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Measures to Control Air Pollution in Urban Centres of India: Policy and Institutional framework

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Background and Objective

- Many Indian cities including New Delhi are included in the list of most polluted cities in the world (WHO 2014, Cheng *et al.* 2016). About 80 per cent of cities in India violate the prescribed standards of ambient air quality (CPCB 2014). Multiple sources contribute to the problem and, hence, sector-specific strategies are required for control of air quality.
- This policy brief aims to analyse the whole issue in terms of key drivers, such as rapid urbanization, transportation, industrialization, power generation, and agricultural activities, that subsequently lead to air pollution at different scales in India. These drivers lead to generation of pressures on the air quality through release of pollutants. The brief assesses the contribution of different sources of emission and pollutant concentrations at urban and national scales and the impact on human health and other important receptors and discusses the key measures required for improvement of air quality in urban centres of India.

Drivers of Air Pollution

- Urbanization, transportation, industrialization, power generation, and agricultural activities are the key drivers that lead to air pollution through release of emissions.
- Population in India has grown from approximately 36 crores in 1951 to 121 crores in 2011. Urbanization levels grew from 17 per cent in 1951 to 31 per cent in 2011, mainly driven by rural to urban migration. Growing population has a direct linkage with fuel consumed in the residential sector. Households in urban slums and rural areas surrounding cities still depend on biomass for cooking. Refuse generation (which is sometimes burnt later) is another activity driven by population and urbanization levels. Population along with economic growth in cities has also led to increase in mobility and transportation demands. Registered vehicles in India have grown from 5.3 million in 1981 to 159 million in 2012, with two wheelers and cars having 73 per cent and 14 per cent shares, respectively. Fuel used in residential and transportation sector contributes to air pollutant emissions. Also, movement of vehicles causes re-suspension of dust, which adds to the ambient concentrations of particulates.
- Industrial production in India has grown exponentially over the past two decades. During 2001–11, the production of finished steel, cement, coal, and crude oil has grown at the rate of 9.0 per cent, 8.1 per cent, 5.5 per cent, and 1.5 per cent, respectively. A Comprehensive Environmental

Pollution Index formulated in 2009 showed that 43 of 88 industrial areas/clusters were critically polluted (CPCB 2009).

- The overall electricity generation in India has gone up from 5 billion kWh to 811 billion kWh during 1951–2011. Coal-based power plants are important sources of pollution. Despite tremendous increase in capacity, there is a significant demand–supply gap, and many regions including suburban areas face acute power shortages that leads to use of diesel generators (DG sets) as standby power source. DG sets contribute significantly to pollutant loads in and around urban areas.
- Steep rise in cement and steel production also points towards growth of the construction sector in India, predominantly in urban regions. The share of construction in overall GDP in India has increased from 6.1 per cent in 2002–03 to about 8 per cent in 2014–15. Non-adherence to the guidelines for control of dust generated during construction activities further contribute to air pollution. Other than in-house sources in the cities, there are contributing factors in surrounding areas. Most urban regions in India are surrounded by rural regions where agricultural activities are carried out. Open (*in-situ*) burning of agricultural crop residue is practiced for quick preparation of the land for the next crop, which leads to emissions of pollutants. Other than this, agricultural activities such as tilling for soil cultivation and crop harvesting also contribute to generation of dust.

Growth of Pollutant Emissions in India

- Drivers discussed above lead to generation of emissions. While some of these pollutants are emitted due to inefficiency of the combustion processes, many others are generated due to fuel properties, chemical reactions, and lack of tail pipe controls. The main pollutants that are emitted from different sources are particulate matter (PM), carbon monoxide (CO), oxide of sulphur (SO_2), hydrocarbons/volatile organic compounds (hydrocarbons -HCs/VOCs), and oxides of nitrogen (NO_x).
- Contribution of different source to air pollution varies at different scales. PM_{10} emissions at national scale in 2016 are dominated by industrial (51 per cent) and residential combustion (28 per cent) sectors (Figure 1). Tail pipe emissions from transport sector contribute just 2 per cent of PM_{10} emissions at the national scale. However, their contribution is much higher at urban centres because these emissions are concentrated in these centres. The contributions from residential and transport sector increase in $PM_{2.5}$ emissions. Most emissions from domestic cooking and open burning of agricultural residues are released in rural regions. Power plants contribute limitedly to the national inventory of PM emissions, but may contribute significantly to pollution levels in specific zones of influence of power plants.
- Spatial distribution of emissions of PM2.5 shows that emission intensity is highest in the Indo-Gangetic plains as well as in the states of Gujarat, Tamil Nadu, and Maharashtra.
- Future projections of PM_{10} emissions suggest further increase till the year 2030 due to rapid industrial growth and limited tail pipe controls. Transport sector emissions are expected to reduce by introduction of advanced fuel quality and technological controls. Residential emissions will decrease due to improved penetration of LPG. Black carbon emissions are projected to decline with decreased shares from the residential and transport sectors. On the other hand, NO_x, and SO_x emissions will grow due to absence of control norms for most industries. VOC emissions will also grow due to rise in evaporative emissions from solvent use and oil handling.

Impacts of Air Pollution in India

- Air pollution is now widely known to have impacts over human health, agriculture, ecology, buildings, and climate. It affects the respiratory, cardiovascular, cardiopulmonary, and reproductive systems and can also lead to cancer (Steinle *et al.* 2015). International Agency for Research on Cancer (IARC) has classified outdoor air pollution as carcinogenic to humans (Group 1) (IARC 2013). Lim *et al.* (2012) estimated 0.62 million mortalities annually in India that could be attributed to PM2.5 pollution in 2010 (Figure 2a). This makes air pollution the fifth largest killer in India. TERI projected the mortalities to increase to 1.1 million in 2031 and 1.8 million in 2051, in a business as usual scenario (Figure 2b). IHME (2013) also lists air pollution among the top 10 health risks in India.
- Other than outdoor pollution, biomass used in rural regions and urban slums for cooking and kerosene for lighting is associated indoor air pollution and with a variety of health diseases such as Chronic Obstructive Pulmonary Disease (Sukhsohale *et al.* 2013), tuberculosis (Lakshmi *et al.* 2012), cataract (Pokhrel *et al.* 2005), and adverse pregnancy outcomes (Lakshmi *et al.* 2013).
- Other than health, impacts have also been noted on buildings; cultural monuments and national heritage

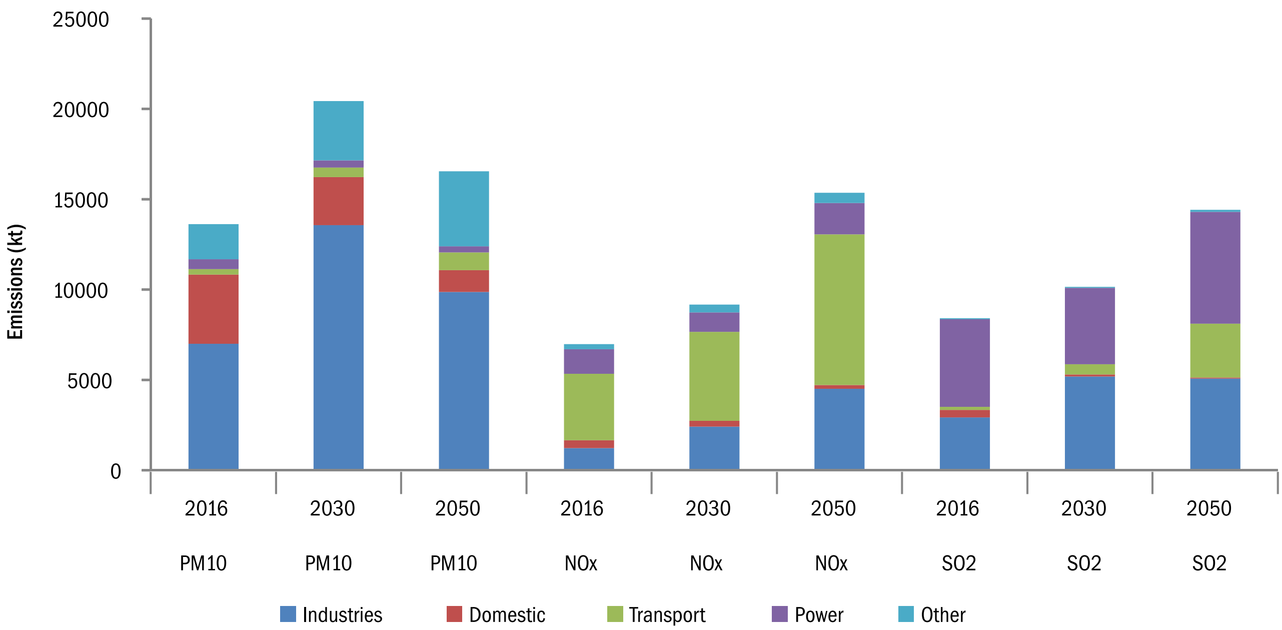


Figure 1: Sectoral air pollutant emission inventories for India (2016–50)

Source: TERI estimates

sites are of particular concern (Tidblad *et al.* 2012). The Taj Mahal is one such example of degradation of a cultural heritage building due to air pollutants. Air pollution, and particularly ground level ozone, also impacts agricultural productivity of many crops such as wheat, rice, maize, etc. Burney and Ramnathan (2015) estimated a relative yield loss of approximately 33 per cent for wheat and approximately 20 per cent for rice due to ozone pollution in India.

