Executive Summary

Source Apportionment Study to Prepare Action Plan to improve Air Quality of Ludhiana City

2017-2020

Prepared by

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and
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THE ENERGY AND RESOURCES INSTITUTE
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Executive Summary

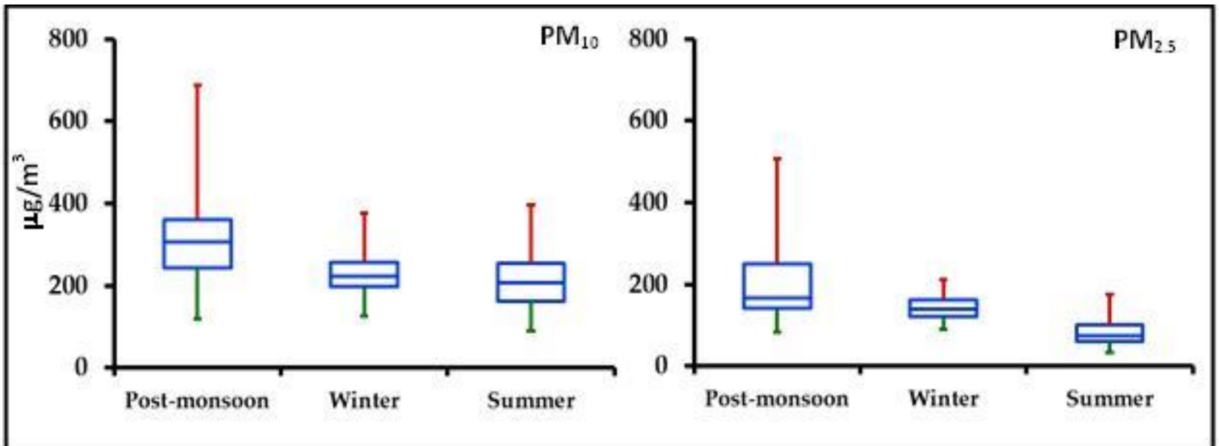
Ambient air pollution adversely affects human health and related damages to the ecosystem and economy. Deteriorating ambient air quality is perhaps the problem of all cities in the developing countries; however, the sources of ambient air pollution vary from place to place. It is important to identify the key sources of air pollution to curb the level of ambient air pollution for the wellbeing of the residents and economic growth of an area. Ludhiana city is amongst the most polluted cities of Punjab besides being a major industrial hub of the state.

The Energy and Resources Institute (TERI), New Delhi has undertaken this study from the Punjab State Council of Science and Technology (PSCST), Chandigarh in the month of June 2017 as part of the Punjab Pollution Control Board (PPCB) approved project "To carry our Source Apportionment Study and Prepare Action Plan to Improve Air Quality of Ludhiana City" awarded to the PSCST in the month of March, 2017. The major objectives of this study were to undertake source apportionment of ambient particulate matter (both $PM_{2.5}$and PM_{10}), and develop an air quality action plan based on future projections of source emissions levels based on different control options for the city of Ludhiana. As the project was sanctioned in the year 2017, the same year was taken as the base year for the development of the source emission inventory in the study.

The major sources of ambient air pollution in Ludhiana city were qualitatively and quantitatively assessed through two different simulation approaches, where one approach identifies different sources at a particular site using the marker pollutants specific to a particular source (receptor model), and the other uses the source emissions inventory alongside the meteorological parameters, landscape parameters, etc. to simulate the ambient concentration of the air pollutants at a particular site (dispersion model). The simulated ambient concentrations of different air pollutants were validated with the actual on-ground measurement of air pollutants before undertaking source sensitivity analysis. The source distribution of air pollutants from both simulated approaches were statistically validated before using the second approach for projection of future ambient air quality involving different emissions control options under alternate scenarios. Finally, required policy interventions were suggested in consultation with the PSCST, Chandigarh to achieve the estimated future ambient air quality under the alternate scenarios.

