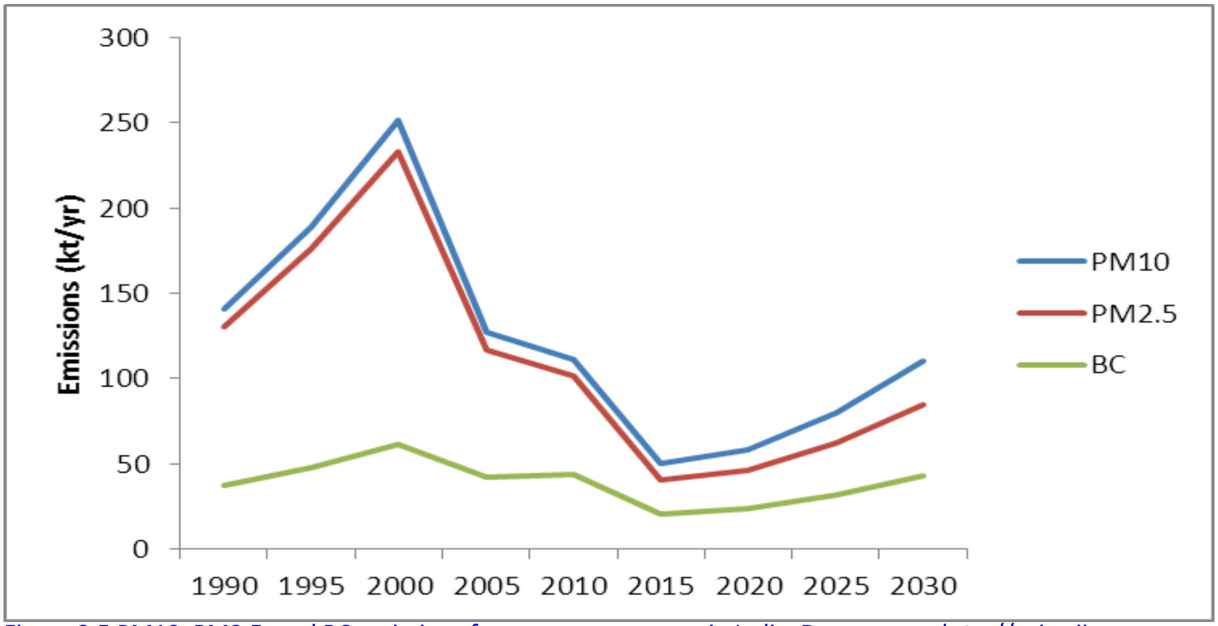

Figure 3.5 PM10, PM2.5, and BC emissions from transport sector in India Data source: http://gains.iiasa.ac.at

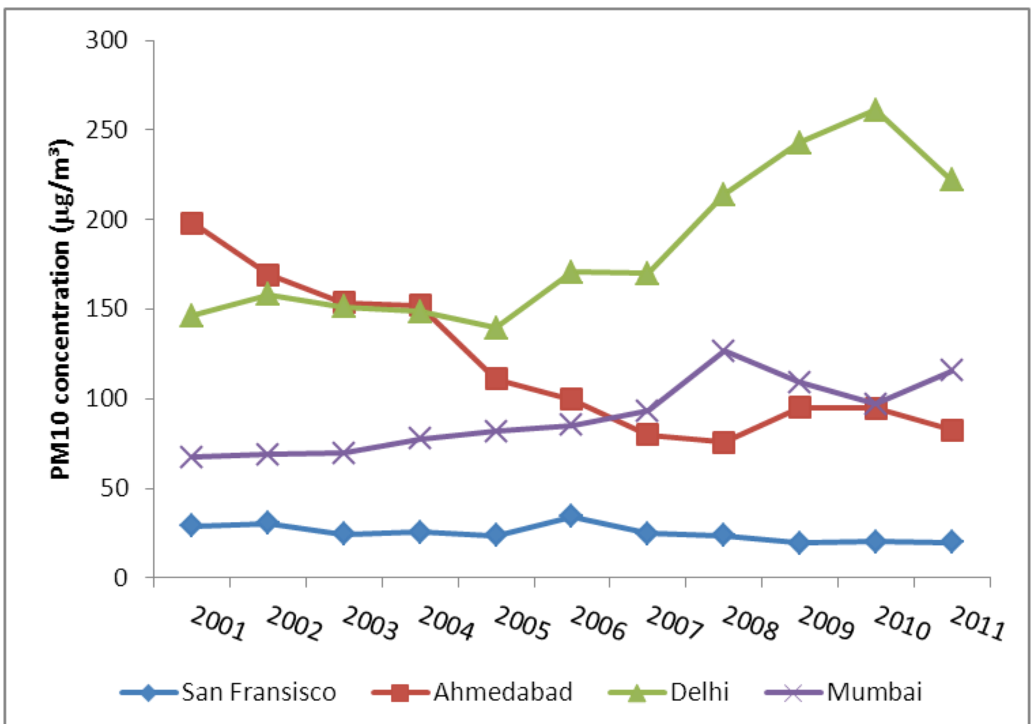

Figure 3.6: Ambient PM10 concentrations (µg/m³) in different Indian cities during 2001-2011
Data source: NAMP, CPCB and CARB (www.arb.ca.gov/html/ds.htm)

introduction of improved fuel quality and vehicular emissions norms in India. While, about 20 cities have adopted Euro 4 equivalent (BS-IV) standards,. Rest of the country has moved to Euro-3 equivalent (BS-III) norms. In general, vehicles account for over half of all NOX emissions and about a quarter of fine particulate matter (PM2.5) emissions—the two most problematic air pollutants—in Indian cities.[3] Annual vehicle sales, about 17 million today, are on a path to more than double by 2030. If per-vehicle emissions are not reduced significantly, the progress toward reducing emissions in India that has been made since 2003 will be erased in less than a decade. Growth in India's transport sector is also driving greenhouse gas emissions rapidly upward and making the national economy ever more dependent on imported fossil fuels.

The estimates of the WEO-IEA scenario show that PM10 emissions from the transport sector in India grew to the level of 250 kt/yr in the year 2000. However, with the introduction of improved vehicular emissions and fuel quality norms, the emissions have gone down to 111 kt/yr. However, in the absence of a road map for further advancement, the emissions are likely to grow again in future (Figure 3.5).

Unlike, California, the growth of number of vehicles in Indian cities has been faster than the effect of interventions taken for emission control. Owing to the interventions taken, there has been some reduction in PM10 levels observed in some of the cities but enormous growth in the total fleet of vehicles has negated the benefits accrued earlier. Figure 3.6 shows the trends of PM10 concentrations in Indian cities like Delhi, Mumbai and Ahmedabad compared with San Francisco (California). In the last decade or so, while, there is decrease in PM10 concentrations in California, however, it has increased significantly in Indian cities like Delhi and Mumbai. As exceptions few cities like , Ahmedabad have shown decrease in PM10 concentrations.

Other than particulate matter, the transport sector also contributes significantly to emissions of other pollutants such as NOx, NMVOC, and CO (Figure 3.7). As per TERI's estimates, 32% of NOx emissions are released from the transport sector in India. In NMVOCs and CO, transport sector has a share of 9% and 8% respectively. It is to be noted that these pollutants are themselves have quite potent effects on human health, and are also known to produce secondary pollutants such as ozone and secondary particulates. NOx in the presence of VOCs and sunlight forms Ozone at the ground level, which is not only a respiratory irritant but also known to have detrimental effects for crop productivity. Emissions of gaseous pollutants such as SO2, NOx, and NMVOCs lead to secondary particulate formation such as sulfates, organics and nitrates.

Health effects of emissions

Air pollution has remained a major health concern in India. Fumes from vehicular exhausts constitute particulate matter (including black carbon) and gaseous pollutants like CO, HC, SO2, and NOx. Each of them is associated with a variety of health effects which are summarized in Table 3.1.

Air pollution causes cardiovascular and respiratory diseases, damages crop quality, reduces the biodiversity of plants, and contributes to global warming (UNECE, 2012). The decisive factor for the quality of life and health, however, is not primarily the total emissions of air pollutants but their concentration in urban areas. The pollutants' characteristics and the level of people's exposure to them are the decisive factors for the effect of the pollutants on human health. It is likely that within any large human population, there is such a wide range in susceptibility that some subjects are at risk even at the lowest end of the concentration range. The elderly and people suffering from cardio-respiratory problems such as asthma appear to be the most susceptible groups. Children and newborns are also sensitive to the health effects of air pollution since they take in more air than adults for their body weight and consequently, a higher level of pollutants. An important point in this context is that socio-economic conditions play an important role in health effects of air pollution. People who are poor and less educated are more vulnerable to illness and death from air pollution exposures (Krewski et al., 2000; Pope et al., 2002).