- Some of the air pollutants such as black carbon, ozone, and methane also have warming potential and are known as short-lived climate pollutants. Aerosols reduce the light and heat reaching the Earth's surface, causing heating of the atmosphere and cooling of the Earth's surface (Sharma et al 2016). This changes evaporation rates and precipitation efficiency of the clouds and can eventually impact the rainfall patterns in a region, which has implications over several aspects including rain-fed

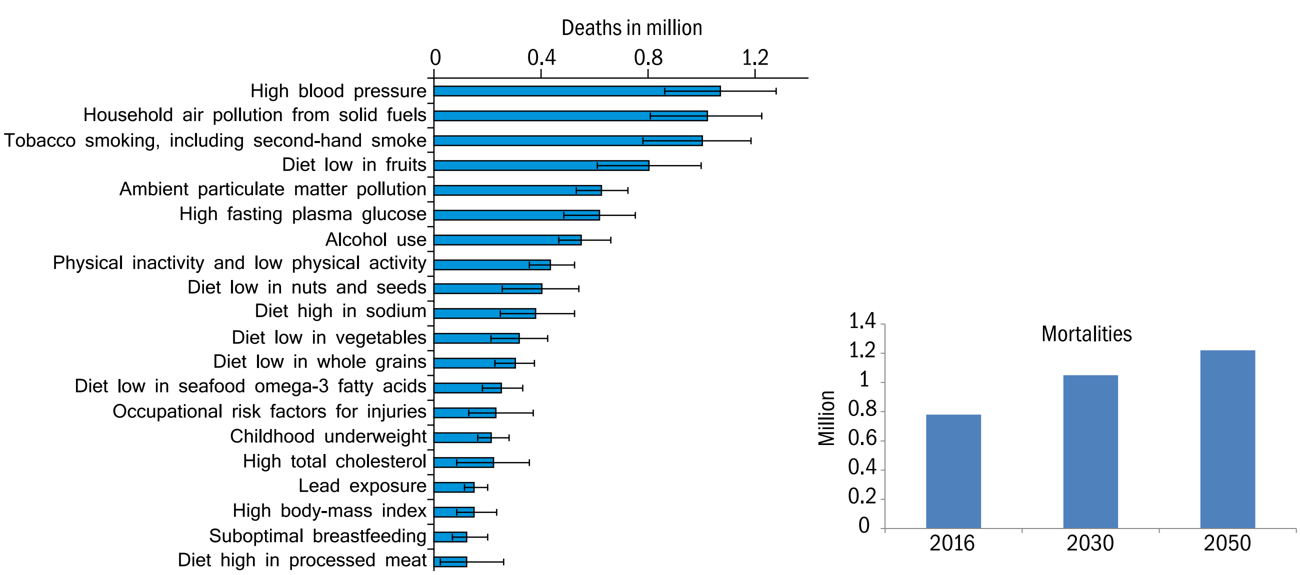


Figure 2: (a) Mortalities attributed to PM2.5 concentrations in India in 2010, 2031, 2051. (b) Projected increase in mortalities attributed to PM2.5 in a BAU scenario in India.
Source: Lim et al (2012) (Global burden of disease) and TERI (2015)

agriculture. Other than these impacts, there could be larger regional impact over the monsoons in Indian peninsula (Ramanathan *et al.* 2008).

Urban Air Pollution Source Apportionment Studies

- The drivers discussed in section1 lead to generation of pollutant emissions from a number of sources. Prioritization of remedial action to improve air quality thus requires information on the contribution of different sources.
- World Bank, 2004, conducted a limited scale study for cities of Delhi, Kolkata, and Mumbai, which found diesel combustion, road dust re-suspension, and biomass burning contributing significantly to PM2.5 concentration, with smaller contributions from gasoline and secondary particulates. The study also pointed out inter-city variations and confirmed that each city has its own characteristics and needs to be dealt differently.
- Central Pollution Control Board (CPCB 2011) shows the results of the first comprehensive source apportionment studies carried out in six cities in 2007—Bangalore, Chennai, Delhi, Kanpur, Mumbai, and Pune (Figure 3). Dust from road dust re-suspension, construction activities, and soil has the major contribution (6–58 per cent) to PM10 concentrations in the six cities. The share of transport sector increases significantly, when focus is shifted from PM10 to PM2.5 (finer fractions) concentrations. The average share of transport sector increases from 19 per cent in PM10 to 31 per cent in PM2.5 concentrations. In Bangalore, it emerged as the single largest source (49 per cent) of PM2.5. The share of NO_x emissions in different cities shows a dominance of transport across all six cities (CPCB 2011). Secondary particulates formed due to chemical conversion of gaseous pollutants such as SO_2 and NO_x also contribute significantly to PM2.5 concentrations in different cities.

Strategies for Control of Air Pollution in Urban Centres

For each of the drivers (urbanization, transportation, industrialization, power generation, and agricultural activities), strategies are discussed for controlling air pollution in urban centres of India.

Urbanization

- **City planning and management:** To an extent, pollution can be abated by urban design, topography, and meteorological factors, other than control of emissions. City planners can effectively plan spatial distribution of point sources of pollution, such as industries, landfills, treatments plants, transportation routes, open spaces, which impact the quality of air in an urban region. Regional and metropolitan strategies that are long range should go together with the small-scale short-range location and design strategies. Regional physical structure—shape, density, and organization of settlement areas; orientation and composition of subareas; pattern and type of transportation systems; and shape and location of open spaces—have major implications on air pollution. While selecting from several urban growth forms, emphasis must be laid on patterns that have potential for improving air pollution dispersion efficiency and reducing motorized travel. Adopting a *balanced sub-regional approach* for regional and metropolitan development with integration of mass transit is found to be helpful in reducing trip lengths, motorized travel, and urban sprawl. *Landuse planning with plans of reduced population density* around industrial zones or in downwind direction can help in reducing exposure to the pollutants released from

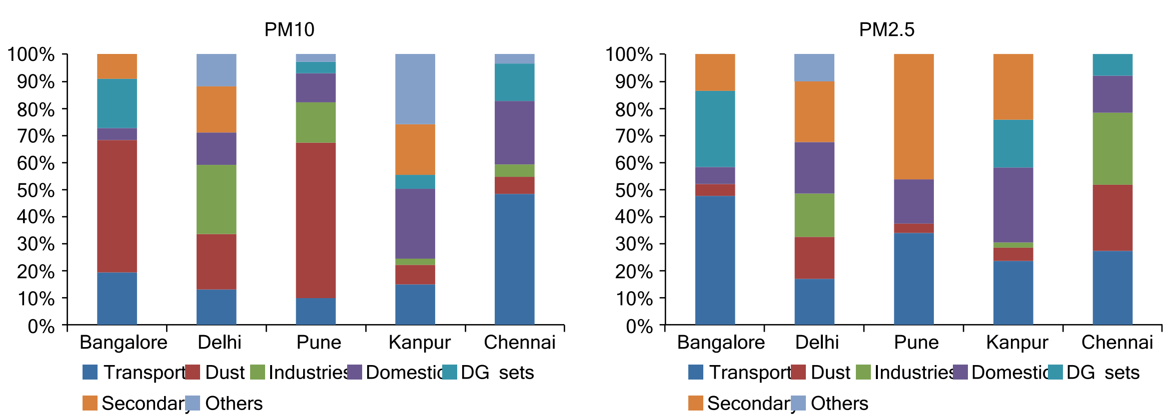


Figure 3: Source contributions to PM10 and PM2.5 concentrations in residential areas of six cities.
Source: CPCB (2011)

industries. This requires comprehensive studies of local meteorology and topography in order to improve spatial arrangements of industrial, commercial, and residential areas. *Open spaces* acting as buffer zones are also important but often such planned buffer strips get absorbed for other landuse applications during the lifetime of the development plan and therefore require strong laws and enforcement for their retention. Planning and siting of solid waste management sites also needs to be done carefully and proactively. For large projects, mandatory requirement of prior environmental approval provides mechanisms for mitigating key adverse environmental impacts.

- Updation of State/UT Town and Country planning acts as per the suggested updates provided in the URDPFI (Urban and Regional Development Plans Formulation and Implementation) guidelines, 2014. Few urban design interventions may also be implemented through appropriate modifications in development regulations and building bye-laws. Master Plan/Development plans including City Development plans, city mobility plans and other special plans to strongly focus on optimizing the landuse integration with transportation planning and some of the points mentioned above. Use of appropriate tools and techniques (also mentioned in the URDPFI guidelines) including simulation tools can greatly facilitate in selection of better alternatives (plan proposals). Visualisation tools can also facilitate in more citizen engagement at early stages instead of depending on public participation after the draft stages. Capacity building of the staff of urban planning departments who are involved in making such short term, medium term and long term plans is imperative and long pending. Allocation of separate funds to do consistent fact-finding research on scientific analysis of public health and transportation/urban planning will greatly help in building evidence for course correction/better implementation of perspective and development plans. This will influence getting political support for implementation of development plans.

- **Supply of cleaner fuels, stoves to rural areas and urban slums:** There is a need to widen the access of LPG or PNG and, wherever appropriate, smaller packaging and safe refilling options. Several government schemes designed to increase LPG/ PNG access across India have successfully enhanced the use of clean fuel in urban areas. Urban households using LPG has increased from 44.2 per cent to 68.4 per cent during 2000–12. However, dependence on biomass is still noted, with highest in Odisha (36.5 per cent) closely followed by Kerala (36.3 per cent) and Chattisgarh (34.7 per cent) (NSSO 2012). Fuel-efficient biomass-based improved cook stoves can bring down exposure level relatively close to cleaner fuels. Even as the government aims at providing LPG to all, it is evident that several million households will continue to depend on traditional biomass for cooking due to economic, supply, and delivery constraints. There is a need for more efficient use of biomass as a cooking fuel through the improved stoves with efficiencies ranging between 30 and 40 per cent as compared to 8 and 10 per cent of traditional cook stoves. Figure 4 shows the reductions in indoor concentrations of pollutants due to use of improved cookstoves in comparison to the traditional ones. Equally important is the need for research on development of more efficient processed fuels that have relatively higher calorific value and less smoke.
- **Solar lighting options to rural areas and urban slums:** For lighting, 7 per cent urban households still use kerosene in India (Census 2011). Until they connect with electricity, they could benefit from solar lamps, which can continue to be used even after grid-based electricity is provided (IEP 2008). There is need for an adequate institutional mechanisms and delivery channels for sale and after-sales service. Solar lanterns should be promoted to households in urban slums and rural un-electrified regions that use kerosene (for lighting) while simultaneously phasing out the kerosene subsidy.
- **Awareness generation:** Programmes to generate awareness are needed to increase adoption of simple household level measures such as improved ventilation and selection of cleaner traditional fuels (Sehgal *et al.* 2014).

Controlling refuse burning:

- Waste is sometimes burnt both at the site of generation and where it is disposed of. The per capita waste generation reported in India is 0.45 kg/day in urban areas and 0.29 kg/day in rural areas. The collection efficiency in urban areas is 70 per cent (Planning Commission 2014). At India level, 552 kt/yr of PM2.5 emissions are estimated from refuse burning activity in 2011 (Sharma and Kumar 2016), which is projected to grow to 1,452 kt/yr in 2051. To tackle the issue of solid waste management, firstly there is a need to formulate a National and state level policy for solid waste management (SWM) and to address these issues in municipal bylaws and waste management