Ambient air quality was measured during three seasons (post monsoon, winter, and summer) at six different locations within Ludhiana city, along with a background location in the up-wind direction of the city. All seven air quality monitoring locations were selected in consultation with PPCB, Ludhiana. The air quality measurement locations within Ludhiana city were classified as industrial (2), commercial (1), kerbside (1) and residential (2) locations. The post-monsoon, winter and summer season measurements of ambient air quality at each monitoring location were carried out for 10-days continuously during October-November, 2017, December 2017 to

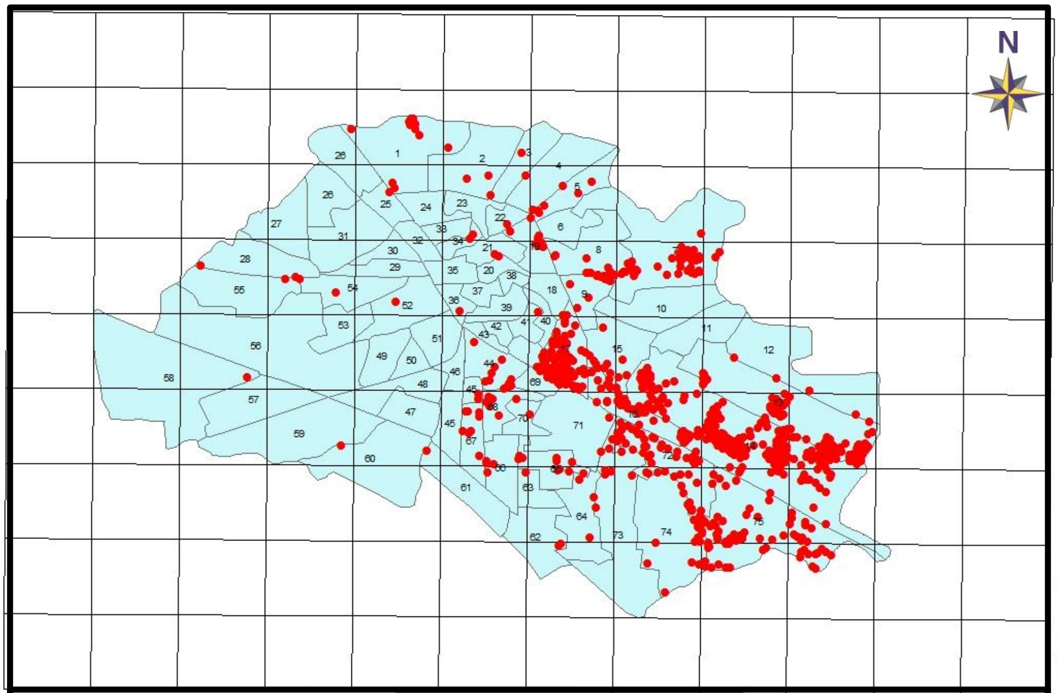
January 2018 and May-June 2018 respectively. Irrespective of the monitoring location and seasons, the average PM_{10} and $PM_{2.5}$ concentrations were above the 24-hr average National Ambient Air Quality Standard (NAAQS) prescribed by CPCB. The average PM_{10} concentrations across different sampling locations in Ludhiana city during post-monsoon, winter and summer seasons varied between 252 to 452 µg/m^3, 195 to 277 µg/m^3 and 150 and 298 µg/m^3, respectively. The average ambient $PM_{2.5}$ levels across these locations during post-monsoon, winter and summer seasons varied between 179 to 309 µg/m^3, 127 to 158 µg/m^3 and 64 to 130 µg/m^3, respectively. The ratio of $PM_{2.5}$ to PM_{10} was more than 0.5 at all sampling sites, during both post-monsoon and winter seasons, indicating the dominance of combustion sources during these seasons. However, the ratio was below 0.5 at all sampling locations during the summer season, which may be attributed to the episodes of dust storms in the study area, which increase the coarser particles (PM_{10} and above) in the atmosphere.



Seasonal variation of ambient PM_{10} and PM_{25} concentrations over the Ludhiana city during the measurement period

The particulate matter (both PM_{10} and $PM_{2.5}$) samples collected at each of the sampling locations during different seasons were analyzed for metals, ions, carbon (EC/OC) and selected organic chemicals (molecular markers). Metals remained major constituents of the particulate samples during all three seasons at all sampling locations. The metal constituent (40 to 55%) of the PM_{10} and $PM_{2.5}$ sample of the Ludhiana city was higher during the winter season compared to others. Calcium was measured as the most dominant metal (38 to 60%) in the particulate matter samples (both PM_{10} and $PM_{2.5}$) throughout the study period. Organic carbon constituted 60-83% of the total ambient particulate carbon in all three seasons, with comparatively higher share during the winter seasons (68 to 83%). Levoglucasan and stigmasterol were identified as the major organic species in the particulate matter samples of Ludhiana city during all the three seasons; however, both their concentrations were lower during the summer season compared to other two seasons. Rice crop residue burning in agriculture fields around the Ludhiana city during the month of October to November might have contributed to higher concentration of levoglucosan and stigmasterol in ambient air during the sampling period of post-monsoon and winter seasons compared to that of summer.

