Comprehensive Clean Air Action Plan for Muzaffarpur

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Executive Summary

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, launched the National Clean Air Programme (NCAP), which proposes strategies to reduce air pollution. The NCAP identifies 122 non-attainment Indian cities [cities that violate the National Ambient Air Quality Standards (NAAQS)]. Muzaffarpur is one of the 20 most polluted cities in the world (WHO, 2019) in terms of particulate matters (PMs) and has also been identified as one of the non-attainment cities under NCAP. In this context, a clean air action plan was prepared under which an emission inventory was developed for Muzaffarpur. Muzaffarpur Clean Air Action Plan (MCAAP) identified source-specific Control Measures (CMs) and performed a Techno-Economic Assessment (TEA) of the CMs. This helped to identify technically and economically feasible solutions/technologies to reduce pollution levels in Muzaffarpur. Moreover, several focused group discussions with various stakeholders were also conducted to understand the pollution landscape in the city. Workshops were conducted as a part of the study, to discuss and validate the findings.

The emission inventory was developed to estimate the total emission load from various polluting sources in the city. The research team conducted dispersion modelling using the emission inventory, which was projected for the year 2030 using various scenarios. Surveys were conducted to collect data and substantiate the emission load.

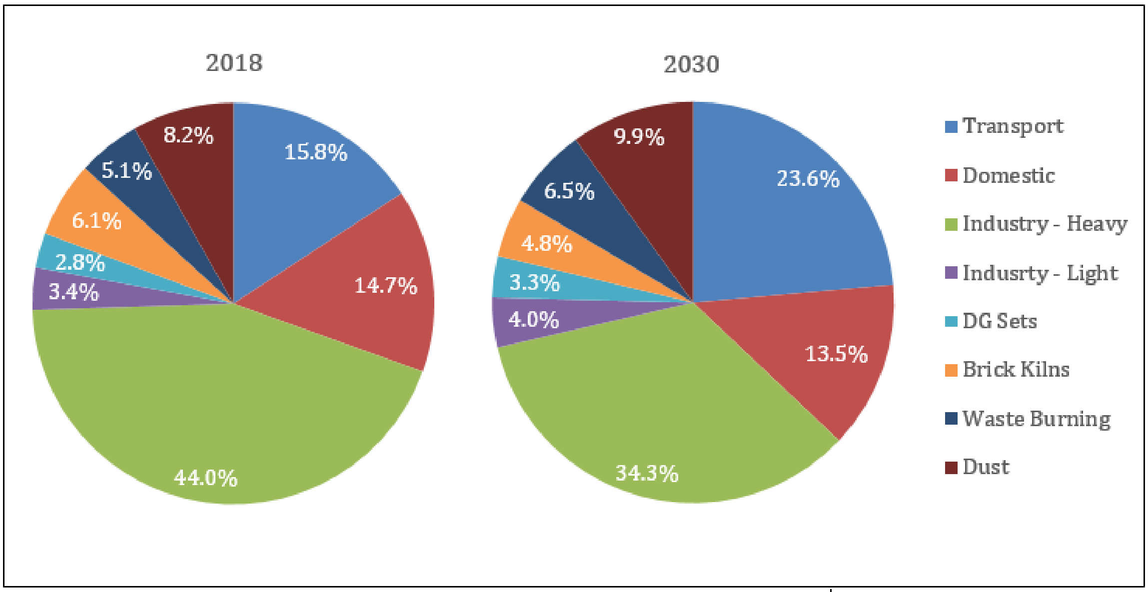

Figure 1: PM 2.5 Emission share 2018 vs 2030 (BAU)

Under business-as-usual (BAU) scenario, it was estimated that the total PM2.5 emission load for the year 2018 is around 27,000 tonnes/year and for the year 2030 it is estimated to reach around 34,000 tonnes/year. Figure 1 presents the sectoral share of emission in the air shed region (30km X 30 km) under the BAU scenario. The air-shed region is beyond the city boundaries. In the air-shed region, heavy industries (including power plants) and the transportation sector were found to be the most polluting sectors, contributing 34% and 24% respectively, to the total PM2.5 emission load in 2030. The concentration levels of PM2.5 is estimated to reach from 88.5 μg/m3 in 2018 to 120.8 μg/m3 in 2030. The estimated mortality, due to air pollution, in the BAU scenario would touch 650/year in 2030 from 350/year in 2018.

To identify source-specific CMs, pollution determinants for various sectors such as transportation, domestic, industry, open waste burning, DG sets, construction, and road dust were identified. Existing policies, alongside these determinants, were also considered while developing CMs.

Transportation:

PM2.5 emissions from the transportation sector is estimated to increase by 92% by 2030 from the baseline emissions (2018). Increasing the mode share of public transportation, promoting the use of EV/CNG vehicles, strict enforcement of PUC norms, incentivising the installation of Diesel Particulate Filter (DPF) are few of the measures that would help improve the existing transportation scenario and reduce pollution levels in Muzaffarpur.

Industries:

The Bihar government has mandated the brick industry to adopt cleaner technologies such as zigzag, as fixed chimney kiln (FCK) is a major contributor to pollution. Effective implementation of the zigzag technology would help reduce the emission load from brick kilns by 40%. Even though the share of emission load in the air-shed region, from heavy industries is above 30% during 2018 and 2030, its influence on the pollution concentration levels in the city is low as these industries are located outside the city.

Solid-waste management:

By ensuring effective waste collection and disposal strategies, 90% of the emissions from open waste burning could be reduced. Muzaffarpur is estimated to generate around 290 tonnes per day (TPD) of solid waste by 2030. The city would need an additional 110 TPD of composting plants and 30 TPD dry-waste collection centres for proper waste management by 2030. The Muzaffarpur municipality would require at least INR 25 crore (capital cost) to install these plants.