Literature survey reveals that long-term (chronic) exposure to high concentrations of particulate matter (PMs) in the air may cause a wide spectrum of adverse health effects, ranging from reduced lung function and development of chronic respiratory disease (Naeher et al. 2007), severe pulmonary inflammation and hemorrhage, high degree of alveolar and interstitial edema, disruption of epithelial and endothelial cell

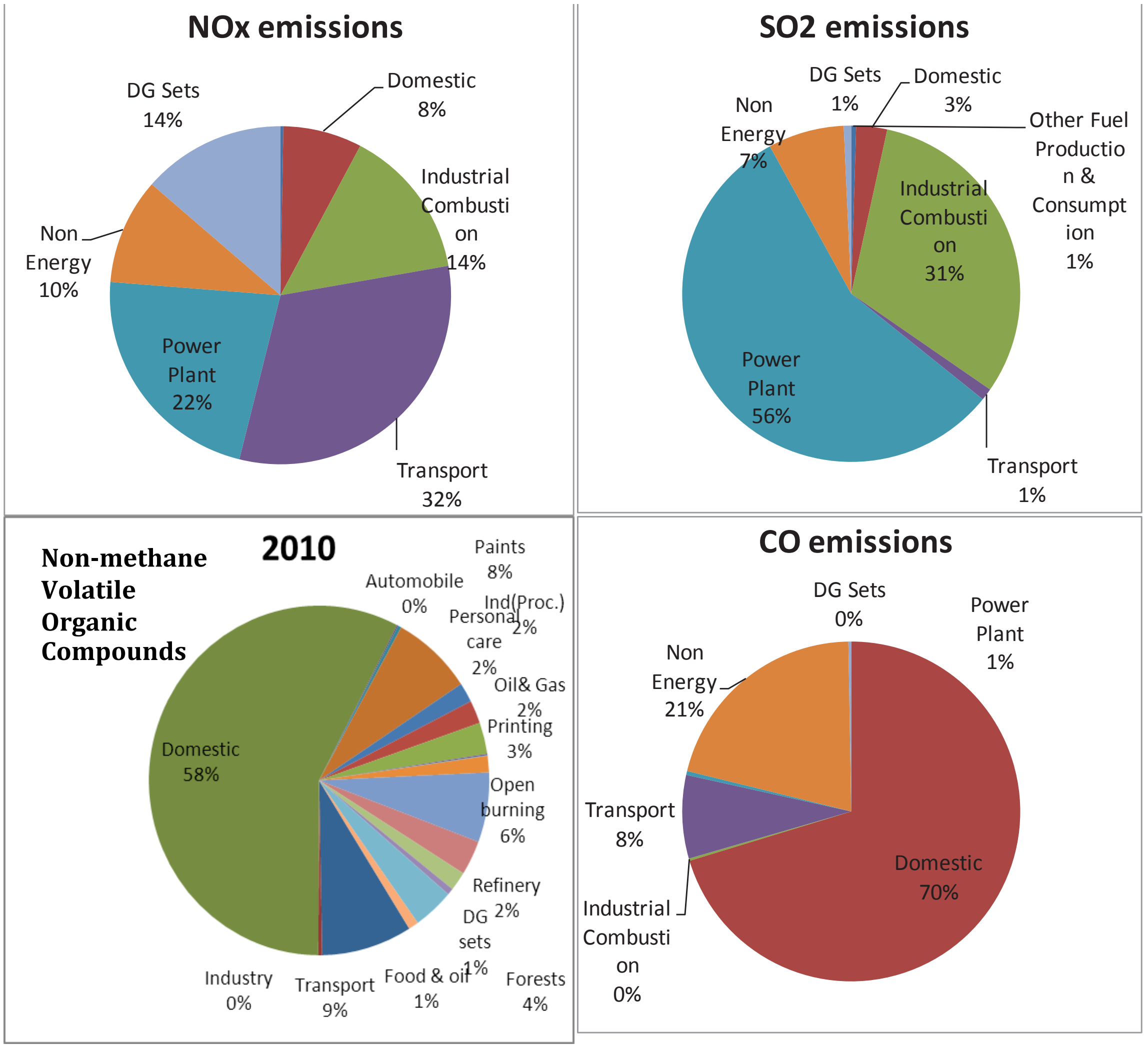

Figure 3.7: Share of transport sector in overall emission estimates for different pollutants in India
Source: TERI, 2013

Polutants	***Effects***
Nitrogen dioxide (NOx)	Bronchitis in asthmatic children. Reduced lung function growth
Particulate Matter (PM2.5, PM10)	Cardiovascular and respiratory diseases, lung cancer, ALRI, COPD.
Carbon monoxide (CO)	Reduces the oxygen carrying capacity of blood, causes headaches, nausea, and dizziness. Can lead to death at high levels
Sulfur dioxide (SO2)	Affects respiratory system and lung function. Coughing, mucus secretion, asthma and chronic bronchitis. Causes acid rain.
Lead	Affects intellectual development of children, and at very high doses poisoning, brain and organ damage can occur.
Benzene	Exposure over a long time can lead to cancer
1, 3 Butadiene	Exposure over a long time can lead to cancer.
Ozone	Breathing problems, asthma, reduce lung function. Ozone is one of the most damaging pollutants for plants.

Table 3.1 Health effects of different pollutants

layers, cardiopulmonary problems (Brunekreef and Forsberg 2005; Mar et al. 2005; Harrabi et al. 2006; Naeher et al. 2007), cardiovascular diseases (CVD; Anand 2000; Sugathan et al. 2008), cancer (Vinzents et al. 2005), to death (Peters et al. 1997; Oberdörster 2000). This exposure has been found to be associated with increase in hospital admissions for cardiovascular and respiratory disease and mortality in many countries (Samet et al. 2000; Dockery 2009) including India (Kumar et al. 2010; Balakrishnan et al. 2011; Rajarathnam et al. 2011). It may also lead to a marked reduction in life expectancy. Each 10 µg/m3 elevation in fine particulate matter has been associated with approximately a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively (Pope et al., 2002; Vineis and Husgafvel-Pursiainen, 2005; Vineis et al., 2006; Gallus et al., 2008). Lung can be injured directly by air pollutants as it is the primary route of entry. Reduction of lung function has been linked to vehicular pollution (Ingle et al., 2005) and ambient ozone (Walker, 1985; Tager et al., 2005). Urban air pollution is known to trigger asthma (Behera et al., 2001; Mishra, 2004; Halonen et al., 2008) and has also been associated with chronic obstructive pulmonary disease (COPD), which is projected as the third leading cause of total mortality and the fifth leading cause of disability by 2020 (Murray et al., 2004; Mannino et al., 2006).

Chronic exposure to air pollution is an established risk factor for morbidity and mortality from CVD (Brook et al., 2004; Miller et al., 2007). Traffic-related PM is a risk for CVD (Peters et al., 2004) and even death from the disease (Hoek et al., 2002). Epidemiological studies have shown that chronic exposure to moderately elevated levels of particulate air pollution enhances the risk of hypertension and systemic atherosclerosis (Brook, 2007). Even short-term exposure to PM2.5 over a few hours can trigger myocardial infarctions, cardiac ischemia, arrhythmias, heart failure, stroke, exacerbation of peripheral arterial disease, and sudden death (Brook, 2007). For every 10 µg/m3 increase in PM2.5 in ambient air, the risk of a cardiovascular event increases by 24% and death from CVD by 76% (Miller et al., 2007). Smaller particles (PM2.5 and UFPs) were found more potent than larger particles due to their higher surface area and reactivity (Mills et al., 2005; Schlesinger et al., 2006; Tornqvist et al., 2007). Recent studies from India have reported that residents of Delhi (Banerjee et al. 2012) and Kolkata (Dutta and Ray, 2012) are at increased cardiovascular risk from exposure to ambient air pollution. PM exposure can increase the risk of CVD by a multitude of mechanisms that include increased production of C-reactive protein (CRP) and blood coagulation proteins (Barregard et al., 2006; Rückerl et al., 2006), and fibrinogen (Schwartz, 2001; Ghio et al., 2003) from the liver , increased plasma viscosity (Peters et al., 1997), increased neutrophil and platelet numbers (Salvi et al., 1999, 2000), over-expression of adhesion molecules on leukocyte or in plasma (Rückerl et al., 2006; O'Neill et al., 2007), and oxidation of proteins and lipids in plasma (Sørensen et al., 2003; Barregard et al., 2006).

