Assessment of Gaseous and Respirable Suspended Particulate Matter (PM_{10}) Emission Estimates over Megacity Delhi: Past Trends and Future Scenario (2000-2020)

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Introduction

- Delhi, the capital city of India, home to more than 16 million people (Singh and Dey, 2012), is one of the fastest growing economic centers of southeast Asia (Sindhwani and Goyal, 2014).
- Rapid Urbanization and Industrialization has led to rise in population and increase in the demand of transportation in Delhi. Thus, during the past decade, Delhi has increased manifold across all sectors, industry, transport, and housing, which has resulted in increase in air pollution of the region (Guttikunda and Gurjar, 2012).
- According to Ambient Air Pollution (AAP) database released by WHO in 2014, Delhi is the most polluted city in the world.
- According to the National Ambient Air Quality Standards, the normal annual average for PM10 is 60 microgram per cubic meter. But during 2008-2010, PM10 in Delhi has gone up from 198 in 2008 to 243 in 2009 and 259 in 2010 .
- It has been estimated that nearly 18,600 premature deaths occur per year in Delhi, due to air pollution (TERI,2001).

Literature Survey

Numerous studies have been made in the past to estimate emissions from megacity Delhi.

- Gurjar et al. (2004) estimated emissions for 1990-2000 period and concluded that SO_2 (~68%) and Total suspended particulate matter (TSP) (~80%) are largely emitted by power plants whereas transport sector contributed >80% of NOx, CO and VOC towards total emissions.
- Kansal et al. (2011) estimated emissions from power plants, vehicles and industries for the year 2006 and presented that vehicular emissions are major sources of TSP (54%), followed by power plants (32%). Power plants and transport sector added ~67% and ~33% of SO_2 and 10% and 90% towards NOx emissions respectively.
- Mohan et al. (2012) estimated emissions for the period of 2000-2008 period based on emission factors (EFs) from previous studies and concluded that >90 % of SO_2 and TSP are contributed by power plants, whereas transport sector contributes ~60% of NOx toward total emissions.
- Nagpure et al. (2013) presented traffic–induced emission trends for megacity Delhi for the years 2000-2005 and concluded that the levels of NOx and TSP did not show appreciable increase, which might be due to CNG effectiveness as an alternative fuel.

Introduction Continued…..

- Various policy measures have been implemented in the past to tackle the problem of rising emissions from these sectors which included
  - ✓ Switching to cleaner fuels (i.e. unleaded gasoline, reduction of sulphur in diesel, reduction of benzene content in gasoline),
  - ✓ Phasing–out of old age vehicles and maintenance of in–use vehicles, conversion of all buses and public transport vehicles to natural gas,
  - ✓ Implementation of Bharat Stage II (EURO-II equivalent)norms for passenger vehicles in 2000 and Bharat stage III (EURO-II equivalent) norms for all categories of four-wheeler vehicles in 2005,
  - ✓ Introduction of Metro Rail, and closing or relocating polluting industries and industries operating in non–conforming areas (Khare and Kansal, 2004).
- However, in spite of these measures, vehicular pollution contributed about 72% towards total air pollution load in Delhi, which was only 23% in 1970–71(Goyal et al., 2006) .