Domestic:

The domestic sector contributed to around 15% of the total PM2.5 emission load in 2018. Incentivising the use of induction stoves/smokeless *chulahs* and increasing the penetration rate of LPG cylinders would help reduce emissions from the domestic sector. The government would have to invest around INR 1.75 crore in the form of incentives to increase the LPG penetration rate. The government would also need to incur around INR 6 crore as incentives to increase the refuelling rate of the LPG cylinders.

Capacity building:

To further strengthen the existing monitoring infrastructure in Muzaffarpur, the state government should consider installing additional Continuous Ambient Air Quality Monitoring (CAAQM) stations for the effective measurement and monitoring of pollution levels. This could help identify pollution hotspots and prepare appropriate strategies accordingly.

Scenario analysis:

Three scenarios were created based on the CMs and their emission-reduction potential. These scenarios had varying levels of compliance vis-à-vis the suggested CMs. These scenarios focussed on high (scenario 1), medium (scenario 2), and low (scenario 3) emission-reduction potential of CMs. The reduction in mortality rates for the different pollution-reduction scenarios were estimated on the basis of PM reduction between 2018 and 2030.

The study estimated that under high-, medium-, and low emission-reduction scenarios, the PM2.5 emission level can be reduced by 37%, 28%, and 19% respectively, with reference to the BAU scenario for 2030, as described in Figure 2. Under the high emission-reduction scenario, the city would save at least 800 lives by 2030.

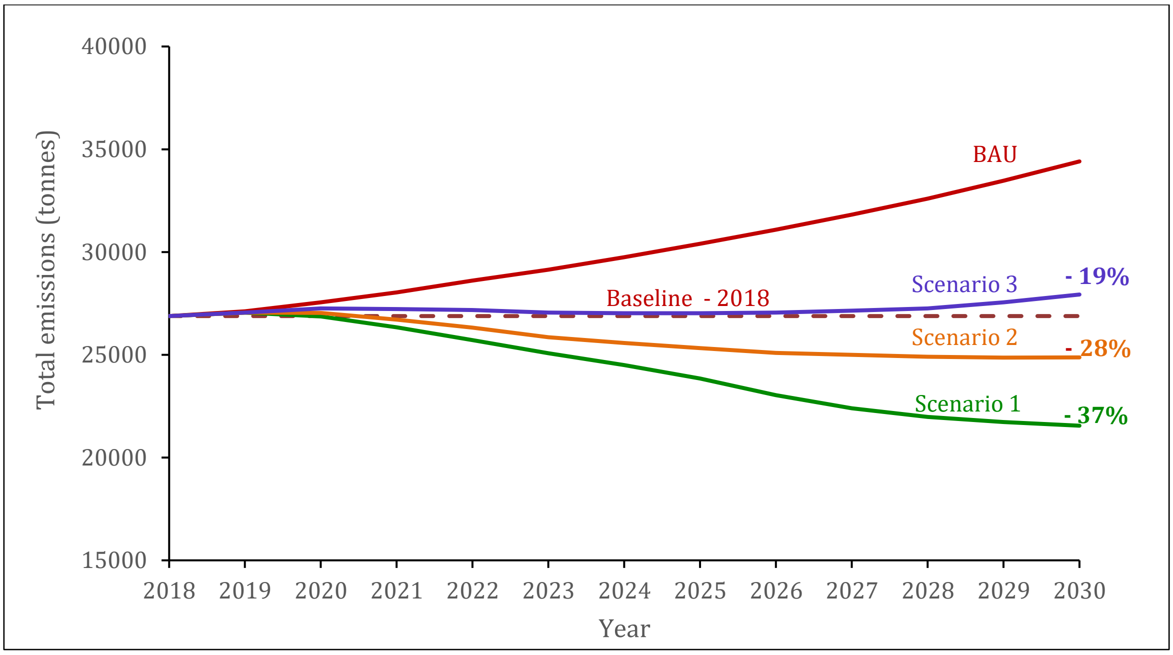

Figure 2: Scenarios— A comparison on emission reduction potential

Based on the study conducted by the consortium partners, the Bihar State Pollution Control Board (BSPCB) suggests that the state government and concerned line departments should implement the following CMs, which would result in maximum pollution reduction:

- Improve the public transportation infrastructure
- Promote advanced technologies in industries/brick kilns
- Decrease the use of solid fuel either by increasing the use of LPGs or promoting the use of smokeless *chulahs*/induction stoves

It is necessary for the government to work closely with citizen groups to sensitise them about the effects of air pollution. Existing policies like traffic regulations, construction-and-demolition waste management rules, and construction of road pavements are a few of the measures that could be implemented with immediate effect by the line departments.

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Abbreviations

AAQ	Ambient Air Quality
AQI	Air Quality Index
As	Arsenic
BaP	Benzo(a)Pyrene
BAU	Business as Usual
BC	Black Carbon
BSPCB	Bihar State Pollution Control Board
BSRTC	Bihar State Road Transport Corporation
C_6H_6	Benzene
CAAP	Clean Air Action Plan
CBA	Cost Benefit Analysis
CM	Control Measure
CMVA	Central Motor Vehicles Act
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CPCB	Central Pollution Control Board
CRF	Concentration Response Function
D.O.T	Department of Transport
DALYs	Disability Adjusted Life-years
DG Sets	Diesel Generator
DPF	Diesel Particulate Filter
DRF	Dose Response Function
EI	Emission Inventory
ER	Excess Risk
EV	Electric Vehicle
FAME	The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FCK	Fixed Chimney Kiln
GBD	Global Burden of Disease
GDP	Gross Domestic Product
HHK	Hybrid Hoffman Kiln
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
LPG	Liquid Petroleum Gas
LULC	Land Use and Land Cover
MLH	Mixing Layer Height
M-CAAP	Muzaffarpur Clean Air Action Plan
MMC	Muzaffarpur Municipal Corporation
MoEFCC	Ministry of Environment, Forest and Climate Change
MoRTH	Ministry of Road Transport and Highways
MSME	Ministry of Micro, Small and Medium Enterprises
N_2O	Nitrous Oxide
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality Monitoring Programme
NCAP	National Clean Air Programme
NGT	National Green Tribunal