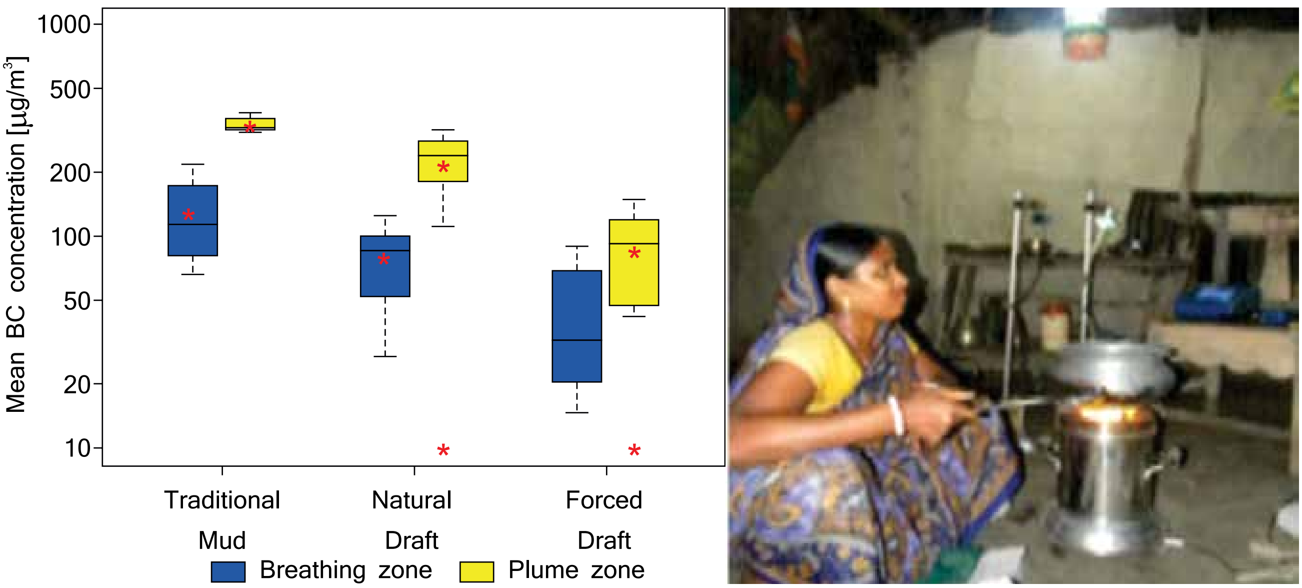


Figure 4: Reductions in indoor concentrations of pollutants due to the use of improved cookstoves in comparison to the traditional ones

action plans of cities. Within the SWM policy, mandate can be issued for strict adoption and adherence to the '3R (reduce, reuse, and recycle)' with an aim to reduce volumes of waste generated and maximize resource recovery and reuse. To ensure effective enforcement SWM cells needs to be created at state and city levels and state pollution control boards need to monitor implementation of action plans. The SWM cells will impart technical guidance to urban local bodies on the rules and regulations pertaining to municipal solid waste management; will advise them on ways to achieve the specified standards and participates in public awareness and clean city programs. Further, the SWM cells need to facilitate creation of market for recycled products derived from waste. Bureau of Indian standards need to formulate standards for the recycled goods based on international experiences and good practices. Also public and private procurements should incentivize recycled products derived from waste materials. Extended Producers Responsibility (EPR) is a main feature of waste management Rules notified in 2016. However the enforcement of EPR is currently weak and it can be strengthen either by creating recycling banks by producers where waste can be recycled or creating producer responsibility organizations (PRO) for collection, transportation and recycling of waste.

- **Improving collection efficiency and segregation**: Collection efficiency of waste is not satisfactory even in urban regions. State pollution control boards in collaboration with City Corporations can develop a mobile application to put up the complaints to the concerned authorities with upload of the actual site pictures and coordinates. Based on data of complaints, intercity and intra city comparisons can be made to generate competitive spirit for municipal solid waste management among the cities. To manage the waste generated in the societies, QR code can be provided by RWA's to each household, which needs to be scanned every time the waste is collected from the house. Data generated by QR code can directly go to RWA's and corporations. Based on the number of times the QR code scanned in a month, responsible person can be penalized.
- **Complete ban on refuse burning**: Ban on refuse burning needs to be strictly enforced with substantial penalties on non-adherence. State pollution control boards in collaboration with City Corporations can develop a mobile application for bringing any major refuse burning event to notice in a region. State governments need to set up winter shelters with heating arrangements for homeless people.
- **Waste to energy options**: With proper segregation of high calorific value non-recyclable and non-biodegradable waste, waste-to-energy options with proper pollution controls need to be explored on public private partnership mode; initially, on pilot basis and then at larger scales in the cities.

Maintaining quality and cleanliness of roads:

- Re-suspended road dust is one of the significant contributors to PM10 concentrations in cities. Dust gets re-suspended in the air due to movement of vehicles. The particles re-suspended from road side are mainly coarse (>2.5mm) by nature but still can cause respiratory illnesses.

- There is a need to ensure quality control in construction of roads through random tests and checks and IT-based monitoring systems. Wall-to-wall paving (with provision of rain water percolation) and maintenance of roads can be ensured with the use of mobile applications to spot and inform irregularities.
- Regular and efficient road sweeping is required; vacuum cleaning devices can be used. Unpaved roads need to be paved and, if not possible, they can be covered with gravel and maintained on annual basis.

Dust control at construction sites:

- There is a boom in the construction sector in India, more specifically in urban regions in order to sustain an ever-increasing pressure of housing and commercial space. Different activities at the construction site cumulatively account for generation or re-suspension of dust. To control emissions from construction activities, wind speeds need to be reduced and moisture content can be enhanced at the construction site for reducing the possibilities of dust getting air borne. This should be done by proper fencing of the construction site with barriers set perpendicular to the direction of the wind. Trees and shrubs can also act as wind barriers. Depending upon availability of water, fogging systems could also be used to trap dust particles.
- Vegetation on certain parts of the un-stabilized land can reduce dust emissions from the ground. Un-stabilized soil should be compacted using rollers and spreading heavy rocks and gravel on the recently excavated land can also reduce dust emissions. Storage piles should be in the downwind direction and should be kept within enclosures. Pre-fabricated material should be used at construction site to minimize activities such as cutting, grinding, and drilling in an open area.
- Under the EIA guidelines, all major construction projects need to develop and adhere to an environmental management plan, which lists down the measures to be taken for control of dust at the construction site. For enforcement, all the contractors/builders should be asked to provide online continuous air quality data of the site on their websites. The calibration and accuracy of data collection should also be the responsibility of the builder/contractor. Visible violations should be reported through mobile applications.

Transportation

- AVOID–SHIFT–IMPROVE approach needs to be adopted for effective control of vehicular emissions. While the AVOID strategies aim to reduce travel demands, the SHIFT strategies attempt to move the modal shares from private/motorized modes to public/non-motorized options. Shift towards more efficient modes such as from road to rail are also covered within this. Finally, IMPROVE strategies focus on enhancement in quality of fuels, technologies, and strengthening of the systems for control of pollution.

Travel Demand Management (TDM)

- Ministry of Urban Development has suggested planning and implementing travel demand management (TDM) measures as part of Comprehensive Mobility Plans in Indian cities. The Ministry with help of TERI has also brought out a toolkit on TDM strategies to implement them in Indian cities. TDM measures can be classified into pull and push measures. Pull measures involves strategies that are targeted at promoting public transport and non-motorized transport (NMT). They need to be combined with push measures to encourage modal shift from private to public modes. "Push" strategies generally involve economic measures to internalize the negative externalities of private vehicle use. The TDM push measures can be mainly classified into vehicle ownership controls and vehicle usage controls.
- Vehicle ownership controls can be implemented through vehicle quota systems and taxes and insurances. A quota system aims to control the vehicle ownership of individuals by permitting a certain monthly quota on registration of new vehicles, which is then open for bidding/lottery as tried out in Singapore. High taxation strategies can be used to control vehicular growth by increasing the cost of owning a car. These taxes can be institutionalized at the centre or state level in various forms—registration taxes, excise and customs duty, road tax, fuel taxes, etc. These measures are used in Singapore, Japan, and Hong Kong to increase the cost of owning a car and thereby restricting car ownership. High insurance costs have also been employed in places such as Singapore and Japan to discourage private vehicle sales. Other ways to control vehicle ownership are through ensuring that an owner has an exclusive parking space for the car before for owning it. The parking rentals costs are generally kept high to act as a discouragement to private vehicle purchase and use. Similarly in Japan, heavy charges were charged for fitness inspection certificates to restrict the movement of older/unfit vehicles and also to increase cost of car ownership.
- Vehicle usage controls are applied in the form of road space rationing, congestion pricing, parking

management, etc. Road space rationing is commonly known as the alternate-day travel or driving restriction or no-drive days, restricts entry of vehicles into certain areas based on the last digit of the number plates. This is found to reduce pollution levels in a short term, but eventually people get over the restriction by buying more vehicles. This has been tried out in Beijing, Paris, Mexico City, Rome, etc. Delhi has also implemented this strategy in 2016 to bring down pollution levels and was limitedly successful in reducing pollution levels and congestion on the roads. Road usage/congestion pricing is based on 'pay as you use' principle and usually takes three forms: cordon pricing, area license, and priced roads/road pricing. This aims to reduce number of vehicles to encourage modal shift by charging vehicles on entry in restricted zones/times. This can be complemented by providing exemptions to higher occupancy vehicles. This strategy has been used in cities such as Singapore, London, Sweden, Rome, Durham, Seoul, San Diego, etc. Parking management used to reduce car usage through constraining parking supply and pricing. Parking pricing and setting time limits can increase the cost of using a car and discourage people from using cars. It is seen that priced parking can help reduce the vehicle trips by 10–30 per cent (Litman 2015).

Public Transportation

- Use of public transportation can result in 90–95 per cent reduction in CO, VOCs, and 50 per cent reduction in CO_2 and NO_x emissions as compared to private vehicles.[1] The share of public transport in category 6 cities (above 8 million population) was 44 per cent, category 5 (4–8 million) was 21 per cent, category 4 (2–4 million) was 10 per cent, category 3 (1–2.0 million) was 13 per cent, and category 2 (0.5–1 million) was 9 per cent;[2] however, its share is going down in favour of private vehicles due to many reasons. National Urban Transport Policy (NUTP) 2007 lays special emphasis on encouraging public transport in Indian cities through financial assistance. The JNNURM scheme was responsible for setting up and strengthening bus-based public transportation system in many cities. Despite various efforts by the government, only few Indian cities have some form of public transportation systems. Many cities are planning and implementing mass rail transit systems like metro systems that require huge investments, hence should only be planned as per the needs and spatial characteristics of a city. In many cases, the mobility needs of the city can be met by a bus-based system, which is much less expensive. There is a great need to enhance the public transportation system in the cities to shift people from private vehicle to more efficient and less polluting public modes. India also has a rich history of informal transport that offer shared services in absence of public transport systems or support public transport systems by providing last mile connectivity.

Non-Motorized Transport (NMT)

- Non-motorized modes of transport are non-polluting modes of transport and traditionally used to have high modal shares in Indian cities, which is depleting rapidly due to lack of or poor quality pedestrian infrastructure, amenities, and services. Indian cities having population of above 8 million had 30 per cent modal share of walking and bicycling. The modal share for walking and bicycling in category 5 (4–8 million) cities was 36 per cent, for category 4 (2–4 million) and category 3 (1–2 million) cities, it was 43 per cent, and for category 2 (0.5–1 million) cities, 52 per cent[3] in 2007. NUTP acknowledges the need for NMT and has called for equitable allocation of road space to encourage these. The current share of walking and cycling in cities should be maintained and encouraged through physical intervention in terms of road design and other facilities such as provision of providing exclusive lanes providing safe, efficient, and integrated network for NMT movement. NMT exclusive lanes should be complemented by good shade, bike parking facilities, road crossing priorities, etc. Cycling in cities should be encouraged through public bike sharing systems, as available in cities such as Paris, Copenhagen, Amsterdam, London, etc.