The female reproductive cycle is a sensitive hormone-synchronized process controlling fertility and related reproductive outcomes. Vehicle-related emissions are associated with dysmenorrhea in pre-menopausal women (Mavalankar et al., 1991; Mishra et al., 2004), and increased risk of various adverse pregnancy outcomes like selected cardiac defects and oral cleft formation in the growing fetus resulting in early childhood defects (Kristensen et al., 1997; Farr et al., 2004; Mishra et al., 2005), significant increase in the risk of first tri-semester miscarriages, stillbirths, reduced birth-weight of infants (Liu et al., 2003, 2004; Salam et al., 2005; Sram et al., 2005; Wilhelm and Ritz, 2005; Bell et al., 2007; Ritz et al., 2007; Siddiqui et al., 2008; Windham and Fenster, 2008; Hansen et al., 2009; Woodruff et al., 2010; Yildiz et al., 2010), preterm births, intrauterine fetal growth retardation and decreased fetal head circumference in pregnant women (Bean et al., 1979; Cooper et al., 1996; Lipfert et al., 2000; Arbuckle et al., 2001; Ozbay et al., 2001; Boy et al., 2002; Gilboa et al., 2005; Lacasana et al., 2005).

Particulate matter, especially traffic-related airborne particles, contains a large number of genotoxic/

mutagenic chemical substances which are capable of causing DNA damage and promoting carcinogenesis (Cooper, 1980; Alfheim et al., 1983; Zhang and Smith, 1996). Vehicle emissions are associated with the development of cancer, particularly lung cancer (Vineis et al., 2006; Parent et al., 2007). Early life exposure to traffic emissions may be associated with breast cancer in women; higher exposure to traffic-related emissions at menarche was associated with pre-menopausal breast cancer while emissions exposure at the time of a woman's first childbirth was associated with postmenopausal breast cancer (Nie et al., 2007). A study in Finland among individuals occupationally exposed to diesel and gasoline exhausts showed an association between ovarian cancer and diesel exhaust (Guo et al., 2004).

Exposures to increased levels of some air pollutants are associated with psychiatric symptoms, including anxiety and changes in mood, cognition and behavior (Lundberg, 2002). Toxic air pollutants including CO interfere with the development and adult functioning of the central nervous system (CNS) causing impairment of memory, learning ability, attention and concentration (Amitai et al., 1998).According to the most recently published 2010 Global Burden of Disease (GBD 2010), published in The Lancet in December 2012, outdoor air pollution in the form of fine particles is a much more significant public health risk than previously known – contributing annually to over 3.2 million premature deaths worldwide and over 74 million years of healthy life lost. It now ranks among the top global health risk burdens. Overall GBD 2010 estimates over 2.1 million premature deaths and 52 million years of healthy life lost in 2010 due to ambient fine particle air pollution, fully 2/3 of the burden worldwide. Among other risk factors studied in the GBD, outdoor air pollution ranked 4th in mortality and health burden in East Asia (China and North Korea) where it contributed to 1.2 million deaths in 2010, and 6th in South Asia (including India, Pakistan, Bangladesh and Sri Lanka) where it contributed to 712,000 deaths in 2010. The GBD quantified health losses from a wide array of diseases and injuries. These losses are expressed in units of disability-adjusted life-years (DALYs: YLLs + YLDs), which account for both premature mortality - measured as years of life lost (YLLs: number of deaths at age 'x' multiplied by the standard life expectancy at age 'x'), and time spent in states of reduced health - measured as years lived with disability (YLDs).

GBD 2010 analysis showed that the large burden of disease is attributable to particulate matter pollution in ambient environments. The magnitude of disease burden from particulate matter is substantially higher than estimated in previous comparative risk assessment analyses. Previously, ambient particulate matter pollution was estimated to account for 0.4% of DALYs in 2000 compared with 3.1% in GBD 2010. The self-proclaimed limitation of this report though, is that it does not address how the different sources of particulate matter in terms of effects. The report emphasizes the need to implement more stringent regulation of vehicle and industrial emissions, reduce agricultural burning or land clearing by fire, and curb and reverse deforestation and desertification to reduce ambient particulate matter from dust.

A comparative analysis of the top 20 mortality risk factors from GBD 2010 shows that ambient particulate matter pollution ranks 8th in US and 5th in India (Fig. 3.8 and Fig. 3.9). Nearly 103027 deaths in US and 627426 deaths in India have been attributed to ambient particulate matter pollution in 2010 (Fig. 3.1.0). While in India, COPD and ARI account for 24% of the mortalities due to ambient air pollution, it is just 7.5% in US. The mortalities due to cardiovascular problems are predominant in US. Same facts were observed in the case of morbidities.