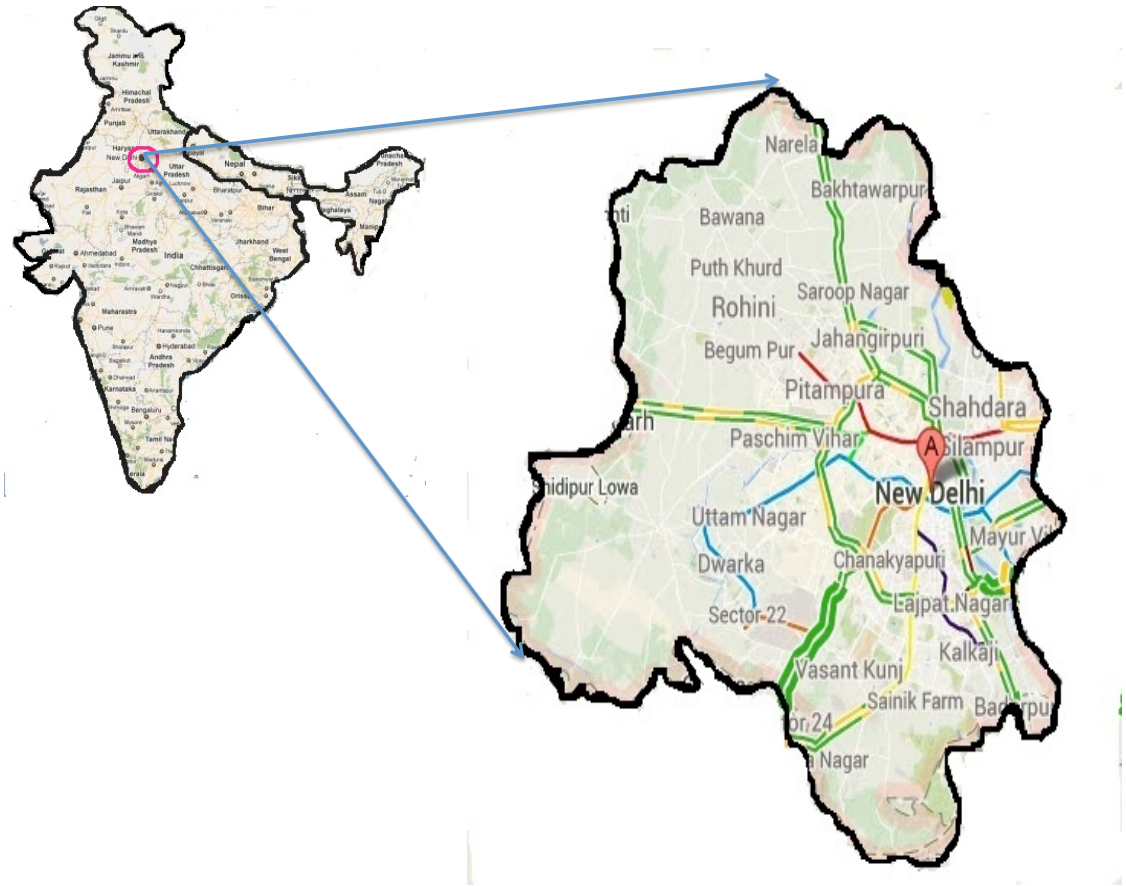
Objective of the Study

- Thus, For the improvement in the air quality of a region, a clear understanding of the emissions from various sectors and their contribution towards the total pollution load is very important as emissions from the megacities like Delhi contribute to large scale phenomena such as acidification and eutrophication (Guttikunda et al., 2003) and the occurrence of large scale haze (Lelieveld et al., 2001).

- The present study aims to estimate emissions of criteria pollutants (CO, NOx, SO_2 and PM_{10}) contributed by different sectors of Delhi from 2000-2010. Further, estimation of emissions for the next 10 years (2011-2020) have been made using business as-usual scenario (BAU) and emission abatement policy scenario (EAP). EAP scenario includes effect of imposing stringent emission reduction measures on total emissions.

Study Area

Delhi (Latitude 28°35'N, Longitude 77°12'E), with an area of 1483 km^2, is situated in the northern part of India. Geographically, Delhi is 160 km to the south of Himalayas, at an elevation of 216 m above mean sea level (Kansal et al., 2011). The river Yamuna forms the eastern boundary of the city whereas the Thar Desert of Rajasthan lies to its west, central hot plains to its south and the cooler hilly region to the north and east. Delhi has a semi-arid climate with extremely hot summers, average rainfall and very cold winters.



Map of the Study Area Delhi

Major Sources of Emission

- Power Plants
- Industries
- Vehicles
- Domestic Sector
- Waste

Emissions from Power Plants

- Three coal fired (i.e., Badarpur, Indraprastha (IP) and Rajghat) and two gas-fired (Gas Turbine (G.T.) station and Pragati Gas Station) power plants were operational during the period 2000-2010. These power plants are located in the heart of Delhi city.
- The amount of fuel consumed is calculated using equations given by Gurjar et al. (2004).

$$Gross\ Generation\ (GWH) = PLF\ (\%)\ x\ capacity\ *\ 24\ *\ 365 \qquad (1)$$

$$Fuel\ use\ (kt) = Gross\ Generation\ *\ fossil\ fuel\ use\ per\ GWH \qquad (2)$$

- Plant Load Factor (PLF) of different power plants is taken from performance review report of thermal power plants issued by Central Electricity Authority (CEA). Emission factors (EFs) for PM_{10} are based on Sahu et al., 2011 whereas EFs for SO_2 and CO have been taken from CPCB (2010) and for NOx (as NO_2) from Kansal et al. (2011).

Emissions from Transport Vehicles

- Emission load from road transport has been estimated using the following equation (IPCC, 2006; Sahu et al., 2011).

$$E_i = \sum (Veh_j * D_j) * EF_{i,j,km} \qquad (3)$$

where, E_i : Emission of pollutant ($_i$)(Gg);

Veh_j : number of vehicles per type ($_j$);

D_j : Distance travelled per vehicle in per year ($_j$)(km);

$EF_{i,j\ km}$: emissions of pollutant ($_i$) vehicle type($_j$) per driven kilometer(g/km).

Emissions from Domestic and Industrial sector

Emissions from fuel consumption in domestic sector are calculated as

$$E_i = \sum(Fuel_j \times EF_{ij}) \qquad (4)$$

where, E_i: emission per pollutant (i) (Gg);

Fuel $_j$: consumption of fuel per fuel type ($_j$)(kt);

EF $_{i,j}$: emissions of pollutant ($_i$) per unit of energy ($_j$)(g/kg).