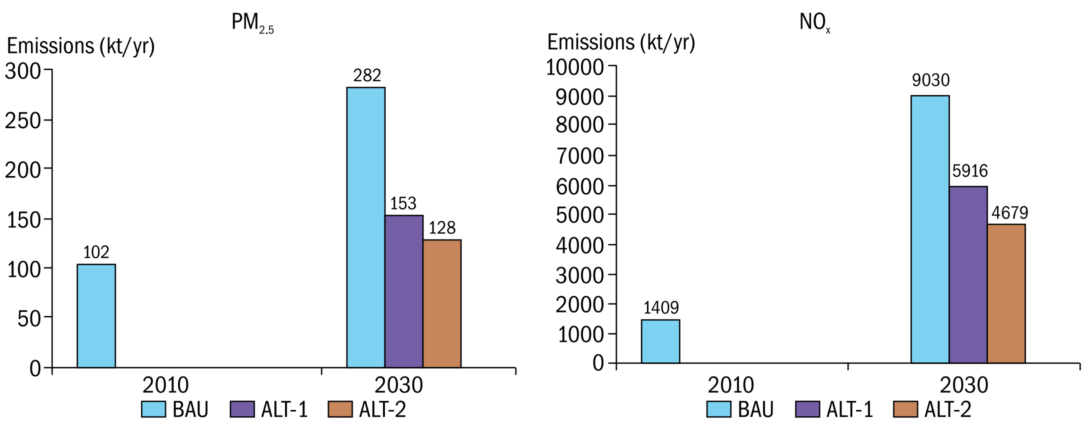
Fuel quality and vehicle emissions norms

- The Auto Fuel Policy 2002 announced by the Government of India laid down a roadmap for introduction of cleaner fuels and vehicles in the country up to 2010, wherein, 13 selected cities moved to BS-IV norms by 2010, while rest of the country was to remain on BS-III norms. Consequently, heavy-duty trucks (which are the largest contributor to vehicular emissions), which move all across the country, remained on BS-III standards across the country, despite BS-IV norms introduced in some cities. Auto Fuel Vision Committee was set up in 2013

1 Shapiro, Robert J., Kevin A. Hassett, and Frank Arnold. Conserving Energy and Preserving the Environment: The Role of Public Transportation. Washington: American Public Transportation Association, 2002.

2 In 2007, Source: Wilbur Smith Associates and Ministry of Urban Development, 2008, p. 38

3 In 2007, Source: Wilbur Smith Associates and Ministry of Urban Development, 2008, p. 38



Scenario	Description
BAU	Based on current plans and policies of the government (BS-III all across the country and BS-IV in 13 cities)
ALT-1	BS-IV all across the country by 2015 and BS-V in 2020
ALT-2	BS-IV all across the country by 2015, BS-V by 2018 and BS-VI emission norms in 2020

Figure 5: PM and NOx emission reduction in 2030 in vehicular sector due to introduction of BS-VI norms in 2020.
Source: Sharma et al. (2014)

to recommend a future roadmap on advancement of these standards. They recommended the introduction of BS-IV and BS-V norms across the country by 2017 and 2020, respectively. However, recently, the MoRTH has announced a move directly to the BS-VI emission standards by 2020, instead of moving to BS-V in between. This is an important move as it can reduce vehicular PM emissions to lowest possible levels (reduction of 55 per cent in 2030 with respect to BAU scenario) (Figure 5) and can lead to 17,000 lesser mortalities annually from 2030 onwards. The health benefits of advancement to BS-VI norms outweigh the costs of its implementation (Sharma *et al.* 2014).

Inspection and maintenance programme (I&M)

- Various studies report that on-road vehicles emit much higher levels of pollutants during their lifecycle as compared to the limits set during their certification stage. A proper inspection and maintenance programme (I&M) system ensures the confined vehicle performance in real-world conditions. Policies targeting in-use vehicles bring an immediate impact, as compared to other policies focusing on fuel and technology improvements that are meant to curb emissions over a longer period. Current I&M mechanism in India is not sufficiently effective to ensure low emissions from in-use vehicles. There is no way to ensure that vehicles during their lifetime, with proper maintenance, comply with their original mass emission standards. For in-use vehicles, instead of the loaded mode tests, stationary mode idling tests have been prescribed which do not reflect the real-world situation. Also, there is no mechanism to recall vehicles, if they do not perform well in real-world driving conditions. Despite the provision for heavy penalties, just 21 per cent of registered vehicles appear for PUC (pollution under control) testing in Delhi (Sitalkashami *et al.* 2015). Moreover, the current system is not fool-proof and allows pass-through without proper testing.
- **In-use vehicle compliance programme (IVCP):** In-use vehicle compliance programme (IVCP) can be initiated under MoRTH to test the in-use vehicles and ensure that they actually comply with their original emission standards (Type Approval standards) throughout their useful life. MoRTH could initially target one vehicle model from all different automobile manufacturing companies operating in India. Vehicles representing different stages of their life cycles can be tested for in-use compliance to ensure performance over their useful lives. The vehicle models emitting greater than Type Approval norms must be further tested comprehensively, and in the event of further failure, the manufacturers should be asked to look into the possible causes and submit a detailed report. MoRTH could decide on further actions deemed necessary, which may ultimately lead to recall.
- **I&M programme:** Apart from the proposed IVCP, it is essential to strengthen the inspection procedure to address the menace of high emitters due to lack of proper maintenance. It is proposed that adequate number of centralized and further strengthened inspection centres be set up in every city, in place

of the existing decentralized PUC centres. These limited number of inspection centres should be closely monitored by the respective state transport departments for quality assurance. They also must be better equipped, manned by trained personnel, and run by private agencies. However, the test data collected in each of these centres must be submitted on a real-time basis to a centralized location managed by the state transport department. Testing frequency can be reduced to annual. I&M check requirements should be linked with the vehicle insurance. Based on an estimate of about 218 million on-road vehicles in 2020, an investment of about INR 7,300 crores will be required to set up these centres. However, this is recoverable in 2-3 years (Sitalakshami *et al.* 2015).

Scrap and retrofit programmes

- There is presently no mechanism for scrapping older vehicles or to retrofit them to make them less polluting. Scraping programmes can be designed to support fleet modernization schemes for providing incentives in the form of scrap value and tax exemptions for replacing older vehicles with newer fleets. However, 15-year-old personal and 10-year-old commercial vehicles should mandatorily be scrapped unless equipped with retrofitted tail pipe treatment technology. With low sulphur BS-VI quality fuel available in 2017, and BS-V fuel in 2019, the efficiency of tail pipe control retrofits could be reasonably high. Financial and technical feasibility studies in this regard should be initiated. The options of retrofitting and fleet modernization should be provided to the operators so that decisions can be made after proper weighing of the options. State Transport undertakings and city bus operators should be motivated with fiscal incentives to modernize their fleets through turnover or retrofitting based on evaluation of cost effectiveness of both options.

Congestion and driving cycle improvement

- Many Indian cities are dealing with heavy congestion on their roads. Average speeds in 10 Indian cities were in the range of 12–23, 11–27, and 9–17 km/h for two wheelers, cars, and buses, respectively (Sharma *et al.* 2016b). About 10–26 per cent driving time is spent idling and more than 4–29 per cent with speeds less than 5 km/h (Figure 6). An annual loss of more than Rs 3,800 was estimated in the 10 cities on account of idling fuel losses.
- Driving cycles are used in vehicle emission test procedures to represent on-road driving conditions and any deviation from them in real world may result

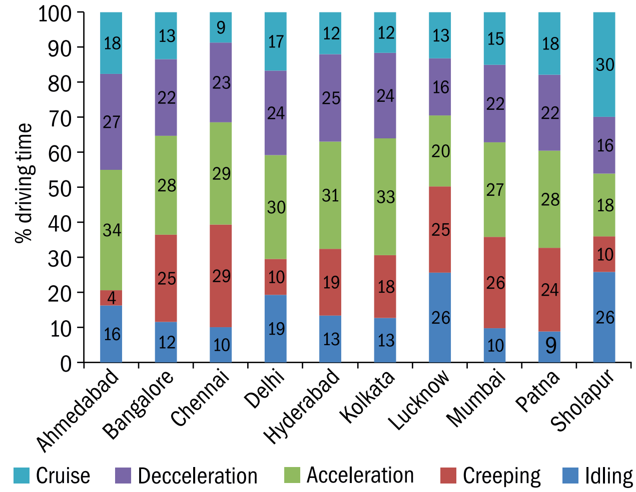


Figure 6: Percentage of driving time spent by cars in different driving conditions in 10 cities.
Source: Sharma et al. 2016b

in higher emissions (Weiss 2012). Real-world driving conditions are found to be very different from the driving cycles used for emissions testing in India. Vehicles that comply with emission norms based on prescribed driving cycles may actually emit higher emissions in real-world conditions. There is need to reformulate the driving cycles to conform more closely to the real-world conditions. Ideally, world harmonized test procedures can be adopted, which cover a wide range of driving conditions than those included in currently used driving cycles.
- There is need to reduce congestion through traffic improvement strategies. Traffic signal improvements can be made through equipment upgradation, timing plan improvements, signal coordination and interconnection, and, in some cases, by signal removal, depending on intersection characteristics. Converting two-way movement to one-way operation, two-way street left turn restrictions, continuous median strip for left turn lanes, and channelized roadway and intersections may improve traffic operations. Roadway and intersection widening and reconstruction will improve traffic movements but their desirability would depend on land availability, connectivity needs, and flexibility of augmenting public transport. Incident management systems should also be implemented to manage traffic during any incident such as accidents, traffic jams, etc. Intelligent transportation systems can help in reducing congestion by improving coordination of traffic signals, improving monitoring capabilities to improve response times to various incidents on roadways, collect data for improved planning and evaluation of various schemes, smart parking options to reduce empty driving to find

parking spots, navigation systems to suggest shortest route/alternative routes, etc.

- Odd–Even schemes, similar to the one introduced by the Delhi Government, in which plying of privately owned cars was restricted on alternate days, can be implemented for control of congestion. However, with many exemptions, the effect of odd–even scheme on reducing congestion and pollution in Delhi was found to be small. This can be used as an emergency measure to cut down on congestion and pollution; however, a regular use of this strategy is not suggested as it can be negated by people buying cars or other vehicles (new or old) with alternative number plates.
- IT-based applications and other means of car-pooling, as well as 'work from home' policies should be promoted. More offices could look at flexible working hours and work from home facilities. Policy and regulatory issues related to the provision of car-pooling IT services, whether on commercial or non-commercial (cost sharing) basis, should be resolved. Purchase of new vehicles could be made conditional on an older car being scrapped.