NH_3	Ammonia
Ni	Nickel
NMVOCs	Non-Methane Volatile Organic Compounds
NO_2	Nitrogen Dioxide
O&M	Operation & Maintenance
O_3	Ozone
OC	Organic Carbon
Pb	Lead
PM	Particulate Matter
PMUY	Pradhan Mantri Ujjwala Yojana
PUC	Pollution Under Control
PV	Photovoltaic
RSPM	Respirable Suspended Particulate Matter
SBPDCL	South Bihar Power Distribution Company Limited
SIAM	Society of Indian Automobile Manufactures
SO_2	Sulphur Dioxide
SPCB	State Pollution Control Board
SWM	Solid Waste Management
TCO	Total Cost of Ownership
TEA	Techno-Economic Assessment
TPD	Tonnes Per Day
VOC	Volatile Organic Compounds
VSBK	Vertical Shaft Brick Kiln
WHO	World Health Organisation

1. Muzaffarpur: Current Pollution Landscape

India is a developing country with a very high rate of industrialisation and urbanisation. These are the key drivers of air pollution. Air quality of Bihar state follows a similar trend as other metropolitan cities in India (WHO, 2019). After Patna, Muzaffarpur has emerged as a rapidly developing city in Bihar in recent years, in terms of economic growth. As per a WHO report, 10 of the world's 20 most polluted cities are Indian cities, based on Particulate Matters (PM) (WHO, 2019). Muzaffarpur is one amongst the 10 cities. The major sources contributing to the deteriorating air quality of Muzaffarpur city are transportation, road dust re-suspension, construction, and biomass burning (BSPCB, 2019). In this context, a Clean Air Action Plan (CAAP)—backed by research-based evidence—is required to precisely determine the air pollution levels, identify the sources, and thus, help formulate policies towards air pollution mitigation.

1.1 Overview

Muzaffarpur city is situated in north of Bihar at 26º7"21' N, 85º23"26' E. The population of Muzaffarpur was 354,462, with decadal growth rate of 34.9% for 2001-2011 (Census, 2011). The area of the Muzaffarpur city is 93 sq. km. Muzaffarpur is centrally located surrounded by Sitamarhi in North, Darbhaga in East, Samastipur in South-East, Vaishali in South, Saran in West and Purvi Champaran in North-West. Figure 3 presents the land use land cover map of Muzaffarpur.

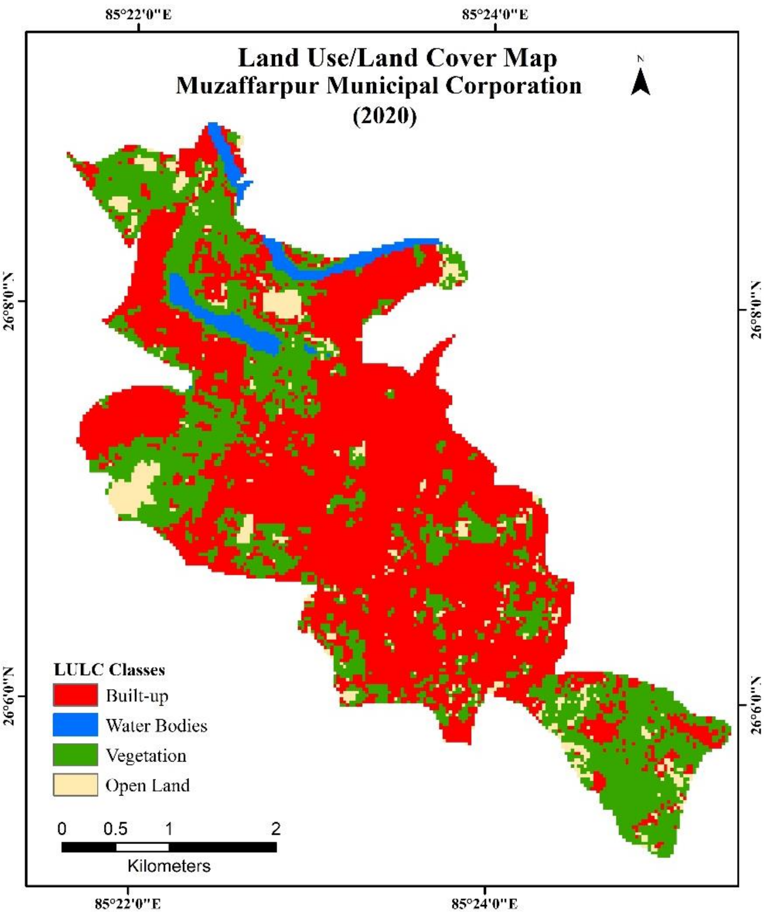

Figure 3: Land use and land cover of Muzaffarpur

According to Census (2011), literacy rate of the Muzaffarpur city was 82.9% and sex ratio was 888 (Census, 2011). The child (0-6 years) population was 12.5% of the total population and the child sex ratio was 894 (Census, 2011). The total number of slums in the city was 9,256 wherein a population of 50,967 resides, constituted 14.4% of total population of Muzaffarpur city.

The climate of the district of Muzaffarpur is usually humid except for summer which is generally dry. The winter season ranges from November to February and summer season ranges from March to May. The monsoon extends from June to September where October acts as transitional month. The coldest month of the year is usually January when temperature sometimes drops to 4-5 °C. Dust storms and westerly wind are common phenomenon in hot weather during early April. The hottest month is usually observed in May when the temperature may rise to 44°C. The monsoon usually begins after the second half of the June and persist till September. After the monsoon, temperature falls and climate becomes favorable. The district also experiences some rains during winter season (IIM-Lucknow, 2019).