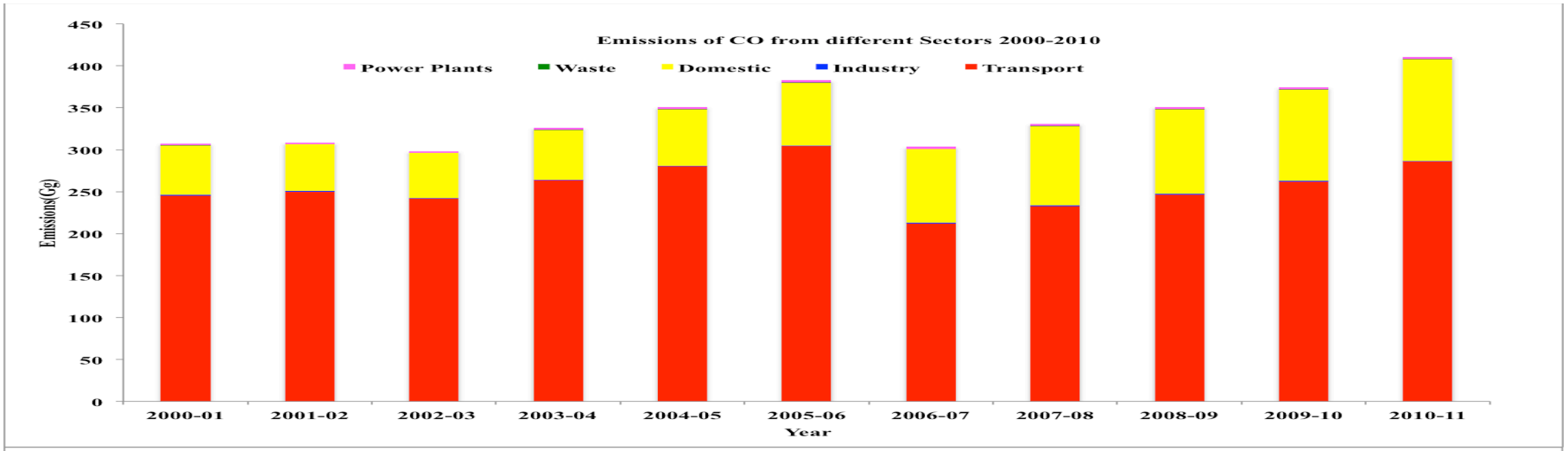
Cow dung, kerosene, crop waste, LPG and wood is used as fuel in domestic sector whereas High Speed Diesel (HSD) and Light Diesel Oil (LDO) are used as industrial oils.