Transit bypasses

- There are significant emission contributions from transiting vehicles in a city. There are trucks that move across different states of India, inter-city buses, and private vehicles transit many cities in between before reaching their destination. Construction of bypass allows the vehicles to smoothly bypass the city without entering it. While it reduces the air pollution loads within the city limits, it also helps the transit vehicles to avoid city congestion. This measure can be complemented by deployment of environment taxes for freight vehicles entering the city to incentivize truck operators to pick alternative routes and to use efficient and less polluting models of trucks. TERI (2011) identified bypassing of transiting trucks as the strategy that has the maximum potential of reducing air pollution in the city of Bangalore. While constructing bypasses, the possible ribbon development around the bypasses needs to be kept in mind. IRC (1976) has suggested minimum spacing that needs to be ensured along various categories of roads (i) Expressways: 1,000 metres, (ii) Arterial Highways/Streets: 500 metres, (iii) Sub-arterial Streets: 300 metres, (iv) Collector Streets: 150 metres (v) Local Streets: Free access. These distances need to be ensured not only for safety reasons but also for reducing exposure to the populations that may come there in future. This calls for strict enforcement of these laws, even if it requires extra land to be procured.

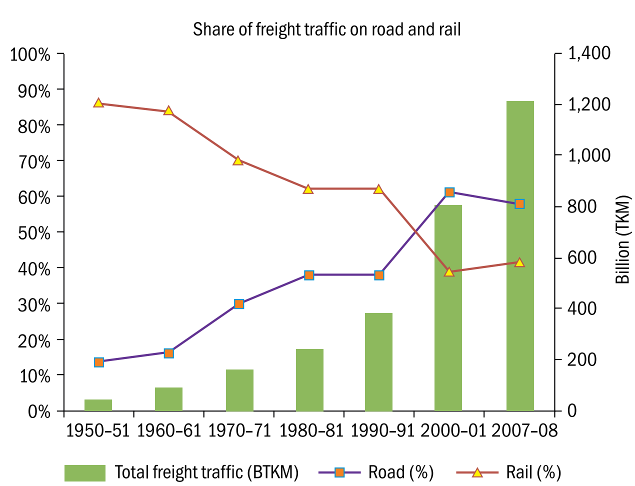
Moreover, the bypasses need to be designed keeping in view the dominant wind direction, so that emissions are not blown towards the city. Bypasses can be built on Public–Private Partnership model and higher fees should be charged from older vehicles.

Road to rail freight movements

- There is sharp increase in energy demand from the heavy duty vehicle (HDV) sector in India, mainly because of the increased transport demand and continuous erosion in the share of railways in freight movement and increase in share of less fuel efficient road transport (Figure 7).
- Share of railways in freight transport needs to be improved considerably. This calls for policies and changes in tariff structures to divert freight movement from road to rail. This calls for improved infrastructural facilities. Railways may also take initiatives to provide door-to-door services in collaboration with local transporters.
- Alternatively, the railway lines passing through cities can be used to transport loaded trucks across the city. This is used by Konkan Railways and the Ro-Ro (Roll-on/roll-off) was implemented to reduce travel time of trucks passing through Konkan route, with added benefits of reduced pollution and accidents.

Electric mobility

- Electric-powered vehicles have no tail pipe emissions, which make them a suitable for reducing pollution levels in cities. India adopted the National Electric Mobility Mission Plan (NEMMP) that aims to promote electric mobility in the country. To counter the high cost of



BTKM: Billion tonnes per kilometre

Figure 7: Share of different modes in freight movement in India during 1950–2008.
Source: RITES (2014), PC, MoR (2012)

electric vehicles, faster adoption and manufacturing of (hybrid and) electric vehicles scheme has been launched under NEMMP with plans to incentivize buyers for purchasing these hybrid and electric vehicles. In parallel, there is a need to develop infrastructure (charging stations) to facilitate use of electric vehicles. A positive leap into electric mobility was seen with the advent of electric rickshaws (e-ricks) in various Indian cities. But their operations were banned due to non-compliance with Motor Vehicles Act in respect of safety. Though the ban was lifted with conditions to get e-rickshaws standardized and registered, the operators are found reluctant to get registrations due to the high cost. The authorities need to look into this issue and implement policies that can encourage these non-polluting modes of informal transport. The goods carriage models of these vehicles can also be used in small cities eliminating the need for fossil fuel-powered vehicles. Public transport systems should also be planned on hybrid/ electric modes.

Environment taxes/fees

- Higher registration taxes/fees can be used by the government to promote low carbon, fuel-efficient vehicles and penalize inefficient and polluting vehicles. Countries such as the Netherlands, Latvia, Portugal, etc. imposed taxes at the time of registration or during renewal of registration, which takes into account age of the vehicles and emissions.[4] The Netherlands imposes registration tax based on purchase price and CO_2 emissions. Low emission vehicles are exempted. Latvia takes into account only the vehicle-specific CO_2 emissions to calculate motor tax.

Industries

- **Vigilance and enforcement:** While there are standards in place for some pollutants for most of the industrial categories, there is an urgent need to enforce these standards effectively. Inspection and monitoring of industries need to be randomized to reduce the scope for collusion of the inspected teams with the inspected units. CPCB has tried out such a random monitoring system, which resulted in increased reporting of violations; the system can be further improved. Third party auditing of industries needs to be strengthened by involving the institutes of highest reputation and capacity for audits and recommending measures for improvement. Continuous monitoring and online reporting can be initiated for major industries for immediate actions on any violations.
- **Cleaner gaseous fuels:** Cleaner **(**gaseous/liquid) fuels, wherever possible, should be supplied at least in and around highly polluted cities. Incentives based programmes need to be developed to switch towards cleaner fuels.
- **Emission trading schemes (ETS):** Emission trading schemes can be developed and enforced for large industries for control of industrial pollution. This parallels carbon trading schemes wherein a cap on emissions is assigned for a region and allocations for each of the contributing large industries are made. The stacks are monitored on continuous basis and the performers beyond compliance are able to trade the emission credits earned in the process to units that find it difficult to comply on their own. The programme is being tried out in India in three states—Gujarat, Tamil Nadu, Maharashtra—under the pilot ETS programme launched by the Ministry of Environment, Forests and Climate Change. The state pollution control boards (SPCBs) are to determine the caps for industries based on desired pollutant concentrations and emission permits can then be allocated to capped industries, which can either comply with their caps or buy credits from the market sold by the better performers. The programme may prove to be cost effective and also spur innovation. Similar programmes have been introduced as past and present cap-and-trade mechanisms of SO_2 trading in the USA, offsets trading programme for suspended particulates in Chile, and EU ETS for GHGs. The most important aspect of the programme is installation and maintenance of continuous emission monitoring systems, which are to be installed at the stacks.
- **New and improved standards**: There are stack emission standards in place for PM; however, they do not exist for many other pollutants, which are measured under the National Ambient Air Quality programme. Even the PM emission standards for many small-scale industries seem to be quite relaxed and are to be relooked. While on one hand there is a need to revise the PM standards for PM10 and PM2.5, there is also a need for development of standards for other pollutants such as NO_x and SO_2.
- **Technological improvements:** With very little awareness on energy efficiency, a majority of micro, small and medium enterprises (MSMEs) depend on conventional technologies and practices leading to high inefficiencies. Without infusion of appropriate technologies, survival in global market place will

4 http://www.unep.org/transport/gfei/autotool/approaches/economic_instruments/varied_registration_fees.asp

become a critical issue for the vast majority of MSMEs in India. The Prime Minister's Task Force on MSMEs has identified inefficient technologies used by the MSME sector as a major cause for poor competitiveness of the sector. A number of sub-sectors in MSMEs are highly energy intensive, such as ceramics and refractories, glass, brick, foundry, forging, secondary aluminium, brass, chemicals, food processing, and textile industries. Several studies indicate that adoption of energy-efficient technologies and practices in production process can lead to energy savings of 15–20 per cent, which can result in substantial reduction in emissions also. For some sub-sectors, the best technological solutions in terms of energy efficiency are available globally and would require customization of the technologies to suit local conditions (e.g., tunnel kilns brick manufacturing technology). On the other hand, there are other sub-sectors that are unique and have adopted locally developed solutions (e.g., melting of glass, brass products, etc.). There is need for development/acclimatization of appropriate technologies for various manufacturing processes that will lead to cleaner production and substantial reduction in cost of manufacturing by enhancing labour productivity, reducing material wastage, and minimizing energy consumption. A multi-tier support system may be required for inducing technology-based competitiveness of the sector with the collaboration of government, industry clusters, industry associations, and private R&D institutions. The technological options and energy saving potential in brick sector is exemplified in Table 1.

- Development of energy efficient technological solutions for MSMEs is not commercially attractive for large engineering firms and consultancies in the private sector in India due to high costs and risk factors. Therefore, to have an impact in the MSME sector and to improve its energy efficiency, there is a need to focus on Research, Development, Demonstration and Dissemination (RDD&D) of cost-effective technologies in the energy-intensive sectors/clusters. These technologies should be promoted with the active involvement of the local industry association(s) to enhance the credibility and impact of the intervention. Financial assistance to adopt new technology can be provided by bilaterals/multilaterals /government.
- Benchmarks for specific energy consumption (SEC) and total energy consumption at the unit, cluster and sub-sector level can be established based on data collected through local institutions like cluster level industry associations, State Designated Agencies etc. Cluster-level energy services for MSMEs should be strengthened by appointing the cluster-specific Energy Managers for MSMEs. There is need for a single national policy for EE in the MSME sector. At present, different ministries/ government departments have different policies for promoting EETs, resulting in confusion on the part of entrepreneurs and other stakeholders. Also, there is a need to develop specific 'Vision Documents' for each major MSME sub-sector (such as brick) with regard to technologies, fuels and products. This will ensure that the achievements of EE interventions are not lost because of sudden changes in policies or regulations. For capacity building of MSMEs, skills training centers such as Industrial Training Institutes (ITIs) should be linked to local MSME clusters. Further, the credit rating of MSME units should be linked to their energy efficiency. MSMEs with higher credit rating can obtain loans at lower interest rates. To implement this, bankers should also be trained on relevant aspects of EE finance. To achieve large-scale financing and adoption of EETs, aggregation of demand should be undertaken to create 'many takers for one technology'. Another way to promote adoption of EE technologies is the creation of a promotional 'energy efficiency fund', through which loans could be provided to MSMEs at minimal interest. Further, knowledge platforms (like SAMEEEKSHA) and the industry–academia interface to spread awareness and information on EE technologies, manuals on Standard Operating Procedures (SOP), and success stories can be strengthened and made available in regional languages.