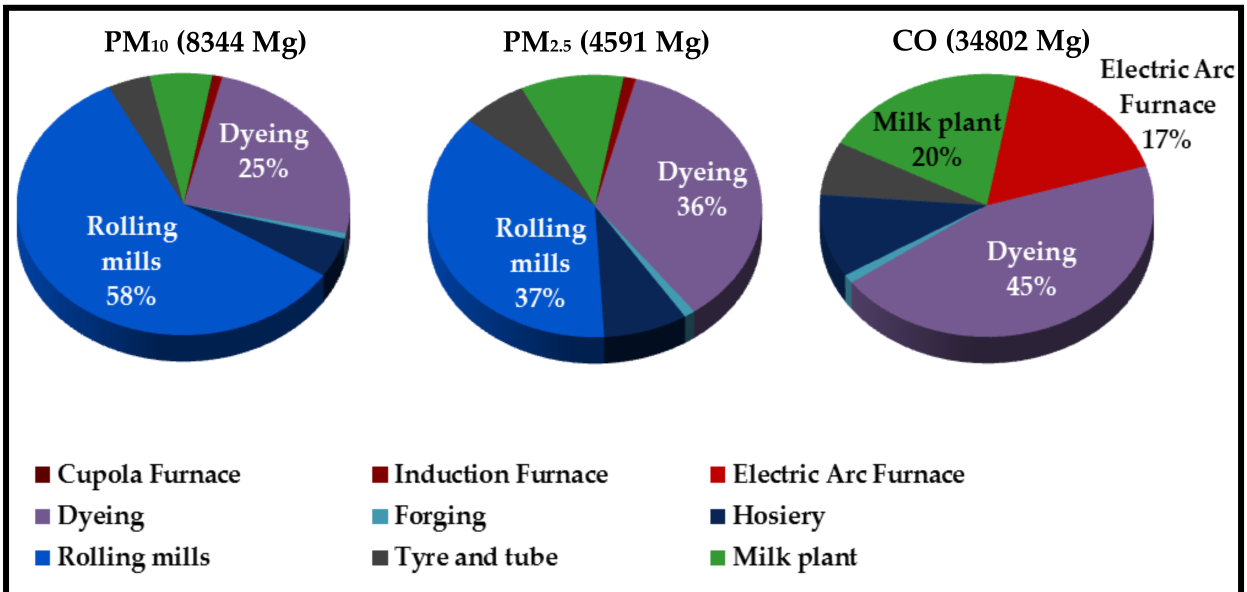
Apart from measurement of the ambient concentrations of different air pollutants, development of comprehensive emission inventory is an important step in air quality management process. 2 × 2 km^2 grid wise emission inventory of air pollutants like PM_{10}, $PM_{2.5}$, NO_x, SO_2 and CO was prepared for different point, line and area sources for the year 2017 in the Ludhiana city. 793 air polluting industries of the Ludhiana city area (as per PPCB) were mapped over the 2 × 2 Km^2 grid. The major air polluting industries in Ludhiana city area are textile dyeing, forging, induction furnaces, re-rolling mills, cupola furnaces, etc. Data related to fuel use, air pollution control device etc. for each industry were collected from the PPCB. Fourteen different types of industries in the Ludhiana city area were selected in consultation with the PPCB to measure the stack emissions without altering normal industrial activities.



Location of industries in Ludhiana city

A detail inventory of crematoria in the Ludhiana city area was prepared based on the data collected from respective crematoria in the study domain. Grid wise survey was conducted to map construction activities, restaurants/hotels, refuse burning, diesel generator use, etc. in the study domain. Gird wise traffic count and parking lot surveys were also undertaken to estimate the number, vintage, kilometers travelled etc. for different categories of vehicles in Ludhiana city. Emissions from the residential sector were estimated based on the fuel consumption data from the National Sample Survey Office (NSSO). Emissions factors of different crop residues burning around Ludhiana city area and road dust suspension from different types of roads in Ludhiana city were developed during the study period.