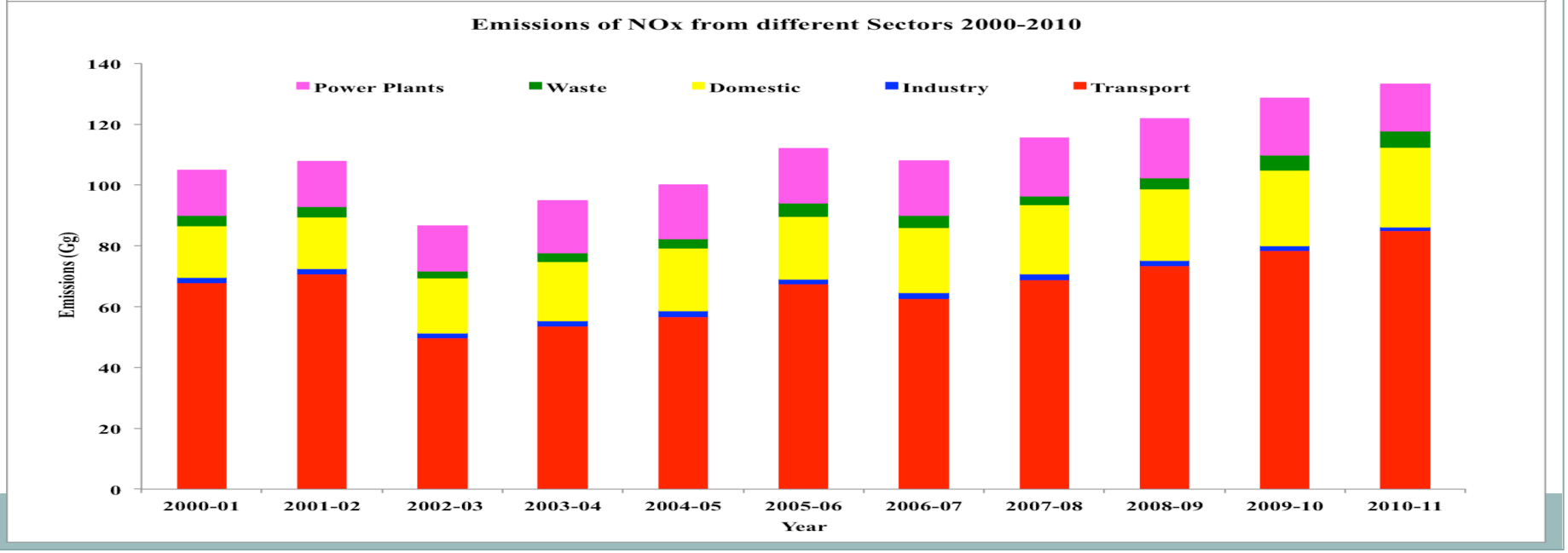
Emissions from Waste sector

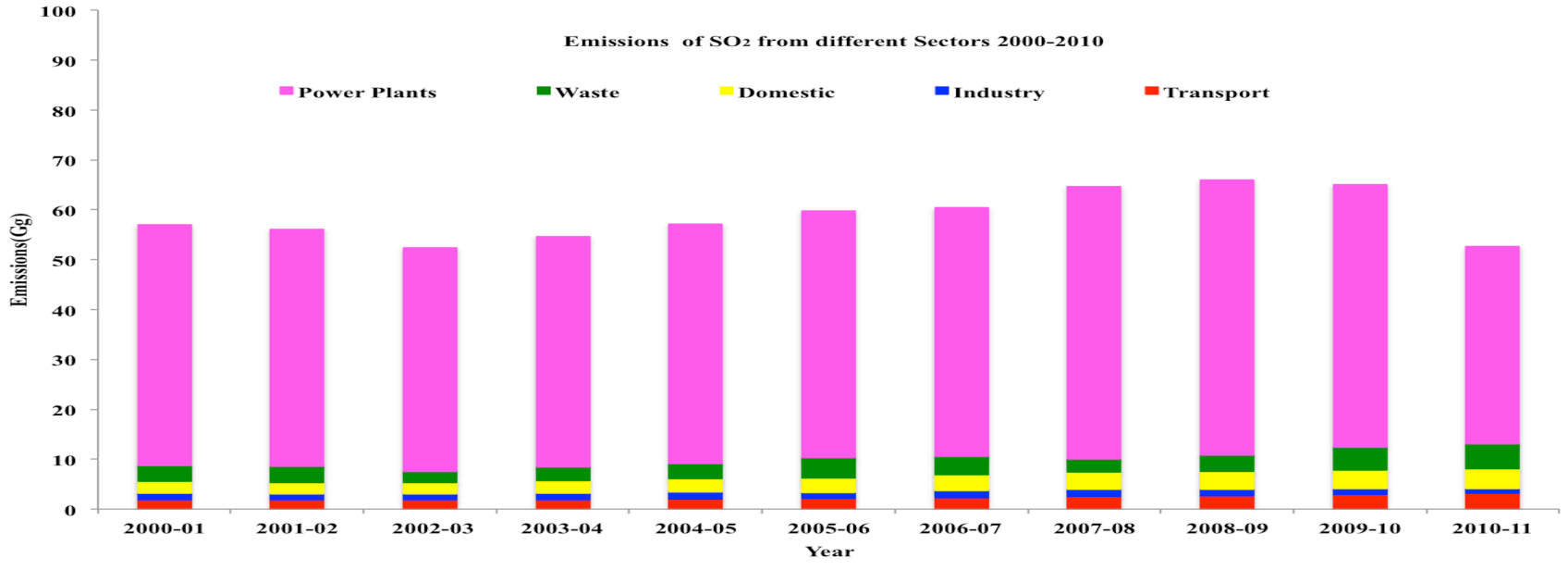
- Landfills are important sources of anthropogenic emissions especially for greenhouse gases in fast urbanizing cities. Solid waste management remains one of the most neglected sectors in Delhi.
- Latest estimates indicate that about 6500-7000 tons of municipal solid waste (MSW) is generated each day in Delhi with per capita generation rate of 0.47 kg per day (Chakraborty et al., 2011).