Power

- Power sector faces numerous challenges in terms of increasing power availability, access, quality of supply, etc., in meeting rapidly growing demand. Installed capacity is 284.30 GW (2015) comprising 198.48 GW of thermal (coal, gas, and diesel) power, 42.62 GW of hydropower, 5.78 GW of nuclear power, and 37.42 GW of renewable sources (CEA 2015a), clearly dominated by coal-based capacity. Demand for power has been growing in terms of both—energy and peak demand—resulting in shortages. The energy shortage in the country was recorded at 2.1 per cent while peak deficit was recorded at 2.6 per cent during 2015/16 (CEA 2015c). Power sector is the largest user of coal with an estimated consumption of 512 MT in 2012/13 (TERI 2015a), which produces fly ash; a contributor to air pollution in India. Indian coal has very high ash content (30–50 per cent). The thermal-based capacity would continue to dominate and grow to 512 GW by 2031/32 (TERI 2015b) thus posing a threat of rising levels of pollution. Another challenge is the use of DG sets by various sectors such as industries, infrastructure, housing, IT, and telecom, when faced with power shortages. The estimated DG sets capacity in 2014 was 60–90 GW. These are important sources of emissions, and studies (CPCB 2011) report their significant contributions in air pollution levels in the cities.

- **Improving power supply:** With demand for power set to rise, and thus the eventual multiplication of our generation capacity, it is imperative that efforts are made to make the generation of power sufficient, cleaner, and sustainable. Provision of sufficient supplies of power will certainly ensure lower usage of DG sets. There is a need to supply 24×7 supplies in the regions of bad air quality.
- **Tackling emissions from coal-based power generation**: Coal beneficiation should be enhanced and promoted for reduction of ash content. Strict monitoring and maintenance of electrostatic precipitators (ESPs) should be ensured for tail pipe controls. Introduction of control technologies (such as wet flue gas desulphurization (FGDs) units) should be made mandatory in all the plants for control of SO_2 as FGD not only helps in reducing SO_2 to a large extent but also significantly reduces toxic heavy metals such as Hg, which are not usually trapped by ESPs and affect the efficiency of boilers. Stringent emission standards should be set to control NO_x emissions from both coal- and gas-based power plants.
- **I&M and retrofitment:** I&M of pollution control equipments installed at power stations should be enhanced for efficient control of emissions. Ash generated in power plants has high electrical resistivity, which hinders the performance of an ESP. Several methods can be used to improve efficiencies of ESPs installed in old power plants, which includes (a) enhancement of collection area of ESPs; (b) pulse and intermittent charging of ESP units; (c) flue gas conditioning by water fogging, ammonia conditioning, (d) dual conditioning with NH_3 and SO_3 and; (e) coal ash conditioning with sodium salt. This is to be noted that different methods for efficiency improvement have their own limitations and should be decided based on plant characteristics.

Table 1: Technology options and energy saving potential in brick sector

Existing Practice	Option for Improvement	Assumption	Estimated Investment per Kiln (INR in Million)	Average Energy Saving Potential (mtoe*)	Other Benefits
BTK technology	• Better operating practices (BOP) • Improved kiln construction practices	• 10–15 per cent fuel saving • 50 per cent BTKs adopt BOP	0.08–0.1	1.32	• Reduced fuel consumption • Increased production of better quality bricks
	Adoption of Zig-Zag technology	• 20–30 per cent fuel saving • 30 per cent BTKs adopt Zig-Zag technology	2–4	1.32	• Reduced fuel consumption • Increased production of better quality bricks
Production of solid bricks	Switch over to hollow blocks/ perforated bricks	• 15–25 per cent fuel saving • 30 per cent BTKs produce resource efficient products	17–23	0.92	• Resource saving • Better thermal insulation in buildings • Reduction in dead load of building • Uniform size and shape of product
Clamp kiln technology	Adoption of improved clamp kiln design	• 35–45 per cent fuel saving • 30 per cent clamp adopt improved design	0.9–1.1	1.30	• Reduced fuel consumption • Improved brick quality • Increased production of better quality bricks
	Adoption of BTK	45–55 per cent fuel saving 10 per cent Clamps adopt BTK	3.5–5.0	0.54	

*million tonnes of oil equivalent

- **Diesel generators**: Manufacturing improvements through standards, and inspection and maintenance of DG sets can not only ensure that they do not emit more than designed limits over time but also that they function efficiently. DG sets should be inspected and maintained on a regular basis. New standards for generator sets have been recently notified; however adherence to these standards in real-world conditions needs to be ensured. This calls for a study of already installed DG sets and accordingly plans for maintenance can be drawn up. This will also be a cross check for real-world performance of DG sets vis-à-vis the lab scale testing for emission approvals during manufacturing process. Once the BS-IV quality (<50 ppm sulphur) would be available in India in 2017, DG sets can possibly be fitted with diesel particulate filters (DPFs), whose efficiency will further go up with introduction of BS-V (10 ppm sulphur fuel) in 2019. Technical and financial feasibility studies for this needs to be initiated.

Agriculture

Urban areas in India are surrounded by rural regions dominated by agricultural activities. Activities in these agricultural areas generate dust, which is carried to urban areas with the winds and further aggravates the problem of air pollution. Emissions are generated in activities like tilling and agricultural residue burning. Crop harvesting is usually done with help of 'combined harvesters' (mechanical harvesters) and a lot of crop residue is not harvested with the application of these machines and the remaining crop residues are being burnt in many places. Agricultural burning in fields of Punjab has reportedly been responsible for increase of PM concentrations in urban areas (Singh et al. 2010). In India, the total contribution of crop residue burning to PM10 and PM2.5 emissions were around 800 kt and 300 kt, respectively (Sharma and Kumar 2016).

There is a need to enforcing a full ban on burning of these residues. There is a need for development and adoption of a business model for collection, transport, and management of waste. A sustainable model for collection and transport of these residues needs to be developed for generation of energy and material recovery through biomass-based conversion technologies. Other agricultural activities, such as tilling, movement of vehicles on soil, application of pesticides, etc., also generate dust, which gets air borne and is carried to urban areas with winds.

The following set of policy recommendations is proposed to increase the demand of crop residues use in industries would help to curb the open burning of these materials:

- There is need to set up State/National level procurement agency for argo- residues procurement from the farmers. In particularly, to involve village level institutions and local entrepreneurs in collection, storage and supply of biomass materials and to link with MNREGA and PMEGP- Prime Minister's Employment Generation Program and setting up biomass depots facilities to address wild fluctuation of biomass material prices during season and off-season period.
- Policy provision for financial incentives and other schemes to encourage briquettes/pellet industries in States and regulation to make mandatory use of biomass briquettes in boilers/furnaces/ brick kilns up to 30% in various industries in these States to create demand of such fuels.
- Generation of electricity is one of the attractive options to utilize farm waste. There is need to make mandatory use of agro-residues as blend fuel in the existing thermal power plants operating in these States. Dedicated policies to encourage crop residues based power generation in these States and private sector to create demand of such fuels.

Table 2: Cross-sectoral fiscal measures for reducing emissions

Sector	Incentive	Disincentive
Transport	Concessional passes for using public transport Tax exemptions for fleet modernization Higher subsidies on electric vehicles	Higher taxes for private vehicles Congestion charges for old vehicles Higher I&M fees for older vehicles Attractive tariff structure for rail-based freight movement
Industries	Tax exemptions and support for process improvements and tail pipe controls Incentives for performance beyond compliance Green awards and recognition to the front runners	Heavy penalties on default on random checking
Residential	Higher subsidies for improved cookstoves and solar lanterns	
Waste burning	Support for waste to energy conversion	Heavy penalties on open burning

- Credit institutions, such as agricultural development banks, which are not familiar with biomass briquettes/pellet production and related opportunities, could be made aware through the awareness and capacity building program.
- There are number of thermo-chemical and bio-chemical technologies which are developed at R&D and academic institutes and these technologies need to be demonstrated in field and to be scale up through viable business models.
- Focus R&D on development of advanced process/technologies for valorization of crop residues into energy and material applications.

Scientific studies based on monitoring and modelling

- **Monitoring requirements:** The air quality monitoring network in India is not sufficient as there are about 600 monitoring stations under the National Ambient Air Quality monitoring programme of the CPCB for the whole country. Bureau of Indian standards (BIS) has listed the criteria for minimum number of stations in a city. Based on this, 3,300 monitoring stations in 605 Indian cities (having more than 50 thousand residents), will be required. The monitoring network needs to be improved gradually not only in terms of number of stations but also for quality of monitoring. Presently, air quality monitoring is carried out in cities only, which should be extended to rural and regional scales. This is essential for pollutants such as ozone, which are generally found to be higher in regions outside cities. The present network monitors PM10, SO2, and NOx regularly across all stations and does not cover all the pollutants listed in the National Ambient Air Quality Standards. Corporate funding can be sought under the CSR activities to extend monitoring networks with enhanced monitoring capability.
- **Source apportionment studies:** While source apportionment studies have been carried out in 6 cities, already there are 53 cities with a population of over a million where air quality is deteriorating. In the absence of regular source apportionment studies, despite several measures taken in past, the air quality in Delhi has deteriorated in the past 5–10 years. Source apportionment studies are the way to understand changing source contributions and accordingly changing the air quality management plans as per the growth patterns in the city. Hence, it is recommended to carry out source apportionment studies in all million plus population cities regularly, at least once every five years. Corpo0rate funding can be sought under the CSR activities for this purpose. Under the supervision of MoEFCC and CPCB, source apportionment studies should be conducted by specifically identified research institutions in the country.
- **Emissions, simulation, and forecasting:** Other than monitoring of pollutants, modelling capabilities need to be built for understanding of current and future air quality. There is presently no database of emissions at the national/regional scales. These inventories need to be developed and maintained. TERI has developed national scale inventories for India for current and future years based on energy and emission models (Sharma and Kumar 2016). These inventories can be further refined for development of national database of emissions for India. While there has been a number of urban scale air quality modeling studies in India, studies on simulation of air quality at the regional/national scale are limited. TERI has simulated air quality at the national scale using state of the art models to predict PM2.5 and ozone concentrations in India (Figure 8), which shows increase in pollutant concentrations that may happen in future following a business as usual trajectory. It also shows the regions under severe pollution levels and the contributing factors. Accordingly, action plans may be drafted for air quality control at regional scale.
- The air quality management plan (AQMP) at city level should be drafted by research institutes identified to carry the source apportionment studies by MoEFCC and CPCB in consultation with SPCBs. For strategies required to be implemented at central level, the steering committee headed by the honorable Prime Minister of India, with highest level representation from states, and the key city governments should be formed.. For implementation of strategies at state or city level, department of environment (DoE) in assistance with SPCBs should be the nodal agency. In the supervision of DoE, high power committee (HPC) with participation from different state level departments dealing with sectors contributing to air pollution in the city should be formed. The HPC, should direct and monitor the implementation of the intervention listed in AQMP in a mission mode. The SPCBs should assess the effect of implementation of the strategies and incase, proposed improvements in air quality haven't been met, and then suggest the reformulation of AQMP. The DoE, should seek the financial assistance from state governments for implementation of strategies listed in AQMP. Institutional strengthening of SPCBs is a must to ensure successful and effective implementation of strategies listed in AQMP. This will call for higher budget allocations, recruitments of scientific professional, and

trainings on air quality monitoring, and modelling tools. Institutional tie-ups can be made for regular trainings of the board officials.