The estimated emissions inventory of different industries suggests that the rolling mills (58% and 37%) and dying industries (25% and 36%) are the major industrial sources of PM_{10} (8344 Mg) and $PM_{2.5}$ (4591 Mg). Among the furnaces of different industries induction furnace (88% and 86%) are the major source of atmospheric PM_{10} and $PM_{2.5}$ respectively. Apart from being a major source of atmospheric particulates, the dyeing industries were also estimated as the major source of CO (45%) from the industrial sector (34802 Mg) followed by milk plants (20%) and industries with electric arc furnace (17%).



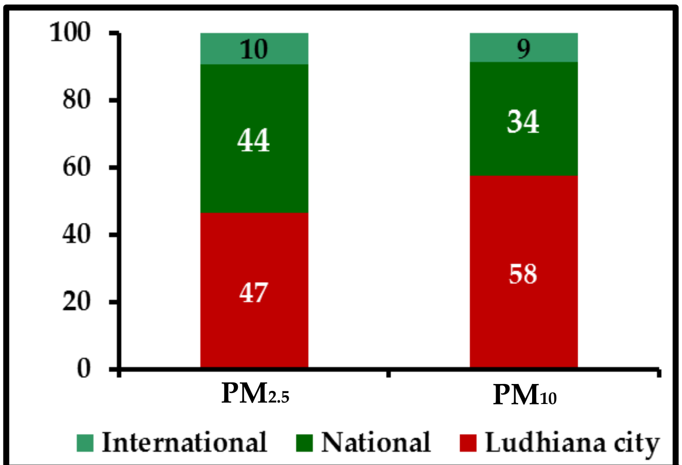
Estimated annual emissions of air pollutants from different types of industries in Ludhiana city. Values in the parenthesis indicate total estimated emissions from the industry sector. Mg (Million gram) = Ton

The estimated total annual PM_{10} emissions (16755 Mg) from different sectors in Ludhiana city followed the order: Industry (49.8%) > Road dust (33.0%) > Transport (11.5%) > others (5.6%). Estimated total annual $PM_{2.5}$ emissions (8533 Mg) from different sectors followed the order: Industry (53.8%) > Transport (22.0%) > Road dust (15.7%) > others (8.5%). The industry sector was also estimated as the largest contributor of annual SO_2 (97.2%) and CO (51.8%) emissions from different sectors in Ludhiana city.

Estimated emissions of air pollutants from different sectors of Ludhiana city during 2017					
Sector	**Emissions (Mg)**				
	$PM_{2.5}$	**PM_{10}**	**SO_2**	**NOx**	**CO**
Industries	4591	8344	8772	1019	34802
Transport	1876	1934	75	15043	29236
Road dust	1339	5533	-	-	-
Residential	28	34	19	129	252
DG set	90	106	99	1506	324
Restaurants	25	41	34	11	101
Crematoria	40	82	2	11	410
Refuse burning	540	656	28	206	2095
Construction	4	26	-	-	-
Total	**8533**	**16755**	**9028**	**17925**	**67220**

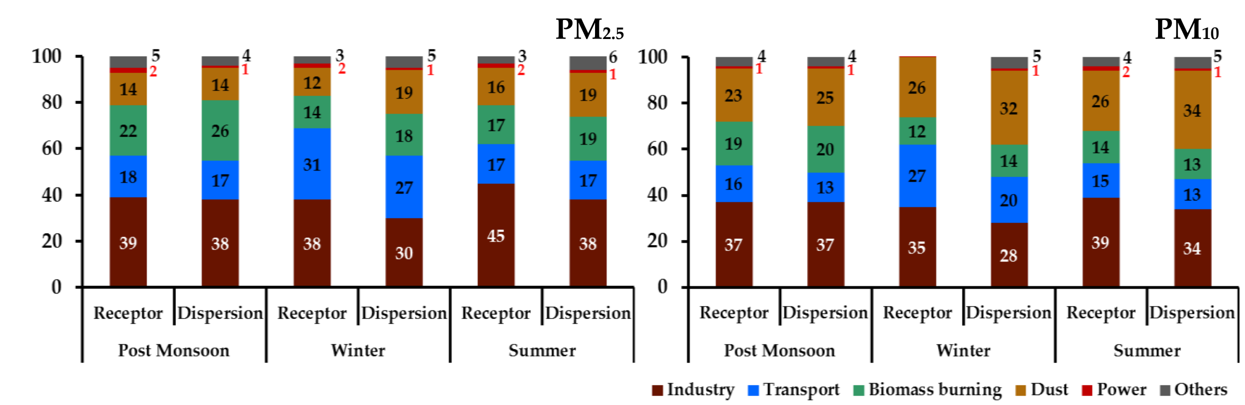
The mass distribution of different chemical species in the atmospheric $PM_{2.5}$ and PM_{10} samples were fed into the receptor model to simulate the contribution from different sources based on the marker species(s) of respective sources. The receptor model suggests that the contribution of industrial sector to both ambient $PM_{2.5}$ and PM_{10} has been higher compared to other sectors in Ludhiana city during the three monitoring seasons of the study. Dust remains the second largest contributor to ambient PM_{10} during all three seasons of the study. However, contribution of other sectors apart from the industry sector, to ambient $PM_{2.5}$ and PM_{10} of Ludhiana city varied seasonally in the receptor model. Biomass burning and transport sector were the second largest contributor to ambient $PM_{2.5}$ in all three seasons.