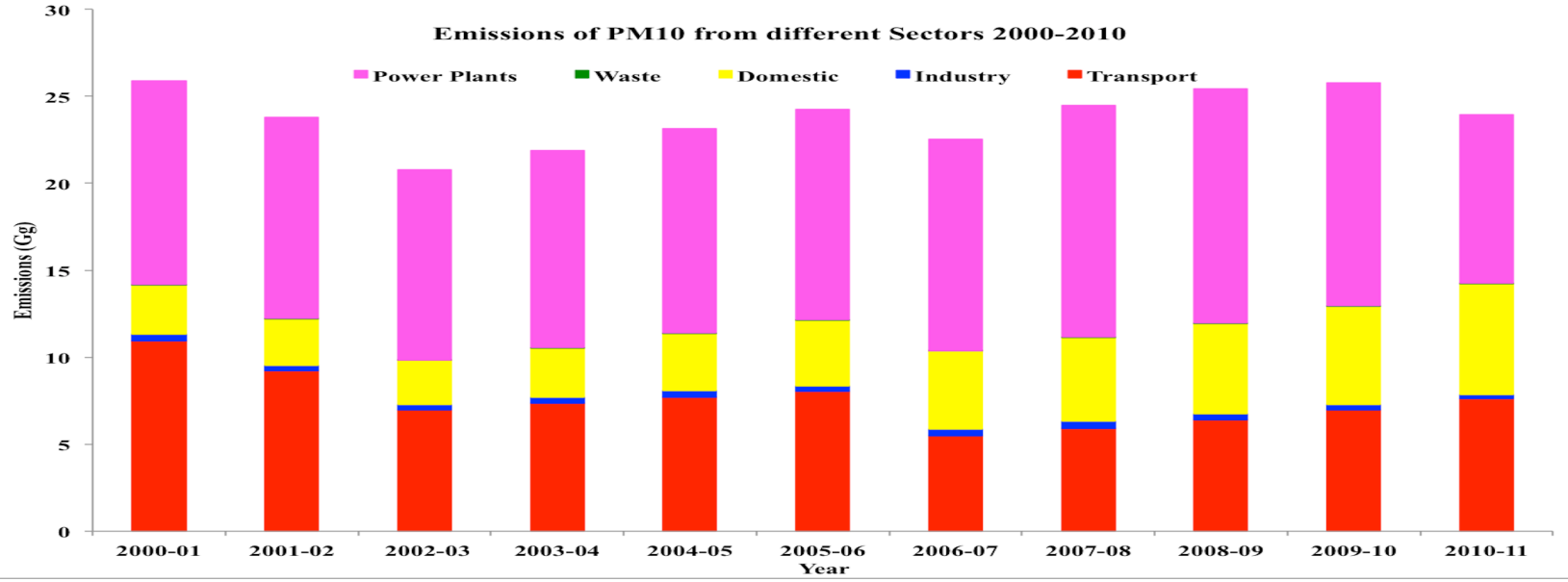
Main Findings

The sector-wise emission trends of the criteria pollutants CO, NOx, SO_2, PM_{10} during 2000-2010 in Delhi






Emissions of SO2 from different Sectors 2000-2010
Power Plants
Waste
Domestic
Industry
Transport
Emissions(Gg)
100
90
80
70
60
50
40
30
20
10
0
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
Year


Emissions of PM10 from different Sectors 2000-2010
Power Plants
Waste
Domestic
Industry
Transport
Emissions (Gg)
30
25
20
15
10
5
0
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
Year

- During 2000-2010, It has been found that CO is mainly emitted from transport and domestic sector.
- Major contribution of NOx comes from transport followed by power plants and domestic sector respectively and has followed an increasing trend during 2000-2010.
- The most significant contribution to PM_{10} emissions is from power plants and transport sector. PM_{10} emissions from transport sector have greatly reduced after to implementation of Bharat Stage –III norms and use of CNG fuel in public transport (buses), auto-rickshaws and taxis in 2000. But increasing number of vehicles in Delhi have offset the impact of control initiatives taken during 2000-2010.
- Major contribution towards SO_2 emissions still comes from power plants.

Further,

- For the estimation of emission till 2020, projection of Delhi's population till 2020 has been taken statistical Abstract of Delhi (2012).
- Growth of Vehicles till 2020 has been estimated using methodology adopted by Das et al. (2012) based on Gomprez function.
- In addition to it, estimation of emissions from domestic, industries, waste and power plants till 2020 has been estimated using population projection.