Interventions taken in past and their impacts: Delhi as a case study

- Air quality in the city of Delhi has attracted international attention as the PM10 concentrations have remained consistently above the standards in the last two decades (Figure 9a). Air quality in the city was critically bad during late 1990s when a number of measures were taken for improvement. Since then, with growth in economic activities (leading to demands for mobility, energy, and products), some interventions for emission control have also been taken. During 2002–07, emission control measures, such as introduction of newer vehicle emissions and fuel quality norms, cleaner fuels, banning of older vehicles, shifting of industries, did not allow the growing economic activities to further deteriorate air quality. However, rapid rise in demands for energy within the city and in the surrounding towns have pushed PM concentrations in Delhi well above the levels of 1990s (Figure 9a). It has been gradually realized that the problem which was restricted to Delhi city has now become a larger problem of the whole National Capital Region (NCR). TERI simulations show that it is not just Delhi that is heavily polluted but that air quality has deteriorated in the larger NCR. The sheer growth of NCR in the last 10 years has negated the effects of interventions taken in Delhi for air quality control. Evidently, the proactive measures for air quality control have not been taken to account for future growth. While, there was a dip observed in PM concentrations in Delhi, there was no decrease observed in NO_x concentrations, pointing to the fact that NO_x controls have not been enforced with required intensity (Figure 9b).
- Other than in-house vehicular sources in Delhi, the city is also impacted by surrounding towns of NCR, several of which grew at a faster rate. Industries were moved

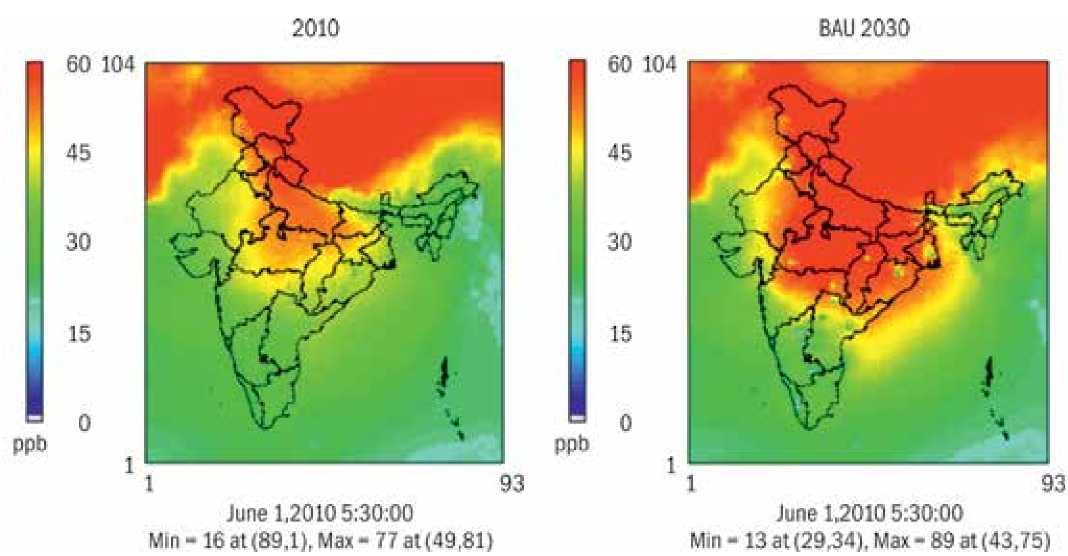


Figure 8: Simulated Ozone concentrations in India in 2010 and 2030

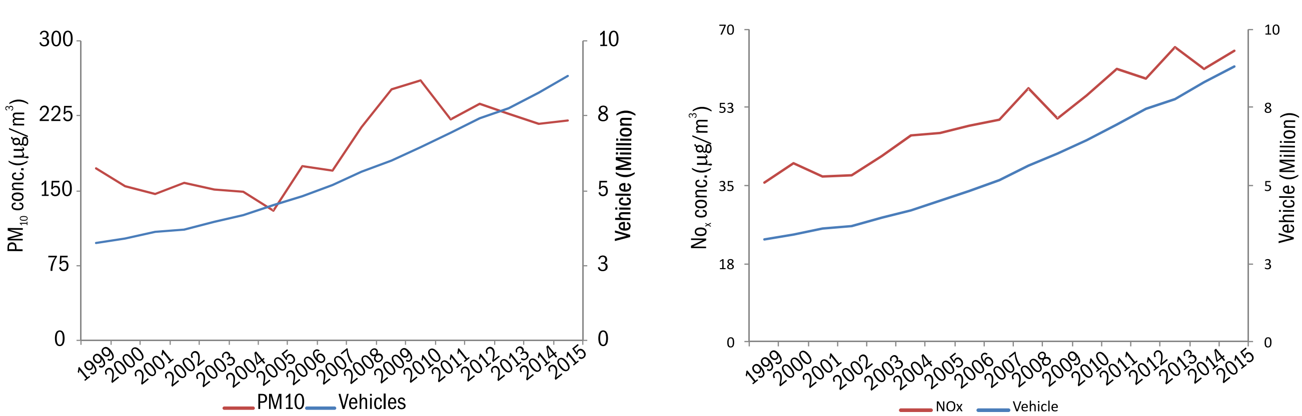


Figure 9: (a) PM10 and (b) NO_x concentrations in Delhi and interventions taken for its control vis-à-vis vehicular growth

out of Delhi, but they still run in NCR and efficiencies of existing control equipments are not regularly monitored and are questionable. There are coal-based power plants; one of which is on the border of the city of Delhi, which also contributes to emissions. In all of the surrounding towns, there are residential apartments and shopping malls, which use diesel generator sets as a standby source of power. Additionally, lower collection efficiencies of waste has led to frequent refuse burning in the NCR, which also contributes to deterioration of air quality. Finally, even the rural areas of NCR also contribute to the problem in three ways. There are more than 2,000 brick kilns in these areas which contribute to PM emissions. Secondly, agricultural residues in the rural regions in and beyond NCR are burnt and add to the pool of atmospheric pollutants in NCR. Thirdly, many households in rural areas and slums use biomass for cooking that not only pollute indoor environments, but also add to air pollution. Conclusively, NCR requires regular assessments through source apportionment studies for proactive planning and control of air pollution.

- There are some success stories also, which explain the reduction in some of the air pollutant concentrations in the capital city. Figure 10a shows decrease of annual average CO concentrations at a traffic-intersection monitoring location (ITO) in Delhi. CO is primarily released from petrol driven vehicles and have seen a gradual decrease with the introduction of catalytic converters, a shift of engine technology from two-stroke to four-strokes two-wheelers, introduction of vehicular emissions and fuel quality norms, and banning of older vehicles. SO_2 levels have also shown a gradual decline with reduction in sulphur content in transport fuels (Figure 10b).

Conclusions

- There are common driving forces, although with differences in shares, in deteriorating air quality in various cities of India. Every city needs to adopt strategies discussed in this brief based on their priorities and findings of source apportionment studies. A step-wise approach to derive air quality management in cities is presented below:
- Monitoring of air pollutants
- Preparation of source-wise air pollutant emission inventories
- Source apportionment studies
- Future air quality projections using dispersion models
- Assessment of potential of different strategies for control of pollution
- Cost benefit analysis for short, medium, and longer timeframes
- Preparation of air quality management plans for short, medium, and longer timeframes
- Implementation of selected strategies
- Assessments of impact of strategies through monitoring and repeat previous steps till air quality standards are achieved.
- Other than local air quality management plans, there are interventions that are relevant at the national scale and are proven worldwide to provide significant air quality benefits. These measures should be adopted for long-term air quality control in India.

Clean Air Mission (CAM) India

On the lines of the Clean India (Swachch Bharat) mission, Government of India should launch a Clean Air Mission to clean the air in India. Clean Air Mission (CAM) at the National scale to draft and implement national level strategies for reduction in air pollution levels at both regional and urban scales. The objective of the mission should be **to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe.** This Clean Air Mission [CAM-INDIA] should mandate to implement government policies for air pollution mitigation across several ministries dealing

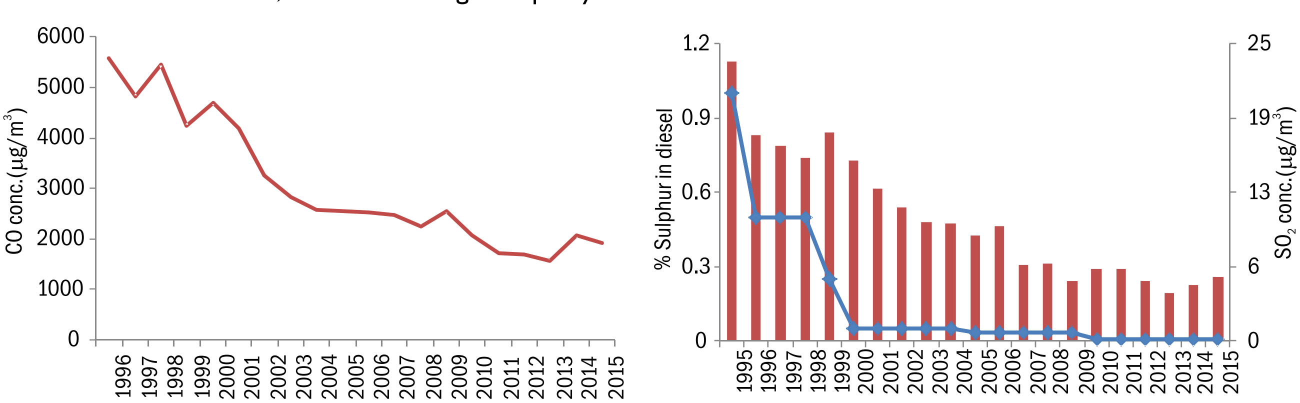


Figure 10: (a) CO and (b) SO_2 concentrations in Delhi during 1995–2012

with transport, power, construction, agriculture, rural development, and environment, as well as across city and state jurisdictions. The targets for the CAM-INDIA are the pollutants defined in the National ambient air quality standards and primarily the particles referred to as PM2.5 to PM10 and Ozone. Control of PM and ozone will ensure virtual control over other pollutants, which act as precursors for their formations through secondary pollutant formulations. Because of long range transport capabilities of these pollutants, it is essential to have national policies for reducing background concentration of pollutants in the country, which will eventually lead to reduction in city level concentrations also.