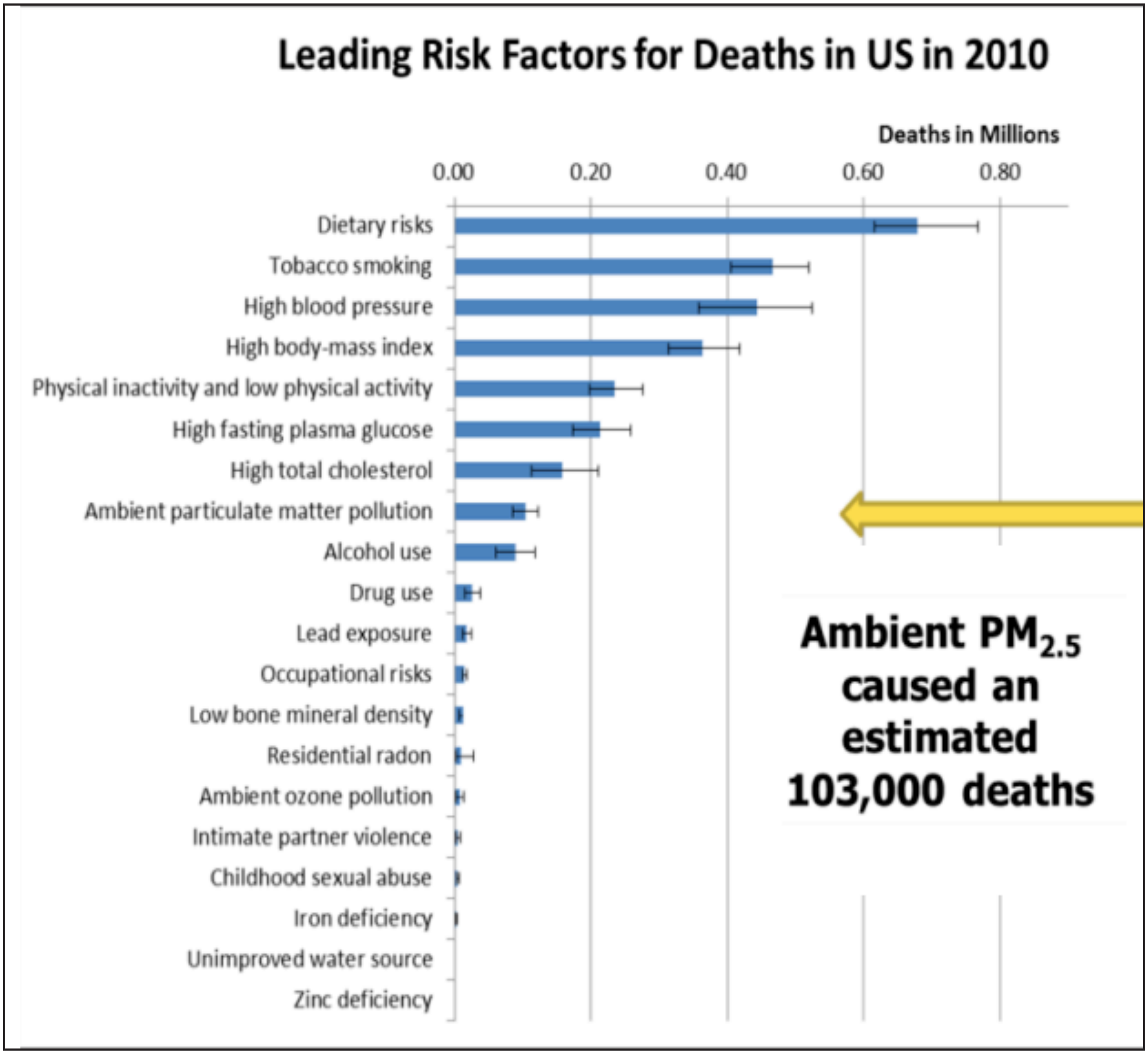

Fig. 3.8: Top 20 mortality risk factors in US and India Sources: GBD, 2010

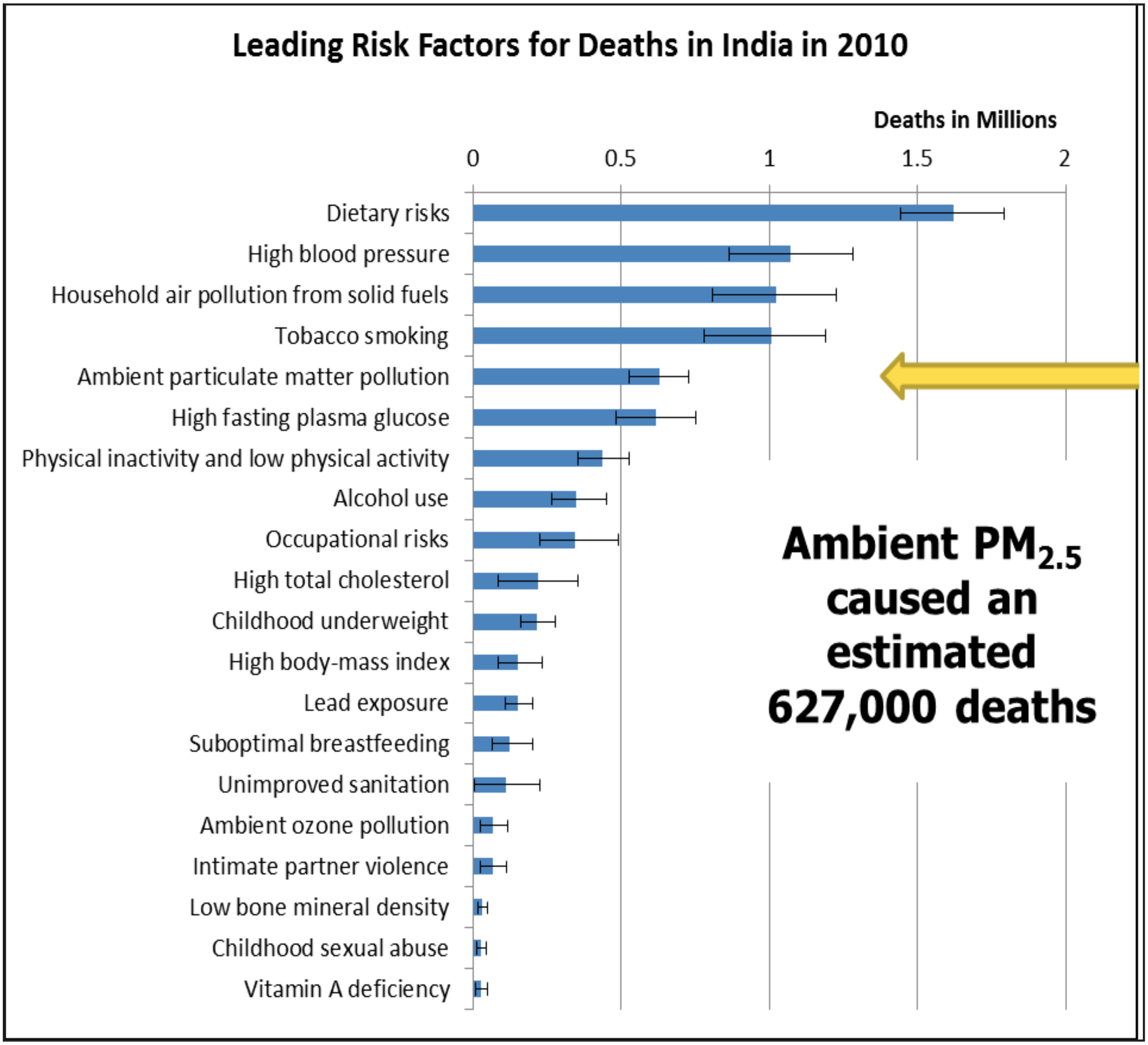

Fig. 3.8: Top 20 mortality risk factors in US and India Sources: GBD, 2010

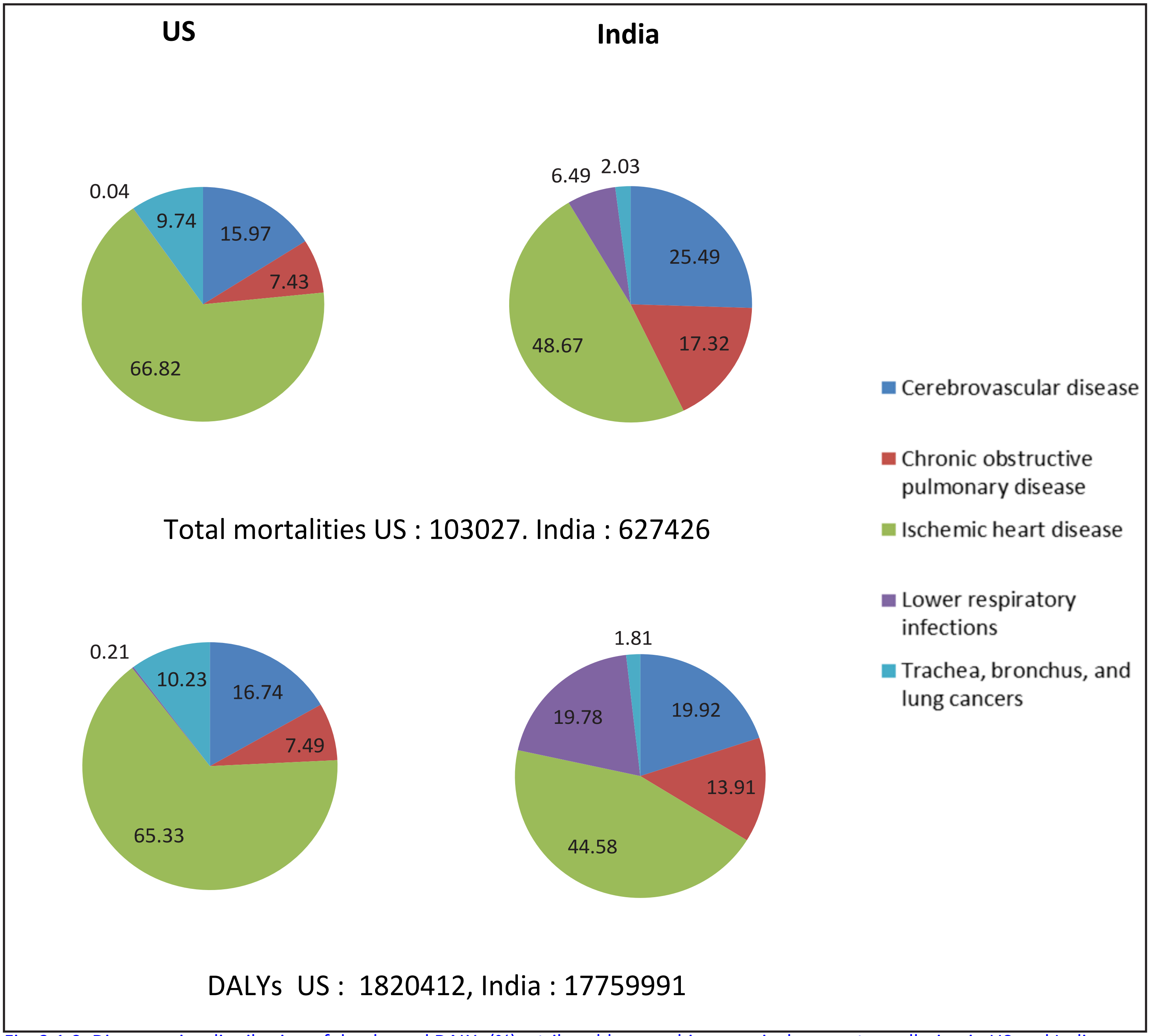

Fig. 3.1.0: Disease-wise distribution of deaths and DALYs (%) attributable to ambient particulate matter pollution in US and India

PART IV: Emission Reduction: Policy Landscape

India's transport needs are currently growing faster than the economy and are likely to continue on this trajectory. Reducing emissions even as the passenger- and freight-kilometers traveled increase will require concerted effort to create the infrastructure and regulatory environment to enable and motivate households and businesses to choose energy-efficient, low-emission forms of transport. These changes cannot simply be decreed, but will require shifts in public investment processes, urban governance, as well as regulatory design and enforcement. Subsection 1 provides a brief overview of the current governance framework for transport and for emissions control, subsection 2 discusses key opportunities to increase energy efficiency of transport, and 3 discusses opportunities to lower emissions per unit of energy used.