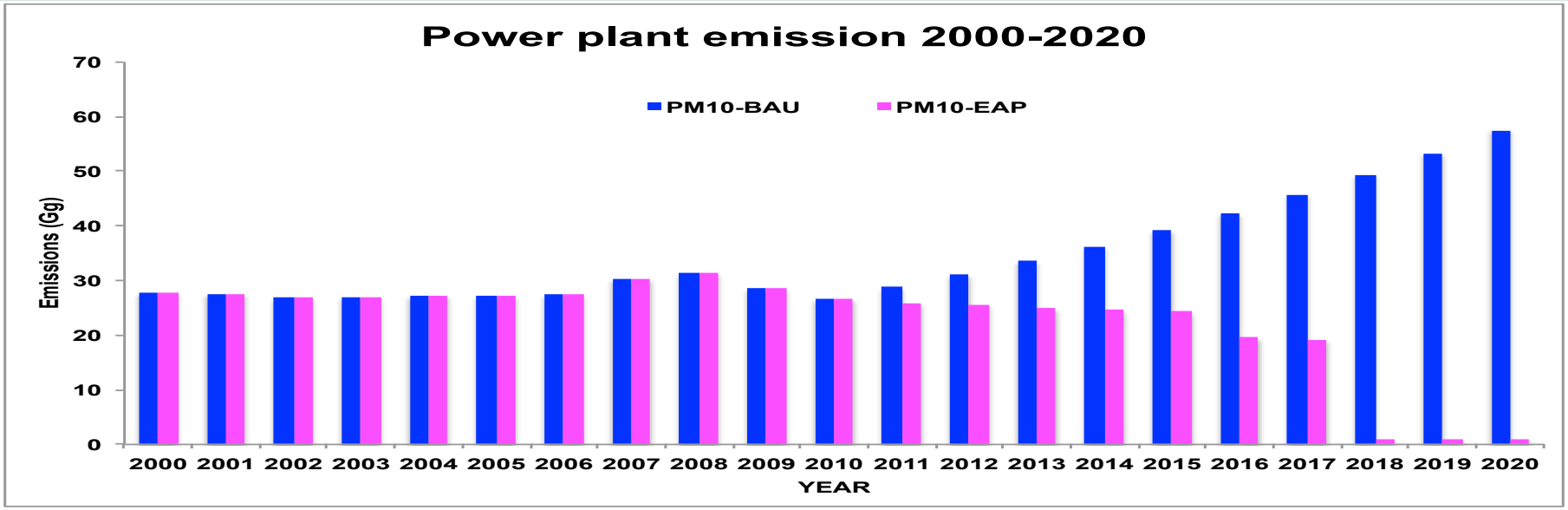
BAU and EAP scenario

Under **Business-as-usual (BAU) Scenario**, following assumptions have been considered.

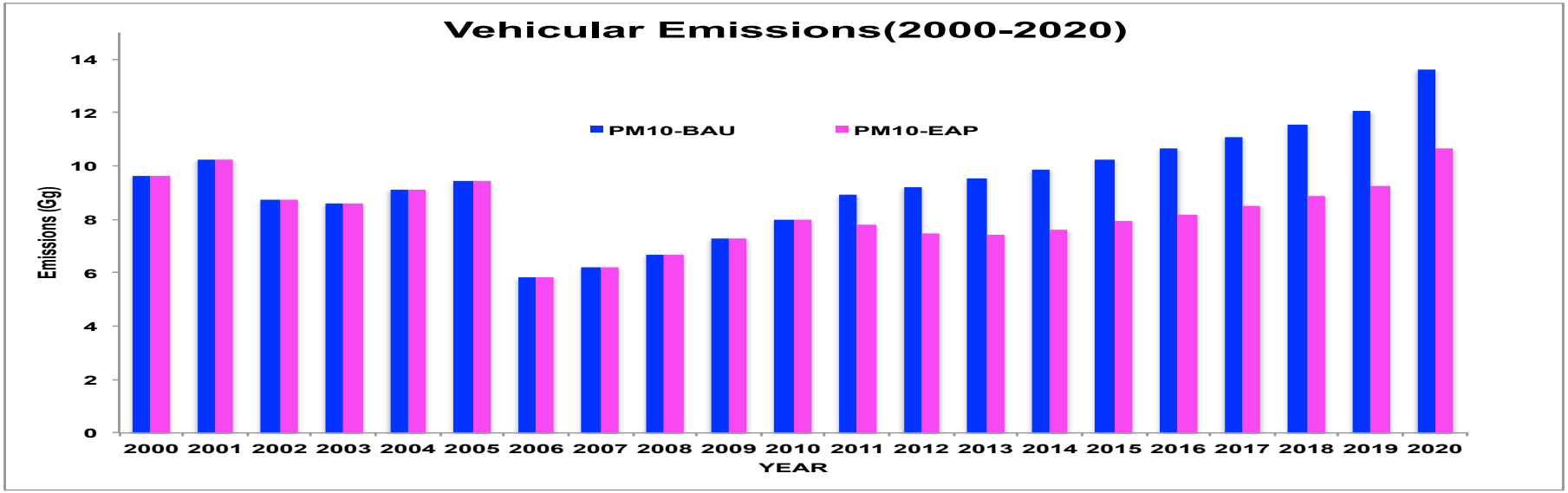
- Proportionate growth across all sectors in relation to increase in population.
- Population projection by 2020 has been taken from Statistical abstract of Delhi, 2012.
- Population growth rate has been considered to project future emissions from domestic, waste, and industries.
- Vehicular growth rate has been estimated on the basis of growth rate witnessed in the past years.
- Rising population would result in more number of private cars in Delhi.