Proposed CAM India framework

The broad institutional framework for introduction of CAM India is shown below in Figure 11. The key components of CAM India are proposed to be

- Air quality monitoring and assessment of sources
  - Monitoring, emission inventories and regional source apportionment
- Targeted air quality management
  - Sectoral strategies for control
- Multi-scale and Cross-Sectoral Coordination
  - Coordination between Central Ministries, State departments and city governments
- Capacity building
  - Institutional strengthening of CPCB and SPCBs
- Public awareness and participation

Targeted air quality management

CAM India should focus on reducing ambient air pollution levels in a stipulated time frame. The mission should focus on reducing overall background levels in the country by strategies prescribed at the PAN-India scale. However, due to presence of air quality monitoring stations in urban locations only, the concentrations measured there will be used to assess the reductions made in pollutant levels in India. Presently, a significant number of cities violate the prescribed standards, mainly for PM10. In absence of PM2.5 and ozone data in all the cities (which should ideally be the pollutants to be considered), PM10 data should be used for setting up interim milestones and final targets for air quality improvement in the country. Table 3 shows the baseline exceedence levels of PM10 in 2015 in 238 cities monitored under the NAMP program of CPCB, under different exceedence categories. The annual average concentration of PM10 are >3 times higher than the standard in 5% cities, 2-3 times higher in 18% cities, 1-2 times higher in 53% cities and 24% cities show no violation of the standards. CAM India program should focus on achieving a final target of meeting the national ambient air quality standard by 2030. However, to keep the progress on track, two interim milestones are also suggested. Interim-I milestone depicts about 20% improvement over the baseline scenario by the year 2020, while Interim-II milestone suggests 50% improvement over the baseline by the year 2025.

The sector specific strategies and their targeted timelines are suggested in Table 4. Other than the strategies discussed in Table 4, there are several actions whose impact will not be directly quantifiable, e.g., improved landuse planning, improving green cover etc. Strategies for energy demand reduction and improvement in energy efficiency are also important and can play an important role in reducing

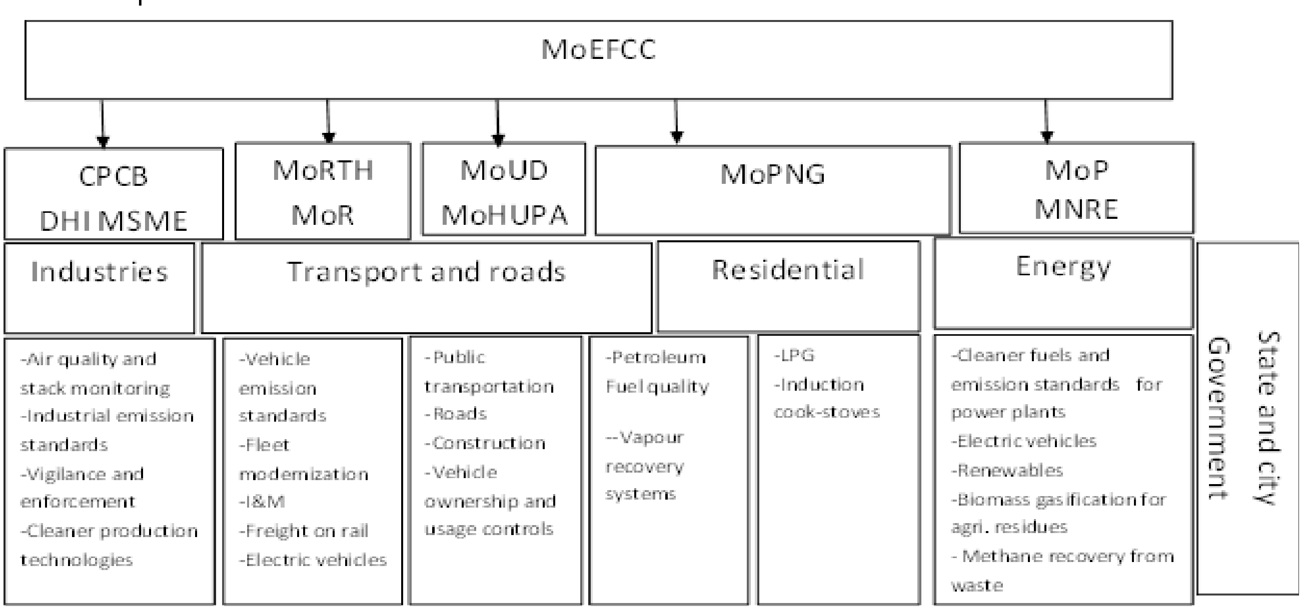


Figure 11 : Broad framework for introduction of CAM India

Table 3 Baseline and targets for ambient air quality under the CAM India			
Baseline	**Interim milestone –I (2020)**	**Interim milestone –II (2025)**	**Final Target (2030)**
Number of monitoring stations * (238 cities)	400	500	All districts head quarters
Annual average concentrations Baseline (2015) in 238 cities % cities violating PM10 standard >3 times : 5% 2-3 times: 18% 1-2 times: 53% Not violating: 24%	20% improvement % cities violating PM10 standard >3 times : 4% 2-3 times: 15% 1-2 times: 45% Not violating: 36%	50% improvement % cities violating PM10 standard >3 times : 2% 2-3 times: 10% 1-2 times: 32% Not violating: 56%	100% achievement of NAQQS % cities violating PM10 standard >3 times : 0% 2-3 times: 0% 1-2 times: 0% Not violating: 100%
Rationale	Immediate actions to be taken on refuse burning, road dust management, construction activities	Control over Agricultural burning (with substitutive options), Fleet modernization, I&M improvements, Public transport, Introduction and enforcement of stringent standards for industries , 24x7 power supply in urban centres.	By then there will significant influx of the BS-IV, and VI vehicles, which should bring down the share of vehicular sector substantially. LPG is expected to reach to more rural-households in India, which presently use biomass.

* number of monitoring stations in each city should be as per BIS and CPCB guidelines

Table 4 Sector Specific Strategies and Their Monitorable Targets						
Sectors	**Strategies**	**Baseline**	**Interim Target –I (2020)**	**Interim Target –II (2025)**	**Final Target (2030)**	**Responsible agencies****
Residential	Enhanced penetration of LPG	Urban-68% Rural- 15%	Urban-75% Rural- 25%	Urban-85% Rural- 50%	Urban-95% Rural- 95%	MoPNG
	Induction cook-stoves	Negligible	3%	7%	10%	MoPNG
Agriculture	Immediate ban on burning agri. residues + Converting Agri. residues to energy and other useful uses	Not fully effective Negligible	100% Ban 25%	100% Ban 50%	100% Ban 100%	CPCB MNRE
Transport	Shifting freight transport from road to rail	36%	38%	42%	45%	MoR
	Introduce BS-VI vehicle emissions and fuel quality norms in India	BS-IV norms introduced in 2017	100%	100%	100%	MoPNG, MoRTH
	Fleet modernization -Setting up scrappage centres and supportive policies	0	50 districts with highest vehicular numbers	200 districts with highest vehicular numbers	All districts	MoRTH
	Reducing fugitive VOC emissions at petrol pumps	Limited number of fuel pumps	50%	100%	100%	MoPNG
	Advanced inspection and maintenance (I&M) centres	10	50 districts with highest vehicular numbers	200 districts with highest vehicular numbers	All districts	MoRTH
	Effective public transport system METRO BRTS City Bus service	Cities 12 11 23			All (2 million plus cities) All (1 million plus cities) 40 buses per lakh population	MoUD
	Electric vehicles (passenger vehicles)	~5%			50%	MoRTH MNRE

Table 4: Contd...						
Sectors	**Strategies**	**Baseline**	**Interim Target –I (2020)**	**Interim Target –II (2025)**	**Final Target (2030)**	**Responsible agencies****
Industries	Develop new stringent standards for industries with prescribed controls	Standards exist except few	New standards for SO2, NOx, PM10/PM2.5			CPCB
	Enforce existing standards by enhancing the scope of continuous stack monitoring and employ emission trading schemes	~1000-2000 stacks	5000	10000	All large and medium scale industries	CPCB
	Use of non-fossil fuels (e.g biomass briquettes/pellets)	Negligible	2%	5%	10%	MoP MSME
	Cleaner production technologies (e.g. Zig zag for bricks)	Negligible	10000	50000	All kilns	CPCB
Waste	Immediate ban on refuse burning	Ineffective	100% Ban (public participative vigilance)	100% Ban	100% Ban	CPCB
	Landfill and STP (from sewage and sludge) methane recovery	Negligible	20%	50%	100%	MoUD
Dust	Paving of roads	Paved 61%	70%	80%	100%	State PWDs
	Road dust reduction (landscaping shoulders, cleaning, maintenance, wall-to-wall paving)	Assess baseline silt loads in Indian cities	Reduce by 40%	Reduce by 60%	Reduce by 80%	MoRTH City governments
	Issuing construction dust management guidelines in 7935 towns *	Negligible	1000 towns	4000 towns	All towns	MoHUPA
	Increased flyash utilization and reducing ash pond fugitive emissions	55%	100%	100%	100%	MoP

* Municipalities need to issue and monitor the compliance of construction dust management guidelines for any construction activities in the towns. Public participative vigilance to be used for monitoring.

** Central agencies should be responsible for action with support from state and city governments.

\+ Sustainable business models need to be developed to support collection , storage and processing of agriculture waste for use as bioenergy or other products.

emissions from various sectors. Other than these broad strategies under the CAM India, city specific action plans will be required to reduce spikes of pollution levels above the background concentrations in these cities. CAM India should also be in sync with the INDCs, NAPCC, and other important missions and policies in place. Investments for mitigation actions should be sought through subsidy reallocations, marginal increase in fuel prices, and corporate social responsibility (CSR) activities.

Multi-scale and Cross-Sectoral Coordination

Considering the enormity of the air pollution problem and its trans-boundary nature, the national scale 'Clean Air Mission' should focus on multi-scale and cross-sectoral coordination to develop and implement national scale strategies for air quality improvement with annual targets. CAM-INDIA should look for ways to integrate efforts across different Indian Ministries, state department and city government listed before to take targeted actions recommended by the national scale air quality management plans.

The steering committee of the CAM India plan should be headed by the honorable Prime Minister of India, with highest level representation from states, and the key city governments. The steering committee should guide the technical committee which should be chaired by the Secretary, MoEFCC, with respective representation from states, and the key city governments, and also from the key experts from non-governmental and academic organizations.

Capacity building

Institutional strengthening of CPCB and SPCBs is a must to ensure successful and effective implementation of strategies discussed above. This will call for higher budget allocations, recruitments of scientific professional, and trainings on air quality monitoring, and modelling tools. Institutional tie-ups can be made for regular trainings of the board officials.

Public awareness and participation

Public awareness needs to be enhanced through display of air quality indices and spatial air quality maps using print and electronic media. Public participation begins with informed citizens with raised awareness levels who can motivate the government for vigorous implementation or adoption of mitigation strategies. Public awareness is also a key aspect of participative vigilance over emitting sources. Along with the regulatory sticks, enhanced awareness levels will build additional pressure on the sources to limit their emissions.

The Clean Air Mission should also envisage public participation, sensitization and capacity building initiatives with academic institutions and local communities. The main objectives will be to educate and empower young minds on aspects related to air pollutants, sources, emission factors, indoor air quality, reduction and control measures, etc. in relation to the existing social structure, cultural norms, economic realities and global trends of the present times, thus creating a multiplier effect within the peers and families. Effective pedagogy, incorporating an array of teaching strategies will be adopted to trigger behavioral change, thus paving way for vigorous implementation and adoption of mitigation strategies.

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