A Brief Overview of Transport Governance and Emissions Control

India's transport policy environment is fragmented. Responsibilities for infrastructure investment planning, policymaking, regulatory oversight, and financing are divided between within and between levels of government. The country is unique among major economies in having separate national Ministries overseeing each mode of transport. The Planning Commission's Transport Division (PCTD) currently functions as the main coordinating body on transport investment, but has limited resources and capacity for system-wide strategic planning, much less integrating sustainability with other goals for the transport system. The Prime Minister's National Transport Development Policy Committee (2013) is expected to recommend the creation of an independent "Office of Transport Strategy," which could become a focal point for integrating air quality and other sustainability goals into India's transport strategy, but developing this new body will take some time even if approved.

Civil aviation, railways, and shipping are primarily national responsibilities, while states play more of a role in road investment, regulation of road use, and road transport, as well as regulation of state-level ports. State-level division of responsibility across different tiers of roads (rural, major district roads, highways), policy and implementation, sources of finance (public, private, or intergovernmental transfer), and links between transport strategy and land-use planning for industrial or urban development vary. Local governments play a limited role in creating and regulating the transport system.

Urban transport, one of the key areas of interest for emissions reduction, has a particularly complex governance framework. It is a "constitutional and institutional orphan" (in the words of the Report of the Working Group on Urban Transport) with many interested parents. National, state, and, to a lesser extent, city government agencies are involved in planning, financing, and maintaining projects. The Ministries of Railways and Urban Development play a key financing and oversight role in rail-based urban transport, and the Ministry of Road Transport and Highways is often involved in setting standards or providing other inputs for bus-based transport systems. State and local government share responsibility for road investment planning and implementation, and the local government undertakes maintenance. Public transport services are operated by a mix of state corporations (primarily focused on inter-city transport), municipal transport corporations (intra-city), and private providers of cabs, rickshaws, and mini-buses.

Capacity for integrating urban transport strategy across modes and with larger urban planning processes (particularly land use) also needs to be built. The Ministry of Urban Development's National Urban Transport Policy (2006) recommended that each city of more than a million residents form an Urban Metropolitan Transport Authority (UMTA). As of the 2011 Census, however, there are 53 cities[1] of that size, but there are only 8-10 UMTAs existing in any form. Available information suggests that even the older UMTAs are in the early stages of institutional development. Several of these committees play an important role in coordinating the many state and urban participants in urban transport, but, at the time of writing, none have sizable permanent expert staff or independent budgets.

Similarly, India's emissions control standards are created and enforced by a range of government agencies, acting under several statutes and legal precedents regarding vehicle emissions, fuel quality and air quality standards. The following is a list of entities involved across national, state, and local governments and their respective roles:

National government:

- Ministry of Environment and Forests: overarching body for environmental quality and standards, sets air quality standards in fulfillment of the Air Act of 1981 and Environment Protection Act of 1986.
- Central Pollution Control Board: technical advice to MoEF in its efforts to fulfill mandate through national air quality standards, monitors compliance with ambient air quality standards including heading the National Air Monitoring Program.
- Environmental Pollution (Prevention & Control) Authority: board set up by Ministry of Environment and Forests under Supreme Court order, convened by Chairman, CPCB and including representatives from industry and civil society as well as relevant government entities to look into pollution abatement measures for India's largest cities. Recently expanded its jurisdiction and established state level reviews.
- Ministry of Road Transport & Highways (MoRTH): nodal ministry for setting vehicle emissions regulations, which states and municipalities then enforce.
- Bureau of Energy Efficiency, Ministry of Power: designing proposed passenger vehicle efficiency standards (along with Ministry of Heavy Industry).
- Ministry of Heavy Industries: designing proposed passenger vehicle efficiency standards (along with BEE, MoP), oversees and partially funds vehicle-testing centres (co-funding from the automobile industry).

State government:

- State Regional Transport Offices (RTOs) (sub-agencies of State Transport Departments): provide "fitness certification" including, in principle, Pollution Under Control (PUC) certification, for vehicles in use, among other duties including licensing, registration, etc.
- State Pollution Control Boards: enforce the regionally varied emissions standards set by the national policy for vehicles.
- Traffic police: charged with enforcing various aspects of Motor Vehicle act, including possession of a PUC certificate. Vehicle owners without valid PUC may be fined.

Other:

- Courts/Public Interest Litigation: Court orders after successful suits from citizen representatives can initiate emissions control policy and regulation. (e.g. Delhi's switch to CNG).

Opportunities & Challenges for more Energy-Efficient Transport

India faces three main challenges in achieving more energy-efficient transport: motivating and enabling a modal shift from road to rail transport for freight; stemming the rising share of private vehicles (two and four-wheelers) in urban mobility by improving public transport and conditions for non-motorized transport (walking and cycling); and increasing overall fuel efficiency of the vehicle fleet.

Road-Rail Balance:

Road transport accounts for nearly 70% of freight and 90% of passenger traffic after several decades of a steady shift from rail to road as the mode of choice. Shifting more transport, particularly freight, from roads to relatively efficient rail will require reducing rail congestion, especially at ports, urban hubs, and other points of interchange, as well as rationalizing freight prices.

Both are well-recognized policy priorities that face politically challenging hurdles. Rail freight and passenger pricing has historically been set by the Rail Ministry, with an eye to the political importance of maintaining affordable passenger transport. Expert committees and rail reform proposals have been nearly unanimous on the need to establish an independent regulator to set prices based on technical and commercial considerations. Similarly, expert reports and investment strategies over the past two decades have nearly called for more investment in track management as well as capacity expansion on existing routes. The stakes are high: McKinsey (2013) estimates economic losses of up to $120 billion/year by 2020 without substantial improvement in rail freight and other investments in India's logistics infrastructure.[2] New track infrastructure as well as six dedicated freight corridors is underway, but running behind schedule. New track investment has a long gestation period in any case, and projects have been further delayed by political challenges of land acquisition.

Urban Transport

India's urban transport choices will set the tone for the energy-efficiency and livability of India's cities. Public transport and non-motorized transport (bicycles and walking) continue to play an important role in urban mobility, but reliance on personal vehicles (two wheelers and cars) is increasing as incomes rise. The economic and environmental costs of the resulting urban congestion are increasingly clear. India is "urbanizing outside municipal boundaries" as congestion in the denser city cores already appears to be motivating more businesses to locate in the peri-urban areas. This in turn places greater stress on water, sanitation, and other infrastructure that is still in development. Transport is expensive: cost per kilometer of short-distance shipping within urban areas can be multiples of long-distance rates.[3] The congestion affects cities' ability to attract investment as well: large international and domestic companies have been quite public about their decision to limit investment in or move out of Bangalore due to its traffic congestion, for example.

All levels of government in India have officially recognized the challenge and committed to responding through increased investment in public transport as well as pedestrian and bicycle-friendly roads. The Urban Transport Working Group of the Prime Minister's National Transport Development Policy Committee argues that India's urban transport planning must move toward an overall approach of "Comprehensive Mobility Planning," to "Avoid" (reduce demand for trips through IT investment, land use planning, and other means); "Shift" (shift mobility from personal vehicles to more energy and space efficient public and non-motorized transport); and "Improve" (increase fuel efficiency, reduce emissions) transport. As discussed, above, however, urban transport governance is complex and the policy framework to infuse environmental goals into urban governance is still nascent.