1.2 Air quality levels and its comparison to national standards

The chief factor of deteriorating level of air quality in Muzaffarpur city is the PM in the atmosphere. Figure 4 depicts that PM2.5 is significantly higher than the National Ambient Air Quality Standard (NAAQS), whereas levels of CO, O_3, SO_2, and Benzene remain fairly below NAAQS. However, NO_2 levels are almost touching the NAAQS (CPCB, 2019) due to heavy inflow of traffic. Since Muzaffarpur is an old and unplanned city, traffic congestion is a common sight, generally caused by the higher vehicular burden.

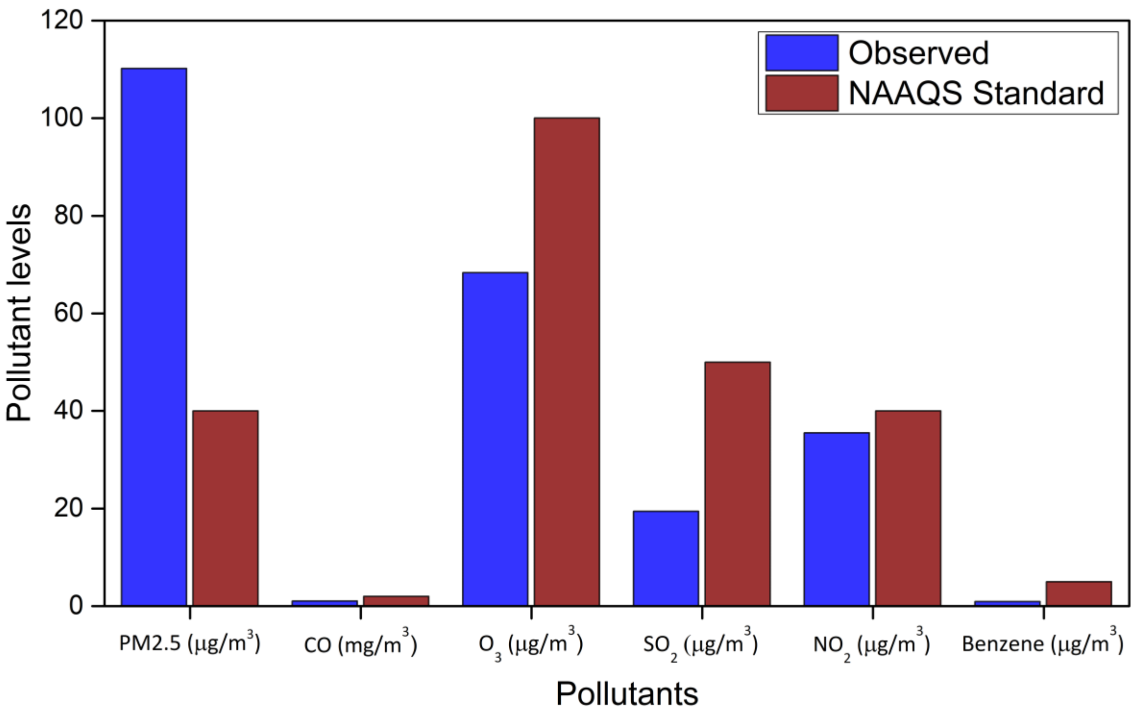

Figure 4: Pollutant levels in Muzaffarpur: observed (2019) vs NAAQS

Source: CPCB, 2019

1.3 Impact on public health, environment and economy:

Air pollutants, including PM, can induce health issues among people (The Global Burden of Disease, 2010) of any region. This holds true for Muzaffarpur city as well. A significant increase in the number of patients suffering from acute respiratory health diseases in last three years has been observed (IDSP, 2018). In 2018, the total number of patients of acute respiratory diseases, registered in government hospitals, was 19,076 (IDSP, 2018). PM can trigger a number of pulmonary and respiratory ailments. Outdoor air pollution has been commonly linked with chronic obstructive pulmonary diseases, respiratory diseases, cerebrovascular diseases, ischemic heart diseases, and cancers of trachea, bronchitis, and lung (The Global Burden of Disease, 2010). However, there is a dearth of research evidence to establish relationship between air pollution and public health for any region including Muzaffarpur.

Additionally, air pollution has a severe effect on the environment as well. Acid rain, eutrophication, haze, ozone depletion, crop and forest damage, global climate change, and impact on wild life are some of the major impacts air pollution can have on the environment (Department of Environmental Protection, 2016). Since air pollution has been linked with crop damage, it also has a significant impact on agricultural productivity. According to a study, a loss in yield of around 100,000 tonnes of wheat and 30,000 tonnes of rice have been observed in Bihar due to NOx, VOCs and other pollutants (Beig, 2014).

Besides the impact on human health and environment, air pollution also has the potential to slow down the economy of a country. The Global Burden of Disease (2016) has reported that more than one million premature deaths were caused by outdoor air pollution in India in 2016. The cost of premature death accounted for USD 800 billion in India in 2016 (OECD Insights, 2017 and OECD, 2017). Air pollution also increases the cost incurred on the economy due to increased number of lost work days and falling labour productivity. In addition, loss in agricultural yield may also trigger increased cost to the economy. According to projection of OECD Insights (2017), the estimated market cost due to air pollution on Indian economy would increase by USD 280 billion by 2060 (based on purchasing power parities exchange rates in 2005). The number of premature deaths per million population due to air pollution has increased from 814 in 2000 to 832 in 2015 in India (OECD, 2017). As the number of premature deaths and cost per death is projected to increase significantly, the social cost for the deaths due to air pollution would also increase by 15 to 33 times by 2060 (OECD Insights, 2017).

1.4 Need for developing a city-specific clean air action plan

Sectorial control measures need to be formulated for better understanding of their contribution to city's pollution. Furthermore, these control measures need to be implemented by the district administration of Muzaffarpur under the guidance of the Bihar State Pollution Control Board (BSPCB). Hence, well-designed, evidence-based research study is required to generate synchronised data and take measures. Continuous air quality monitoring, development of a baseline emissions inventory and techno-economic assessment would be able to provide evidence-based strategic planning, and help design implementation strategies to mitigate air pollution. In this regard, the Ministry of Environment, Forest and Climate Change (MoEFCC) has launched National Clean Air Programme (NCAP) under whose purview, 122 non-attainment cities of India, including Muzaffarpur, are included. The city-specific CAAP for Muzaffarpur is one giant leap towards achieving NCAP goals.