Under **Emission Abatement Policy Scenario (EAP)**, assumptions considered are following:

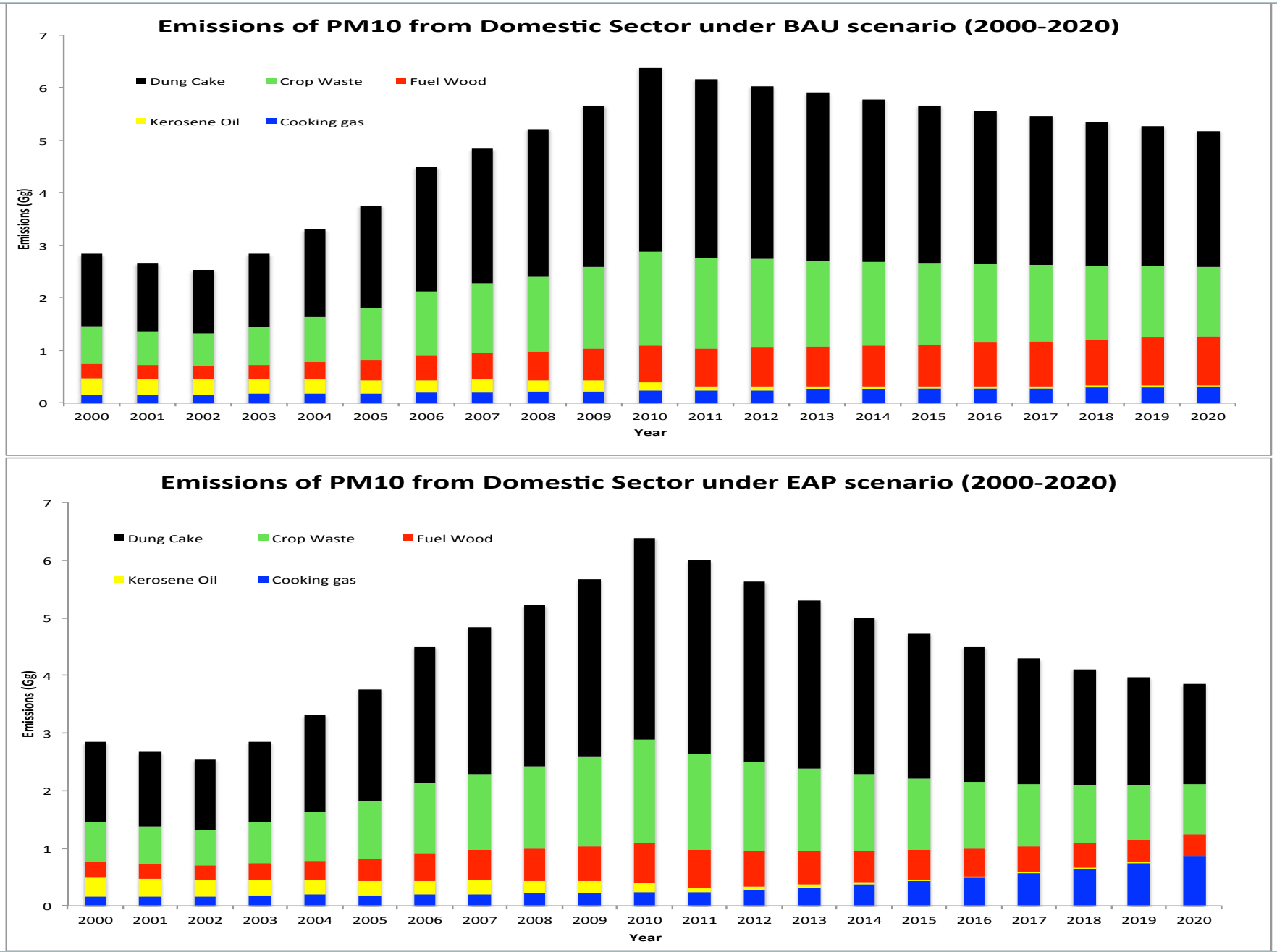
- For power plants, due to rising emissions from coal based power plants Rajghat (135 MW) and Badarpur (735 MW) power plants would be shut down by 2015 and 2017 respectively. Further, to meet the rising demand of electricity gas based Pragati power plant (750 MW) would be operational by 2015.
- Implementation of EURO IV norms on two and three wheeler vehicles and EURO V norms for 4-wheelers by 2015. About 30% increase in public buses.
- Landfill sites to be increased from 3 to 5 with proper sanitary landfill sites.
- No further growth in small and medium scale industries.
- Use of Kerosene, cow dung, wood in domestic sector to be reduced by promoting use of LPG in slum areas of Delhi.



Emissions of PM_{10} from Power plants under BAU and EAP scenario from 2000-2020.



Emissions of PM_{10} from vehicles under BAU and EAP scenario from 2000-2020.



Emissions of PM_{10} from Domestic Sector under BAU (a) and EAP (b) scenario from 2000-2020.