This institutional context poses obvious challenges for policy solutions, but also creates opportunities to develop urban transport approaches that effectively integrate urban planning, climate change, air quality, and other development goals. The National Urban Transport Policy (2006) and the emphasis on sustainability in the NTDPC, suggest an appetite for such innovation. There are also other positive developments to build on. Civic and community associations are beginning to act as informal "policy kitchen cabinets" for the unified metropolitan transport authorities in their areas. These collaborations have led to pilot projects to invest in pedestrian infrastructure and bicycle lanes, officially adopted blueprints for "transit oriented development" investments to make the areas around transit hubs safer and more attractive, and increasingly informed public discussions and demands for functional public transport. National policy dialogue has turned to discuss ways to build stronger incentives for investment in public transport and facilities for non-motorized transport into urban investment programs. There is scope to leverage the next round of National Urban Renewal Mission funding or other statutory intergovernmental transport programs to strengthen incentives for investment in efficient, low-emissions urban transport strategies. The current Finance Commission, a constitutional body created every five years to determine the allocation of taxes and some grants between levels of government and among states, creates another potential opportunity to influence urban transport strategy through incentives linked to funding.

Fuel efficiency

With respect to GHG emissions and vehicle fuel economy, no regulations have been passed to date[4] leaving India a nearly solitary outlier among the major vehicle markets in the world.[5] Nor has progress been made on regulations for commercial vehicles and two- and three-wheelers.

The Bureau of Energy Efficiency (BEE) under the Ministry of Power has proposed fuel efficiency standards based on corporate average fuel efficiency (km per liter), similar to European frameworks, with fuel efficiency standards set in terms of CO2 emissions per kilometer estimated on the basis of average vehicle weight. While the fact of the discussion is a positive step, German and Lutsey (2010) and others argue that this approach to regulation fails to reward many of the most innovative ways to increase efficiency. Vehicle efficiency can be increased by reducing mass or by changing the footprint and its aerodynamic properties. Lower-mass cars necessarily require fewer liters for kilometer (and thus emit less per kilometer), but this does not necessarily mean that they are more efficient in the sense of achieving the same performance with less fuel consumption.6 Also, mass-based approaches can lead to artificially lax standards if regulations are developed around assumptions of average vehicle weight that are lower than actual average vehicle weight.

India's fiscal deterioration, dependence on energy imports, and the potential for higher oil prices have all increased political motivation to reduce fuel subsidies and raise fuel prices. The distributional impact of changes fuel subsidies, however, is murky. On the one hand, consumer fuel prices clearly affect inflation and increases are obviously politically unpopular. They affect the poor through direct costs of personal transport as well as indirect costs embedded in the transport of goods and services they consume.[7]

On the other hand, the fiscal burden of fuel subsidies is distributed among a number of public sector enterprises and not obviously visible in the national budget figures or agency budget constraints. The actual fiscal burden due to petroleum product subsidies is difficult to calculate. Most of the petroleum sector, both upstream extraction of crude oil and natural gas to downstream refining and distribution of petroleum products is dominated by state owned enterprises that are publicly listed, but have opaque transfer pricing. Indian oil marketing companies import crude oil at world prices then refine and sell it for a regulated price in the domestic market. Their losses must then be imputed, and there is some dispute over various means of estimating prices.

Enforcement will require further political will when fuel efficiency standards are passed. The Financial Express quoted one senior official from the Ministry of Road Transport and Highways (the Ministry overseeing enforcement) as saying that "Car companies have already been informed of the fuel efficiency norms and they have time till 2017 to make the changes. Those who are not able to meet these standards will have to stop manufacturing as their vehicles cannot be registered on Indian roads, much like what is followed in case of emission norms."[8] The comparison may understate the potential impact of efficiency standards for new vehicles: emission norms are not regularly enforced for vehicles on the road but efficiency standards could be more readily enforced at the point of sale.

Finally, the impact of fuel efficiency and emissions standards for new vehicles depends on the rate at which old vehicles will be replaced.There are currently no national programs in place to accelerate fleet turnover, though various states have established a Green Tax on old vehicles to encourage faster retirement of private (15 years) and commercial vehicles (7-8 years). Some of these taxes earmark revenues for air quality management. Judicial intervention has led to banning of very old vehicles in some cities like Delhi, but data on enforcement rates are limited.

Emissions Control at Vehicle Level

There are three challenges involved in reducing vehicular emissions: first, motivating a consumer shift away from diesel to petrol vehicles by reducing the price difference between diesel and petroleum; second, tightening and enforcing vehicle emissions standards for all fuels; and third, mandating and enforcing fuel quality standards, particularly for diesel, that allow for some of the latest emissions control technologies to be used. Fuel quality and vehicle emission standards in India lag international leaders by more than a decade, and India is at risk of falling behind other developing countries as well. China, Brazil, Mexico, Thailand, and South Africa all have plans to reduce fuel sulfur content and tighten emission standards beyond those that India has in place.

Fuel Price

India has subsidized diesel prices since the 1970s under the rationale that this fuel is used for tractors, pump sets, and other engines used in agriculture. The subsidies, however, are universally available, and most (60%) of the diesel is used for road transport including passenger cars as well as long-haul transport. About 8% is used for power generation; cell phone towers being the single largest industry consumer. Just 12% is used in agriculture.[9] (Anand, 2012) The price differential between diesel and petrol has led to a consumer preference for diesel vehicles.

Several expert committees over the past decade have outlined roadmaps for moving to more market-based pricing, including reducing the subsidy-induced price differential between diesel and petroleum,[10] and momentum has picked up under fiscal pressure. The government announced removed subsidies from bulk purchases in January 2013, a move that affected Indian Railways State Transport corporations, government utility vehicle fleets, and industries relying on diesel for power generation among others.[11] Retail prices remained the same, and the press reported widespread instances of buses, city vehicles (e.g. garbage trucks) using retail stations to purchase fuel. Citizen activism to limit access to diesel subsidies has also increased. The Indian Investors Protection Council, for example, filed a petition with the Supreme Court in July 2013 to exempt luxury cars, five-star hotels, malls, supermarkets and other commercial establishments using diesel generators, and cell phone towers from subsidized diesel. Retail prices remain subsidized but the differential between diesel and petroleum prices has been decreasing markedly in the past year.

Emissions Standards

The institutional framework for establishing and enforcing emissions standards is described above. This section discusses key areas for strengthening policy and enforcement.

First, while emissions and air quality controls are becoming more stringent over time, there are some important policy vacuums to address: evaporative emissions, for example, must be addressed separately from measures targeting reductions in tailpipe emissions. India currently has no regulations for evaporative emissions, which are a health hazard to those refueling vehicles as well as those living near fueling stations because they contain benzene. The volatile organic compounds (VOCs) in fuel vapors also exacerbate ozone formation. So-called "Stage I" controls should be developed to capture vapors given off when delivering gasoline fuel to underground storage tanks at retail filling stations. Additionally, regulations should be developed to require so-called "Stage II" controls be fitted onto pump nozzles at filling stations, to capture vapors emitted during vehicle refueling, which can be complemented with onboard refueling vapor recovery (ORVR) systems installed on new vehicles.

Second, the governance framework for establishing and enforcing emissions standards could be strengthened by integrating the various responsibilities under a single agency. The Mashelkar Committee (2003) recommended that standard-setting, enforcement, and oversight of testing be combined into a single government agency, but the recommendation has not been adopted.

Third, strengthen in-use vehicle-emission control measures. Fuel standards and emissions controls for new vehicles are important, but strengthening the in-use regime can have a more immediate impact as it addresses emissions from the entire fleet, and in particular the gross emitters. Indian policy should ensure that vehicles already on the road are operating to their design specifications and not emitting excess pollutants. This means enhancing, or perhaps replacing, the current Pollution Under Control (PUC) program with an in-use emissions testing program that selects vehicles off the road and tests them according to their original emission standard. The current in-use testing programs are enforced by state governments and are less systematic than the national standards for Type Approval (TA) and Conformity of Production (COP) testing. Although emissions tests are mandatory when moving a vehicle from one state to another and re-registering it, the provision is not always enforced. Other in-use emission testing remains largely voluntary and are carried out by vehicle owners through local certified centers. Driving cycles on which new vehicles are tested for compliance of emission norms also need to be looked upon. TERI, 2013a12 assessed the real world driving conditions in India and found them to be significantly different from the driving cycles followed for emission testing. This may lead to higher emissions in real world despite the compliance of norms on the prescribed driving cycles. Moreover, In India, there exists no recall policy for vehicles, which do not comply with established norms in real driving conditions.