Community Multi scale Air Quality Modelling System (CMAQ) in combination with the Weather Research and Forecasting (WRF) model was used as the dispersion model in the study. WRF model generated 3-dimensional meteorological fields over the study domain which acts as an input to the CMAQ model along with emissions inventories. The WRF-CMAQ was initially used to develop India level simulation of different air pollutants at 36×36 km^2 scale. The international boundary conditions have been adopted from global air quality products of National Centre for Atmospheric Research (NCAR), U.S.A. to account for transport of pollutants from outside the political boundaries of India. These global products are generated using the global chemical transport model MOZART. The India scale and global simulated concentrations of air pollutants were used to develop the background concentrations of different pollutants over the study domain. The WRF-CMAQ model was then used at the study domain of the Ludhiana city using the 2×2 km^2 gridded emission inventory and the background concentrations. The ratio of simulated and measured ambient concentrations of $PM_{2.5}$ and PM_{10} at six monitoring locations of Ludhiana city were in the range of 0.68 to 0.87 and 0.35 to 0.66 respectively. The lower ratio for PM_{10} especially during the summer season suggests the dominance of some unaccounted natural dust in the ambient PM_{10} concentrations in Ludhiana city. The dispersion model has estimated that different emissions sources of Ludhiana city have contributed 44%, 47% and 49% of the ambient PM_{10} concentration of the city during post-monsoon, winter, and summer seasons respectively, while, more than 50% of the ambient $PM_{2.5}$ of Ludhiana city is contributed by different sources located outside Ludhiana city.



Simulated geographical contributions to $PM_{2.5}$ and PM_{10} concentrations in Ludhiana city

Source sensitivity analysis of different sectors of the Ludhiana city in the WRF-CMAQ model suggests that the industrial sector was the most important source of ambient PM_{10} (28 to 37%) and $PM_{2.5}$ (30 to 38%) during all seasons, as also indicated by the receptor model analysis.



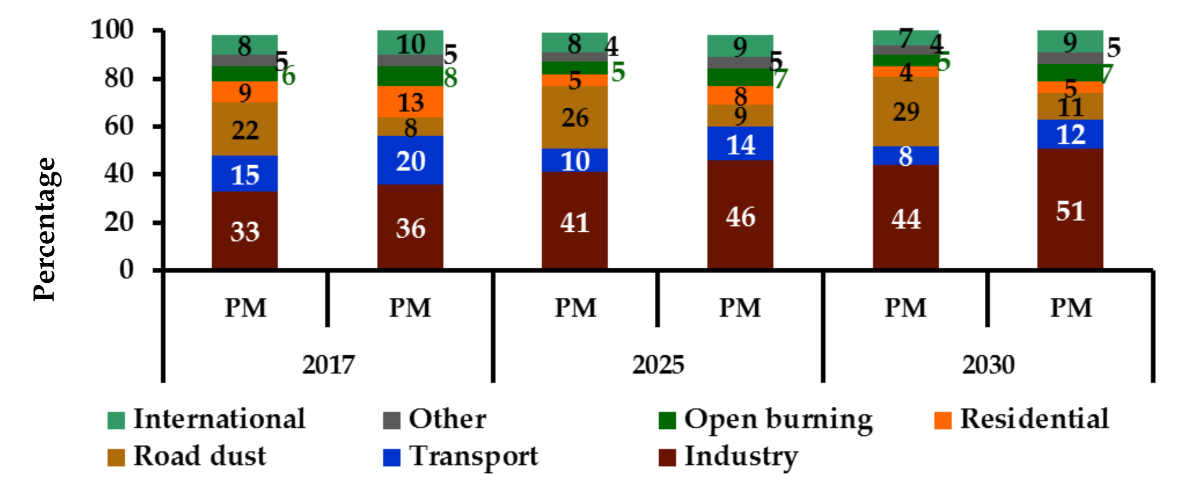
Source contribution of ambient $PM_{2.5}$ and PM_{10} using the receptor and dispersion models.