1.5 Scope of the study

The main objective of this study is to develop a comprehensive clean air action plan for the city of Muzaffarpur to tackle the challenge of increasing air pollution. BSPCB will adopt the suggested strategic plans of the study, based on the findings. The study is primarily aimed at identifying the sources of air pollution in Muzaffarpur and preparing a comprehensive list of control measures (CMs). CMs and policy recommendations will be designed considering the inputs from the district administration of Muzaffarpur and the line departments.

2. Air Pollution Scenario

2.1 Existing policies/interventions in Bihar

The existing set of policies and interventions, which are guided by national compliances and regional-level impositions, have been stated below:

- *National Air Quality Monitoring Programme (NAMP):* The government is executing a nation-wide air quality monitoring platform known as the National Air Quality Monitoring Programme (NAMP). In this regard, CPCB has set online air quality monitoring systems at the Muzaffarpur district administration office[1].

- BSPCB has instructed all brick kiln owners in Bihar to adopt cleaner technologies. In this regard, BSPCB issued the closure of 46 brick kilns in Muzaffarpur and Gaya, which had been violating the environmental protection regulations (BSPCB, 2018)[2]. Additionally, a task force was constituted to monitor brick kilns' adoption of zig-zag and cleaner technologies[3].

- *Central Motor Vehicles Act (CMVA):* As per the CMVA, electric rickshaws have been permitted to ply in Muzaffarpur city, in a bid to curb air pollution. An e-vehicle policy for Bihar is in the developmental phase. Such a policy could facilitate, promote, and enable an increase in e-rickshaws in Bihar, including Muzaffarpur[4].

- Muzaffarpur Municipal Corporation (MMC) has attempted to reduce the biomass and waste burning in the city through notifications. Moreover, the MMC has been spreading awareness against biomass burning. It has also issued penalties to the people burning biomass and waste[5].

- MMC has taken stringent actions towards proper solid waste collection, segregation, and disposal/treatment. It has also set up incineration plants to manage the solid waste load of the city[2].

- District Administration, Muzaffarpur, has decided to impose a ban on diesel vehicles older than 15 years, through stringent PUC and fitness checks[2].

The government of Bihar and the district administration of Muzaffarpur are making efforts to combat the city's air pollution. However, more effective and prudent actions must be undertaken by all stakeholders, including the city's inhabitants to achieve better air quality.

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[1] National Clean Air Program (NCAP) – India, Ministry of Environment, Energy and Climate Change, New Delhi. http://www.indiaenvironmentportal.org.in/files/file/NCAP.pdf

[2] Magic bricks, BSPCB issues closure notice to over 50 brick kilns in Muzaffarpur and Gaya. https://content.magicbricks.com/property-news/other-cities/bspcb-issues-closure-notices-to-over-50-brick-kilns-in-muzaffarpur-gaya/110329.html

[3] BSPCB, Notice regarding brick-kilns. http://www.bspcb.bih.nic.in/int_5.12.19.pdf

[4] The Motor Vehicles (amendment) Bill, 2015, bill no. 37 of 2015. http://www.lamp.prsindia.org/sites/default/files/bill_files/Motor_Vehicles_%28A%29%2C_2015_0.pdf

[5] Information provided by the Muzaffarpur Municipal Corporation during the meeting on 'Comprehensive Clean Air Action Plan for Muzaffarpur'.

2.2 Pollution landscape in the country

The major pollutants considered for any emission inventory in a city are PM2.5, PM10, Black Carbon (BC), Organic Carbon (OC), NOx, CO, VOCs, SO_2, and CO_2 (Guttikunda et al., 2014). The major sources of emissions are transport, domestic, open waste burning, on-road dust, industries, brick kilns, DG sets, and outside contribution[6]. Transportation is considered to be a major source of emission, containing Particulate Matter, NOx, SOx, Volatile Organic Carbons (VOCs), and other hydrocarbons. The construction of buildings and roads can produce significant amounts of PM10 and NO_2 during land clearing, operation of diesel engines, demolition, burning, and while working with toxic materials. In addition, industrial emissions also significantly contribute to regional air pollution. Since Muzaffarpur city is one of the developing cities in Bihar, developmental processes such as urbanisation, industrialisation, construction, transportation, and other anthropogenic activities have increased. This contributes significantly to the city's overall pollution profile.

Moreover, global contributions of sources (51 countries including India) have been studied by Karagulian et al. (2015). Source contribution of PM2.5 for India in comparison with global scenario has been represented in Figure 5. Emissions from traffic contribute up to 37% in India, which is higher than the contribution from traffic in other countries (25%). Natural sources such as dust and sea salt also have a higher contribution in India (21%) compared to other countries (18%). However, domestic fuel-burning contributes as much as 16% in India, which is lower than other countries. Industries contribute only 4% of the total pollution load in India, which is significantly lower than contribution from industries (15%) in other countries.