Regulatory interventions aimed at ambient air quality are also potential source of greater pressure, but only to the extent that these initiatives can be linked to enforceable directives for particular sources to reduce emissions. The Ministry of Environment & Forests notified the revised National Ambient Air Quality Standards (NAAQS) in late 2009. Newer pollutant parameters and stricter standards were included, including replacing particulate matter (SPM) with PM2.5 monitoring New parameters, such as, Ozone, Arsenic, Nickel, Benzene and Benzo(a)Pyrene (BaP) have been officially introduced as air pollutants that would come under the ambit of ambient air quality monitoring in cities. In a press note[13] circulated prior to the notification of the NAAQS, the Ministry stated that; "..........., the CPCB is in the process of creating a road-map for the generation and maintenance of a database, monitoring of required infrastructure and for the development of protocols. ....also in the process of developing additional support systems of enforcement such as the National Environment Protection Authority (NEPA) and the National Green Tribunal (NGT) to ensure the effective enforcement of the Standards."

However, the mechanisms for linking air quality goals to concrete steps in urban planning, transport investment, and design as well as enforcement of vehicular norms are still nascent. Land use and transport development agencies, for example, do not currently face direct pressures to ensure that their policies or investments reduce traffic sufficiently to meet air quality norms.

More specialized taxation measures have also taken shape over the last few years at the state level. The New Delhi Government has created an 'Air Ambience Fund,'[14] which will be funded by taxing sale of diesel at Rs. 0.25 per liter to support clean air policies. Himachal Pradesh and other states in the northeastern region have discussed special taxes for prevention of traffic congestion. Tamil Nadu is contemplating a congestion tax19 to reduce traffic congestion and tackle vehicular air pollution.

Such state and city-level initiatives are likely to accelerate as public awareness about the health impacts of air quality increases and are an important area for discussion at the workshop. The infrastructure for regulation and air quality management is being built in cities around India.

Fuel Quality

One of the primary barriers to progress toward effective vehicle-emission standards (viz. Euro 5/V and 6/VI) in India is the high sulfur content in the diesel fuel and gasoline (petrol) sold in the country: up to 350 parts per million (ppm) in diesel and 150 ppm in gasoline. At such concentrations, sulfur inhibits the proper functioning of advanced after treatment technologies, ranging from diesel particulate filters to lean NOX traps that could reduce vehicle emissions by more than 90%.

The interventions in the sector started with introduction of first ever emission control norms in 1991/92. In 1995, catalytic convertors were made mandatory for cars and fuel quality improvements were also made. In 2002, the Auto Fuel Policy (MoPNG, 2002) recommended a road map for advancement of vehicular emission norms in India (Table 4.0).

The road map was more or less successfully implemented with differentiation between some hotspot regions and the rest of the country.

Indian policy on air quality and vehicle efficiency continues to be undermined by its reliance on two parallel standards, Bharat Stage (BS) IV for a handful of cities and BS III for the rest of the nation. India's current fuel quality standards were implemented in 2010 along with the latest vehicle emission standards. Bharat IV fuel quality standards were mandated in the thirteen cities and Bharat III standards for the rest of the country. Since 2010, at least seven more cities have been added to Bharat IV fuel standards. A total of 63 cities are planned to receive Bharat IV fuel by 2015.

The review of last Auto Fuel Policy 2003 suggests the following main outcomes:

- Heavy duty trucks (highest contributors to PM) could not achieve BS-IV norms due to unavailability of appropriate fuel across the country
- Very high growth of vehicles negated the benefits provided by the last auto fuel policy
- The focus was more on PM control and less reductions achieved in NOx , and hence, further advancements required
- The share of older highly polluting vehicles in emissions is going to reduce in future , hence need to focus on improving emissions from newer vehicles
- Old driving cycles used for testing may not result in on-road reductions as depicted during emissions tests.

The Mashelkar Committee had recommended that

Coverage	**Passenger Cars, light commercial vehicles, and heavy duty diesel vehicles**	**2/3 wheelers**
Entire country 11 major cities (Delhi/NCR, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur & Agra)	Bharat Stage II – 1.4.2005 Euro III equivalent – 1.4.2010 Bharat Stage II – 1.4.2003 Euro III equivalent – 1.4.2005 Euro IV equivalent – 1.4.2010	Bharat Stage-II- 1.4.2005 Bharat Stage III - Preferably from 1.4.2008 but not later than 1.4.2010

Table 4.0 Road map for introduction of vehicular emission norms in India

a new Auto Fuel Policy Committee be formed every five years to review progress and the 2013 Auto Fuel Policy committee has been established. The timeline for updating standards is unclear. At present, there is no road map for further advancement of vehicular emissions and fuel quality norms in the country, though a committee has been set up to develop a road map for vehicular emissions and fuel quality norms through 2025.

This current scenario based on regional differentiation treats consumers and businesses outside of major cities inequitably. Further, it weakens the logic of the policy overall, since all heavy-duty trucks meet BS III standard only, and nothing prevents BS IV vehicles requiring low-sulfur fuels from refueling in high-sulfur fuel areas.

The current dual fuel status in India leads to a situation in which Bharat IV vehicles, designed to operate on lower sulfur fuel, may refuel in Bharat III areas. This is particularly problematic for commercial vehicles, which often do not operate in just one metropolitan area. Since many emissions control technologies require low sulfur fuel to function correctly, Bharat IV vehicles refueling on Bharat III fuel are likely to be emitting more than they are designed to. India has also taken steps to reduce sulfur content in fuels, however, India remains well behind international best practices.

Gaseous fuels like CNG and LPG have been introduced in an effort to reduce PM emissions in some of the hotspot cities like Delhi. CNG is now being supplied in 25 cities of the country (MoPNG, 2012a).[15] In Delhi, all the buses, auto-rickshaws, and taxis have been switched over to CNG. Some gasoline driven cars are also being retrofitted with CNG kits. In Bangalore, all the auto-rickshaws are retrofitted with LPG kits. Traffic management measures including construction of transport management infrastructure have been taken up in some cities for reducing congestion and hence corresponding idling emissions.

Even as movement on the policy front continues, there remain many places where enforcement of fuel quality standards can break down. Fuel adulteration remains a problem in India. Compliance with fuel quality standards is overseen by the Ministry of Petroleum and Natural Gas, but the oil companies implement the testing. MoPNG representatives are legally required to be present at refineries and depots to sign off on each batch of fuel as it is tested at refineries and oil depots but it is not clear that this actually takes place. The state governments issue permits to fuel transporters, who are also required to maintain lists of the retailers whom they supply. Morris et al (2006) found that recordkeeping was limited in practice and that fuel shipments were not tracked to ensure that the transporters were going to their assigned destinations. The study also found high levels of corruption among transporters' employees as well as those overseeing their compliance.[16] Roychoudhury (2002) also found adulteration of fuel to be widespread.[17] An anti-adulteration cell within the Ministry was established in 2001 but shut down in 2004.[18] Independent labs do exist, but these do not have the authority to obtain samples or to punish actors in the fuel supply chain for any violations detected.

A rigorous quality assurance program, operating throughout the fuel supply chain to monitor and enforce fuel handlers' compliance with fuel-quality standards, is needed to ensure that vehicles equipped with high-performing emissions controls and fuel-efficient engines have adequately clean fuel to take full advantage of those technologies. There are some promising efforts in this direction, including research on and tender requests from oil marketing companies for mobile applications to remotely monitor their fleet and maintain locks on tankers as well as fuel testing kits and customer hotlines to report anomalies advertised at major brands' gas stations.

If India were to take a holistic approach and act in a coordinated manner on regulating fuel quality standards and emissions, for example using the 9-point approach developed by the International Council on Clean Transport (ICCT) and outlined in figure 4.0 vehicular emissions could be reduced by more than 80% from where present trends would place them in 2030. Table 4.1 outlines differences between a business-as-usual and an alternative scenario in which India would aggressively adopt international best practices to reduce vehicle emissions. Figure 4.0 shows modeled emissions of the most important air pollutants under these scenarios.