A Business As Usual (BAU) scenario was developed in consultation with the PSCST, Chandigarh accounting for the growth trajectory, government policies, and interventions in various sectors in the city of Ludhiana as well as the state of Punjab. The BAU scenario was used to estimate the emissions of air pollutants from various sectors to the ambient concentrations of air pollutants in Ludhiana city during 2025 and 2030.

Sector specific growth trajectory in the BAU scenario

Sector	Growth rate
Transport	6.20%
Crematoria	Crude death rate for rural population is 6.3% and 6.0% in 2025 and 2030, respectively and for urban population 4.6% and 4.4% in 2025 and 2030, respectively
Restaurants	7.6% in 2025 and 6.8% in 2030
DG sets	No DG sets in 2025 and 2030
Construction	Same as 2016
Industries	4.2% in 2025 and 2030
Domestic	Annual population growth rate 1.47% in 2025 and 2030 (India Census 2001, 2011). LPG penetration will increase at rate 2% in Ludhiana city and 8.1% in the rest of state

Total emissions of PM_{10}, $PM_{2.5}$, and SO_2 were projected to increase by 54%, 43%, 68%, in 2030 respectively compared to their respective emissions during 2017; while, NOx emissions were projected to decrease by 43% during the same period. Emissions of PM_{10} were estimated to increase at a faster pace compared to that of the $PM_{2.5}$. This is expected as the combustion-based sectors like transport and biomass are likely to reduce their shares with the implementation of BS-VI norms in the transport sector by 2020, and increased penetration of LPG in residential sectors of the rural areas. Emissions of PM_{10} and $PM_{2.5}$ have been projected to increase by 71% in the industrial sector by 2030.



Estimated source contribution to ambient PM_{10} and $PM_{2.5}$ under BAU scenario in Ludhiana city

The dispersion model was used to estimate the source contribution of different sectors to ambient PM_{10} and $PM_{2.5}$ during 2025 and 2030 under the BAU scenario. Industry was estimated to remain as the major source of ambient PM_{10} and $PM_{2.5}$ in Ludhiana city during 2025 and 2030 under the BAU scenario. The contributions of national and international levels background concentrations were taken same as in 2017.

Estimated emissions of air pollutants from the Industry sector ($PM_{2.5}$: 4591 t/year) in Ludhiana city was higher compared to other sectors followed by emissions from the transport ($PM_{2.5}$: 1876 t/year) and road dust ($PM_{2.5}$: 1339 t/year). Emissions of air pollutants were higher in 13 – 14 grids (2km × 2km) among 50 grids in the city. In some of the grids, the emissions from the transport sector were higher; whereas emissions were higher from the industry sector in others; however, the road dust emission was higher in all grids with higher transport (tailpipe) emissions. Among industries highest emissions were recorded from the rolling mills, followed by dying industries and milk plant. It is suggested in this report, that the use of pet coke should be banned in all industries the city, all industries using biomass as fuel should be shifted to biochar briquette, which can comparatively reduce the emissions. It is also suggested that the red/orange categories of industries from the Industrial zone – A should be shifted towards south eastern or southern direction outside the Ludhiana city boundary. Apart from other proposals to reduce the transport related emission in the Ludhiana city, it is proposed to develop Eastern peripheral way and Western peripheral way of NH-1 bypassing the Ludhiana city. Reconstruction of city roads particularly in the industrial areas based on the truck loads on each road and wall-to-wall paving of city roads (suggestive design included in the detailed report) are recommended to reduce the road dust level in the city.

The emissions and concentrations reduction potential of different control strategies in biomass, transport, industries, and other sectors were estimated under eighteen alternate scenarios developed in consultation with the PSCST, Chandigarh.