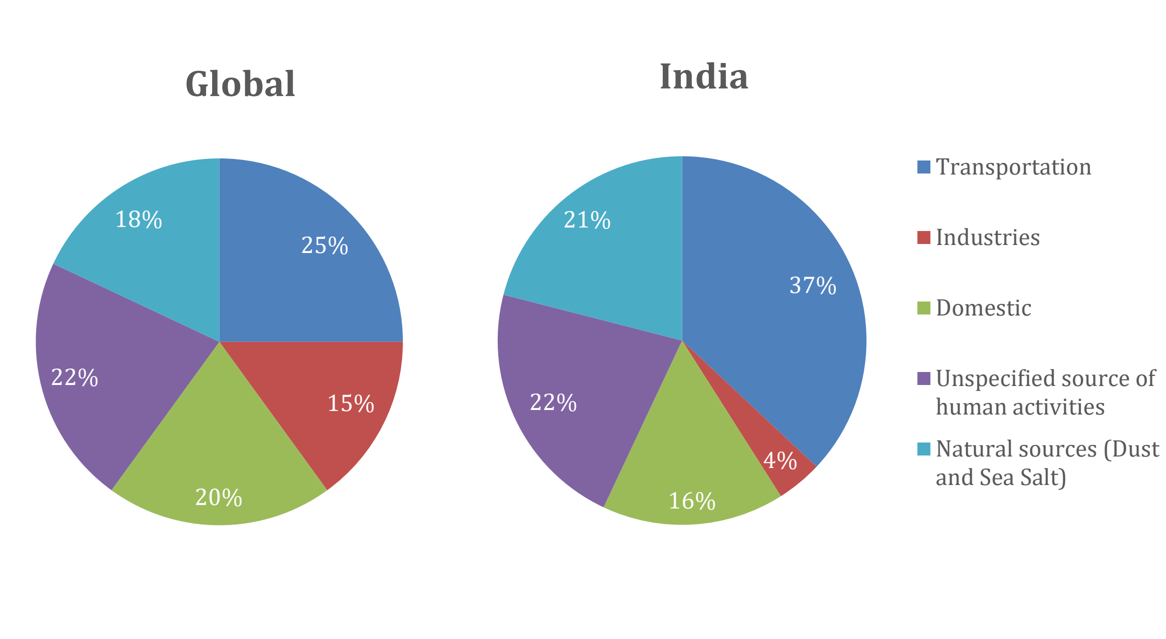


Figure 5: Source contribution of PM2.5 emissions

Source: (Karagulian et al., 2015)

[6] Outside contribution – Emissions from outside the air shed region. This represents most of the non-urban activities outside the city limits, mostly dominated by cooking and heating (in the absence of any big industries).

2.3 Emission Inventory

An emission inventory (EI) accounts for the total emission load from various polluting sources in a given geographical area, within a particular time frame. An EI helps identify the most polluting sources in a city/state/region. It is also used to estimate and project future emissions for various pollution control/reduction scenarios (ACAP, 2017).

There is very limited information that can be accessed to conduct EI studies in Indian cities. Guttikunda et al. (2019) details the model for conducting such studies in various cities of India and the resources accessed for various sectors. There are studies (such as Guttikunda et al., 2014) that discuss the uncertainties, gaps, and pathways for various sectors.

2.3.1 Methodology

EI for Muzaffarpur city was developed for the airshed area (Figure 6) of 30 km X 30 km for the year 2018.

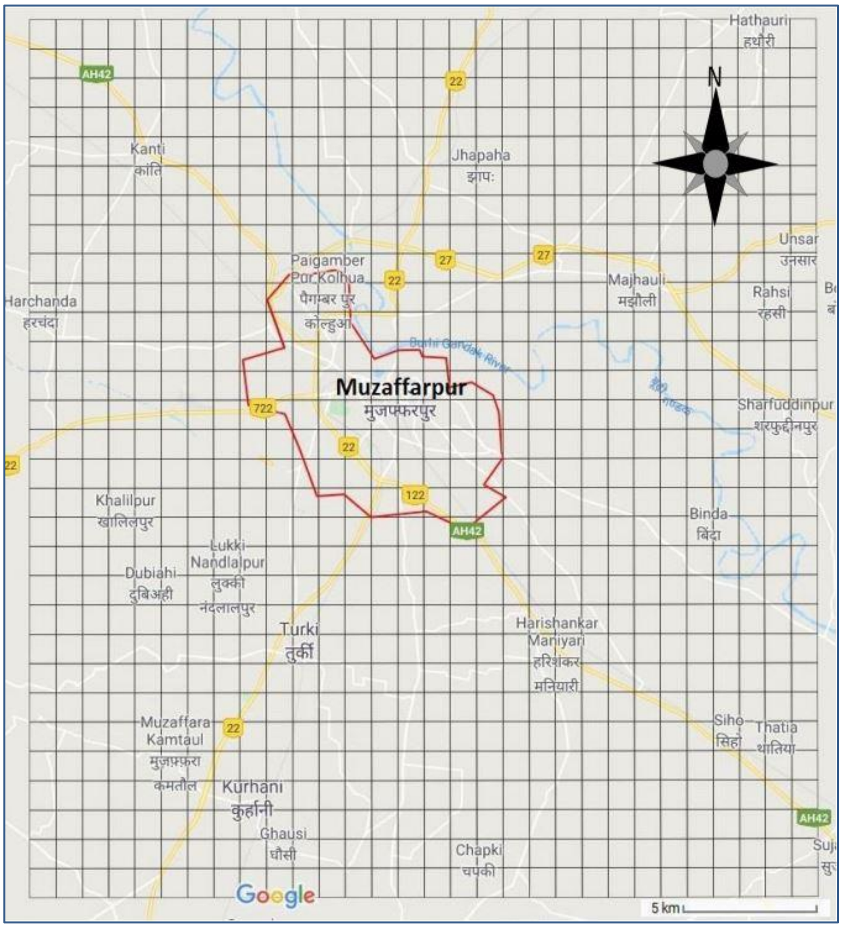


Figure 6: Air shed area - Muzaffarpur

Although an inventory of NH_3 emissions was not prepared, NH_3 emission data was extracted from the Task Force on Hemispheric Transport of Air Pollution (TF HTAP) (http://www.htap.org/), 2012, and the data was used after linear extrapolation. The EI was developed to estimate emissions from the transport sector, domestic and commercial cooking, space heating, diesel generator (DG) sets, solid waste burning, industries, aviation, and dust from different activities (construction and road). The developed EI was also projected for the year 2030 under the business-as-usual (BAU[7]) scenario.

The EI was prepared by considering the various activities (A) in a sector that contribute to the total pollution load in a city/state/region. Activities (A), when multiplied by the respective Emission Factors (EF), provide an estimate of the emission load of any particular activity. This emission load is distributed in a 1 km X 1 km unit of area in Muzaffarpur. The sector-specific methodology for estimating the emission has been provided in the following sections. The model details and the architecture are detailed in Guttikunda et al., 2019.