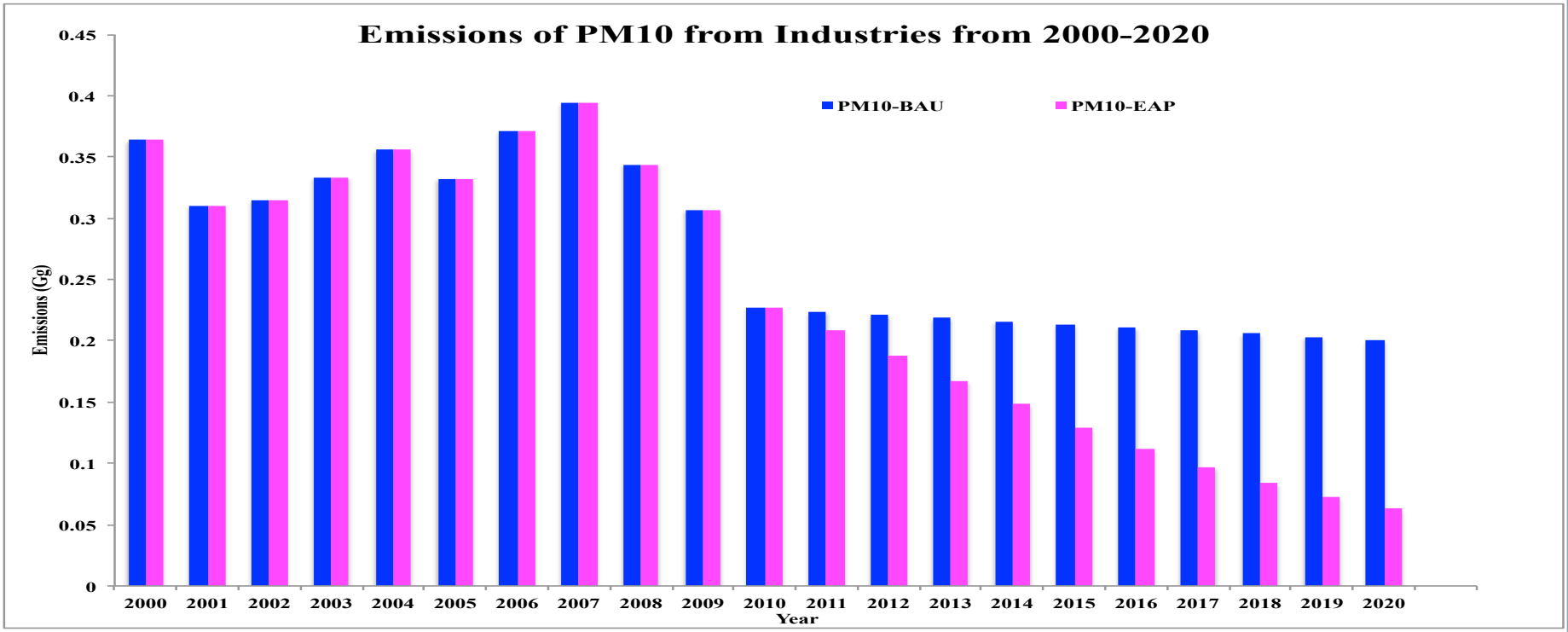


Fig 5: Emissions of PM10 from Industries under BAU and EAP scenario from 2000-2020.

- It has been observed that apart from vehicular emissions all other sectors would show considerable reduction in emissions under EAP scenario.
- Growth in population and as a result increase in number of private vehicles will negate the impact of implementation of Euro V norms on 4-wheelers by 2015.
- Moreover, according to a leading daily newspaper (TOI, 3 may 2014) completion of Phase III of Delhi metro by 2016 is expected to be delayed which would further intensify the vehicular emissions.

References

- ARAI (The Automotive Research Association of India), 2007: Emission Factor Development for Indian Vehicles, Air Quality Monitoring Project–Indian Clean Air Programme, New Delhi, 1-89. http://www.cpcb.nic.in/Emission_Factors_Vehicles.pdf
- Chakrabortya, M., C. Sharma, J. Pandey, N. Singh, P. K. Gupta, 2011: Methane Emission Estimation from Landfills in Delhi: A comparative Assessment of Different Methodologies. Atmos. Environ. 45, 7135-7142, doi: 10.1016/j.atmosenv.2011.09.015.
- CPCB (Central Pollution Control Board), 2010. Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Indian Cities, New Delhi, 1-658. http://cpcb.nic.in/Delhi.pdf
- Das, D., 2010: Commercial Vehicles in Delhi: Diesel Demand and Sulphur Emission. *Journal of Public Transportation*, **13**, 73-96.
- Executive Summary of Inventorization of Green House Gases – Sources and Sinks in Delhi. Department Of Environment, Government of Delhi.
- GNCTD, 2010. State of Environment Report for Delhi, Department of Environment and Forests. New Delhi, India: Government of NCT of Delhi, http://www.indiaenvironmentportal.org.in/files/SoEDelhi2010.pdf

- Goyal, S.K., S.V. Ghatge, P. Nema, and S. M. Tamhane, 2006: Understanding urban vehicular pollution problem vis–a–vis ambient air quality—case study of a megacity (Delhi, India). *Environ. Monit. Assess.* **119**, 557–569.
- Gurjar, B.R., J.A. van Aardenne, J. Lelieveld, and M. Mohan, 2004: Emission estimates and trends (1990–2000) for megacity Delhi and implications.

THANKS