Ambient particulate concentration reduction potential of different alternate scenarios

Sl No.	Strategies	2025		2030	
		$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
	Biomass				
ALT1	Convert 75% and 100% biomass to LPG in 2025 and 2030, respectively	-2%	-1%	-5%	-3%
ALT2	Supply improved biomass cook-stoves to 75% and 100% households using biomass in 2025 and 2030, respectively	-2%	-1%	-2%	-1%
ALT3	Supply improved induction cook-stoves to 75% and 100% households using biomass in 2025 and 2030, respectively	-5%	-3%	-5%	-4%

Sl No.	Strategies	2025		2030	
		$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
ALT4	Zero open burning of agricultural residue in both 2025 and 2030	-5%	-4%	-5%	-4%
	Transport				
ALT5	25% and 50% electric buses in 2025 and 2030, respectively	-0.2%	-0.1%	0%	0%
ALT6	20% and 40% electric Two-wheelers and cars in 2025 and 2030, respectively and 100% electric Autos in both 2025 and 2030	-3%	-2%	-4%	-3%
ALT7	Shift 15% and 30% from Cars and two wheelers equally to correspondingly increased number of buses in 2025 and 2030, respectively	-1%	-1%	-1%	-1%
ALT8	Fleet modernization in Ludhiana	-6%	-5%	-2%	-2%
ALT9	Banning entry of pre BS-IV trucks and buses in Ludhiana city	-2%	-1%	-1%	0%
ALT10	CNG vehicles in Ludhiana city	-1%	-1%	-1%	-1%
ALT11	Congestion management and strict RDE* testing in Ludhiana city	-3%	-2%	-3%	-2%
ALT12	Shift of 50% cars and 2-W to shared taxis in 2025 and 2030 compared to BAU	-4%	-3%	-3%	-2%
	Industries				
ALT13	75% and 100% enforcement of SO_2/NOx standards in other industries in 2025 and 2030, respectively	-6%	-5%	-9%	-6%
ALT14	50% and 100% fuel switch to gas from solid fuels in 2025 and 2030, respectively compared to BAU	-20%	-19%	-44%	-39%
ALT15	Stringent PM_{10} and $PM_{2.5}$ emission Standard	-31%	-29%	-37%	-33%
	Others				
ALT16	Vacuum cleaning of road	-2%	-6%	-5%	-13%
ALT17	Wall to wall paving	-2%	-6%	-5%	-13%
ALT18	Zero emissions from refuse in 2025 and 2030 compared to BAU	-4%	-3%	-4%	-3%

ALT3 was estimated to have higher PM_{10} and $PM_{2.5}$ emission reduction potential compared to all alterative scenarios in the residential sector (ALT-1 and ALT-2). ALT-4 was estimated to have better emissions reduction potential for both PM_{10} and $PM_{2.5}$ during post-monsoon and summer seasons. Electrification of 2-W, cars, and autos

(ALT-6) is likely to result in maximum reduction of 5% 2030 winter in $PM_{2.5}$ concentrations in Ludhiana city. This study has estimated that the ambient $PM_{2.5}$ and PM_{10} concentrations of the Ludhiana city can be reduced by 37% and 33% respectively during 2030 compared to the BAU scenario under ALT15. By applying all the alternate scenarios, there may be a reduction of 73% and 77% in the ambient $PM_{2.5}$ and PM_{10} concentrations respectively in 2030 compared to BAU in Ludhiana city and $PM_{2.5}$ and PM_{10} concentrations at several locations in Ludhiana city are expected to meet the prescribed standards in all seasons. The study has outlined the role of different central, state, and city agencies to reduce the ambient concentrations of particulate matter according to the alternate scenarios in Ludhiana city.

Based on the assessment of PM sources and their future growth potentials, the broad interventions which can be identified for PM pollution control should be focused on industries, transport, road dust and biomass burning sectors. These recommendations are classified into short term, medium, and long term. It was estimated that by adopting short term measures (like vacuum cleaning of roads, full ban on refuse burning, introduction of congestion pricing scheme for transport sector, banning of pre BS IV vehicles entering the city, introducing odd-even scheme during high pollution episodes, and ensuring 24 X 7 power supply to stop the use of DG sets) the $PM_{2.5}$ and PM_{10} concentrations in Ludhiana city may be reduced by 15% and 23% respectively. The desired improvement in ambient air quality at six locations as well as at the city level will lead to both health and ecological benefits. However, the recommended measures to improve air quality in Ludhiana city will not yield anticipated results, if the adjoining cities and states do not adopt measures to tackle the air pollution problems faced by them as pollution sources are not limited to the administrative boundary of Ludhiana city.