EI looks at pollutants at the source and does not include the remote effects of pollutants or the effects of meteorology on pollutant concentration. Dispersion modelling has been used to address this gap.

i) Emission from transportation:

For the *transportation sector*, the ASIF (Schipper et al., 2000) principles were used to estimate the emissions.

$$E_T = A * S_i * I_i * F_{ij} \quad \textbf{(2.3.1.1)}$$

Where,
E_T - Emissions from transportation
A - Total travel activity
S_i - Vector of modal share[8]
I_i - Energy intensity of each mode (i)
F_{ij} - Sum of each fuel (j) in mode (i); the emission factors[9] mentioned below are used to convert fuel used into emissions.

The method mentioned above have been applied for all modes of transportation. The vehicle exhaust emissions factors are adjusted by vehicle type, deterioration of vehicle engine with age (corroborated with the PUC data from the city), fuel type, and local congestion levels. A database of average emissions factors for fleets is available in Goel and Guttikunda (2015) and can also be accessed at http://www.urbanemissions.info/publications.

The emission estimated from the transportation sector is adjusted for traffic congestion. The methodology for estimating the congestion rates in the city is based on the extracts from google maps direction application programming interface (API).

To substantiate the methodology, a transportation survey was conducted at various petrol pumps in Muzaffarpur in 2019, which helped us understand the vehicle characteristics (mode share, age, and fuel use). Evaporative emissions present at the fuel stations add to the VOC totals. Fuel sales information was also gathered as a part of this exercise.

According to the data provided by the Bihar government's transport department, the in-use vehicular population in Muzaffarpur district is around 740,059, as of 2018. Of the total

[7] It is assumed that there are no serious interventions by the government to control emissions
[8] Modal Share – Percentage of travellers using a particular mode of transportation.
[9] Emission Factor – Mass emitted for vehicle km travelled

registered fleet, two-wheelers (78%) and passenger four-wheelers (5%) are the dominant ones. When projecting emissions for future years, the vehicle growth rate was assumed from the national road transport emission study, based on the sales projection numbers from SIAM, New Delhi, India.

ii) Emissions from industry:

Primary information pertaining to industries were extracted from the annual survey of industries, while the information on industries' emissions was estimated based on fuel consumption (Ministry of Statistics and Program Implementation[10]). This has been corroborated with the information provided by line departments.

Google Earth imagery for every grid in the air shed area was used as a reference to locate the industries. Besides the traditional manufacturing industries, there are brick kiln clusters around the city. Brick manufacturing includes a) land clearing[11] for sand and clay, b) combustion of fuel for baking bricks, c) the operation of diesel engines on site, and d) transport of the end product to various parts of the city. It was found that the brick manufacturers use conventional technology - fixed chimney kiln (FCK).

iii) Emissions from waste burning:

Garbage burning in residential areas emits a substantial amount of pollutants and toxins (Guttikunda and Jawahar, 2014). Waste burning is the most challenging source and also the most uncertain for estimating the emission load. Despite government authorities having banned solid-waste burning, citizens continue to violate the regulation. Muzaffarpur metropolitan area produces an estimated 184 tonnes of solid waste per day. The amount of emission from waste burning is estimated using the equation (2.3.1.2) below.

$$E_{WB} = W_b * F \qquad \textbf{(2.3.1.2)}$$

Where,
E_{WB} - Emissions from waste burning
W_b - Quantity of waste burnt (Estimated after adjusting the total amount of waste processed)
F - Emission factor

iv) Emissions from domestic sector:

Domestic-sector emissions are based on fuel consumption (coal, wood, kerosene, and LPG) estimates for cooking, heating, and lighting. Grid-level fuel usage in households was estimated based on census statistics[12]. Apart from LPG, fuels such as coal, biomass, and agricultural waste are used in slum areas, restaurants, and areas outside the municipal boundary. Gridded population data was obtained from the "Gridded Population of the World and Global Rural and Urban Mapping Project (GRUMP)" (2010)[13]. It is assumed that while high-density areas (highly

[10] Ministry of Statistics and Programme Implementation, Government of India, at http://mospi.nic.in/Mospi_new/site/India_statistics.aspx?status=1&menu_id=43
[11] Land Clearing - The process of removing trees, stumps, brush, stones and other obstacles
[12] Household energy usage in India, Database maintained by the Institute for Financial Management and Research, Chennai, India @ http://www.householdenergy.in
[13] GRUMP (2010) - Gridded Population of the World and Global Rural and Urban Mapping Project. Center for International Earth Science Information Network (CIESIN) of the Earth Institute, Columbia University, New York, USA @ http://sedac.ciesin.columbia.edu

urban areas) most likely utilise LPG, low-density areas utilise a mix of fuels. The LPG consumption rates, based on Census 2011 for domestic sector, were adjusted based on surveys (Jain et al., 2018 and Jain et al., 2015) and reports on new LPG connections provided by Bihar (MoPNG & www.data.gov.in).

v) Emission from road dust resuspension:

Vehicular movement on the road triggers resuspension of dust, which is also classified as non-exhaust PM emissions. The dust emissions are also linked to the local meteorology in the chemical transport model, to suppress any overestimation of resuspension during the rains. The resuspension of dust is dependent on the weight of the vehicle, silt load[14], road surface type, and average rainfall. Data from geographic information systems (GIS) helped us understand and identify the types of road (paved/unpaved) in Muzaffarpur.

vi) Emissions from power sector:

A thermal power plant is located in the air shed area of Muzaffarpur city. Most of the electricity needs are met by the coal and gas-fired power plants. However, mobile phone towers, hotels, hospitals, malls, markets, large institutions, apartment complexes, and cinemas supplement their electricity needs with in-situ diesel generator sets.