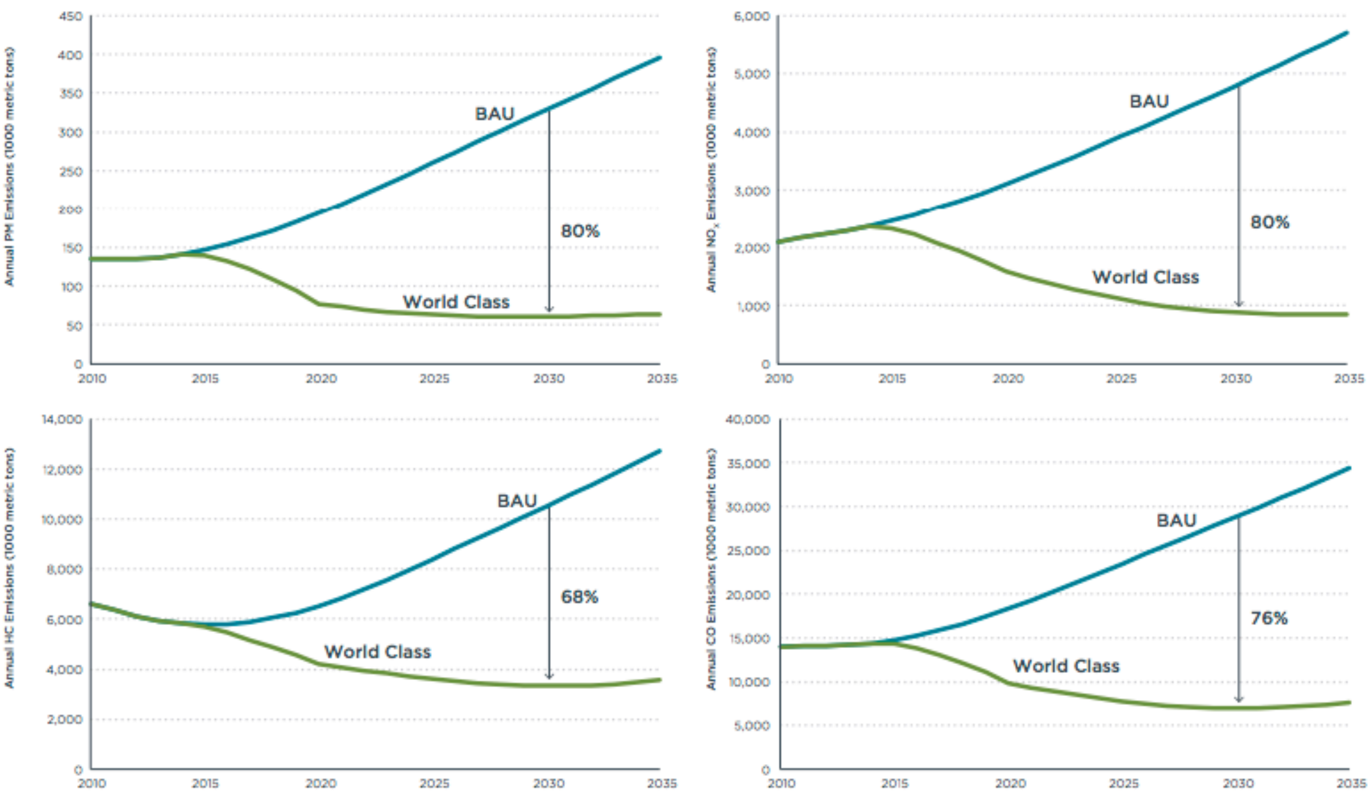

Figure 4.0 Annual vehicle PM10, NOX, HC, and CO emissions from 2010 to 2035. Source: ICCT: Policy Summary: India's Vehicle Emissions Control Program

SCENARIOS	EMISSION STANDARDS	FUEL STANDARDS	ENFORCEMENT AND COMPLIANCE[1]	CHANGE IN FUEL TYPE[2]
BAU	Bharat IV in 50+ cities by 2015, Bharat III in rest of India; Bharat III for 2/3-wheelers nationwide	Low-sulfur fuel (50 ppm) in 50+ cities by 2015, 150 ppm sulfur gasoline and 350 ppm sulfur diesel in rest of India	15% of vehicle fleet are gross emitters	60% of new LDV sales diesel by 2020
World Class	Bharat V by 2015, Bharat VI by 2017, and US Tier 3 equivalent 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% of vehicle fleet are gross emitters	15% of LDV sales CNG and 10% LPG by 2030; 75% bus sales CNG by 2030; 50% of 3-wheeler sales CNG by 2030

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

Table 4.1 Business as usual versus international best practice in controlling vehicle emissions.

Policy Recommendations

Numerous specific recommendations follow from the ICCT's comprehensive analysis of the policy context and options for vehicle emissions control in India.

1. Mandate lower sulfur content (10 ppm) for all road-vehicle fuels and tighten emission standards to Euro 6/VI and beyond for all vehicle types is feasible within a near-term timeline. Table 2 below shows a feasible timeline.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Fuel Sulfur content (ppm)	50		10								
LDV Emission Standard	BS Va		BS Vb		BS VI				Euro 7/US Tier 3 equivalent		
HDV Emission Standard	BS V				BS VI				Euro VII/US2010 equivalent		
2/3-Wheeler Emission Standard	BS IV				BS V				BS VI		

All implementation dates are for the beginning of the fiscal year (April 1)

Table 4.2 Recommended implementation dates for fuel sulfur content and vehicle emission standards.

Vehicle category	Current (km)	Recommended (km)	Notes
2/3-Wheelers	30,000	50,000	Euro V standards proposal, Iyer NV, 2012
LDVs	80,000	190,000	Recommended is US Tier 2 requirement
HDVs			
N1	100,000	190,000	Recommended is US Tier 2 requirement
N2	125,000	190,000	Recommended is US Tier 2 requirement
N3 w/GVW < 16,000kg	125,000	190,000	Recommended is US Tier 2 requirement
N3 w/GVW > 16,000kg	167,000	300,000	Recommended is US MHDDE requirement
M2	100,000	300,000	Recommended is US MHDDE requirement
M3 w/GVW < 7500kg	125,000	300,000	Recommended is US MHDDE requirement
M3 w/GVW > 7500kg	167,000	300,000	Recommended is US MHDDE requirement

Table 4.3 Durability requirements for vehicle emission standards.

2. Increase the durability requirements of emission regulations to match levels that manufacturers have already demonstrated the ability to meet in other jurisdictions, such as the United States. Table 4.3 below summarizes current and recommended emissions durability.

3. Develop, by April 1, 2015, a national program to randomly select properly maintained and used vehicles and test them against their original emission standards, along the lines of the United States Environmental Protection Agency (US EPA) programs, to be implemented starting April 1, 2017. India is already in the process of establishing more than ten vehicle testing centers around the country, which should be used for conducting such in-use vehicle testing. This will ensure that vehicles are meeting durability requirements, and noncompliant vehicle models are identified.

4. Develop a national program to test fuel quality throughout the fuel supply chain, including retail stations, by April 1, 2015. A national fuel-testing lab has already been commissioned in Noida, but as planned that facility would not have authority to take action against noncompliant fuels. Regional fuel testing labs should be established in all regions of the country and given authority to take legal action against fuel handlers dealing with noncompliant fuel.

5. Establish a National Automobile Pollution and Fuel Authority (NAPFA), as recommended by the Auto Fuel Policy Committee in 2002, with power over environmental regulations for vehicles and fuels, to ensure timely implementation of the auto fuel policy roadmap. NAPFA should have the ability and authority to work with fuel quality and vehicle emissions testing labs to issue mandatory recalls, levy fines, and take other legal action against parties dealing with noncompliant vehicles and fuels.

6. Mandate annual vehicle registration for all vehicle types across the country. Currently private vehicles need only be registered 15 years after initial purchase. Annual registration can be linked with PUC testing and proof of insurance. This will provide India more comprehensive data on its vehicle fleet and enable the government to streamline vehicle regulations.

7. Mandate Stage I and Stage II evaporative emission controls by 2017 at all urban fuel retail stations, in time for nationwide deployment of ultra-low-sulfur fuels (<10 ppm sulfur). Additionally, mandate ORVR systems for all new vehicles beginning in model year 2015.

8. Adopt the 2020 passenger car fuel economy standards, already developed jointly by the Bureau of Energy Efficiency (BEE) and Ministry of Road Transport and Highways (MoRTH), without delay, and extend the standards to 2025.

9. By 2015, have in place regulations requiring a 2% annual reduction in fuel consumption by light as well as heavy commercial vehicles between 2016 and 2025.

10. By 2017, have in place regulations requiring a 1% annual reduction in fuel consumption by two- and three-wheelers between 2018 and 2025.

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Footnotes Part IV

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