Since anthropogenic activities increase with an increase in population, we considered population growth rate (Census data) for estimating emissions from the domestic sector, construction activities, brick demand, diesel usage in the generator sets, and open waste burning.

Dispersion modelling:

Dispersion modelling was performed to understand the physical and chemical transformation of air pollutants over a geographical area. Advection of the pollutant refers to a kind of physical transformation that depends on the topography of the area, meteorological conditions, and the pollutant's wet and dry deposition. Area-specific meteorology plays an important role as it influences the transport and vertical mixing of pollutants. Different types of dispersion models are available, based on complexity and computational needs. Comprehensive Air Quality Model with Extensions (CAMx) dispersion model was used to simulate the air quality parameters for Muzaffarpur.

The 3D meteorological parameters from Weather Research and Forecasting (WRF), along with the estimated emissions load of each of the grid points, have been included as inputs to the model. Pollutant concentration is the model output. Concentration is the amount of pollutant matter present in a unit volume of ambient air. It is generally expressed in microgram per cubic meter ($\mu g/m^3$) or part per million (ppm). These values are also the basis for evaluating the effectiveness of existing control measures and a way of identifying the sources of possible problems for the future (Brimblecombe, 2011). The detailed model formulation and meteorological parameters considered in the study can be accessed from Guttikunda et al. (2019).

[14] Silt load – Amount of dust present per unit area on the road

2.3.2 Results

Sectors contributing to the total pollution load in the city of Muzaffarpur are transport, domestic fuel consumption, open garbage burning, road and construction dust, industries, diesel generator (DG) sets, and aviation. Emissions such as Black Carbon, NO_x, CO, SO_2, CO_2, PM2.5, PM10, and non-methane volatile organic compound (NMVOCs) were estimated for all the sectors contributing to the city's pollution (Annexure B).

The PM2.5 sectoral emission loads were estimated for 2018, based on the primary and secondary data collected for different sectors. The sectoral emission loads were also projected until 2030, based on the growth rates of different sectors.

Figure 7 presents PM2.5 emissions projected for the period between 2018 and 2030 (under the BAU scenario) from various sectors contributing to pollution in the city. The year 2018 was considered as the base year for the emission estimation. The total PM2.5 emission load for 2018 is around 27,000 tonnes/year. The transportation sector (16%) and the industry sector (47%) contribute to around 63% of the total emissions, followed by domestic heating (9%).

The total PM2.5 emission is estimated to reach around 34,000 tonnes/year in 2030 of which, the emissions from the transportation sector (24%) and industries sector (38%) are the most. Based on study estimates, PM2.5 emissions from the transportation sector will increase by 92% in 2030, from 2018 levels. The increase in emission load from the transportation sector is mainly attributed to vehicular and economic growth.

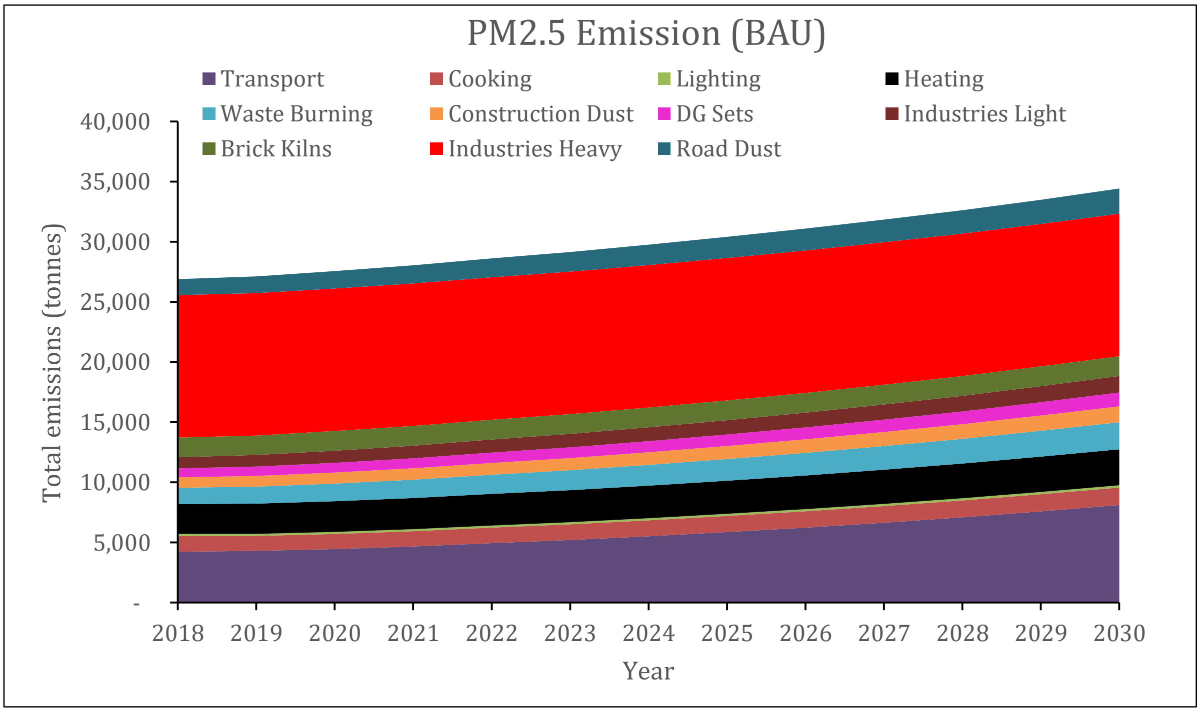


Figure 7: PM2.5 emissions (BAU)

Emission load for the city does not include remote PM2.5, the influence of weather parameters (rainfall, wind speed, atmospheric mixing height, etc.,), and generation of secondary PM due to atmospheric chemistry. In order to incorporate such factors, dispersion modelling was used to determine the concentration levels in the city.

Figure 8 presents the grid wise PM2.5 emissions for Muzaffarpur during 2018. It was observed that the majority of the pollution hotspots are located inside the city (except the grid with the power plant location and few other grids near kurhani).

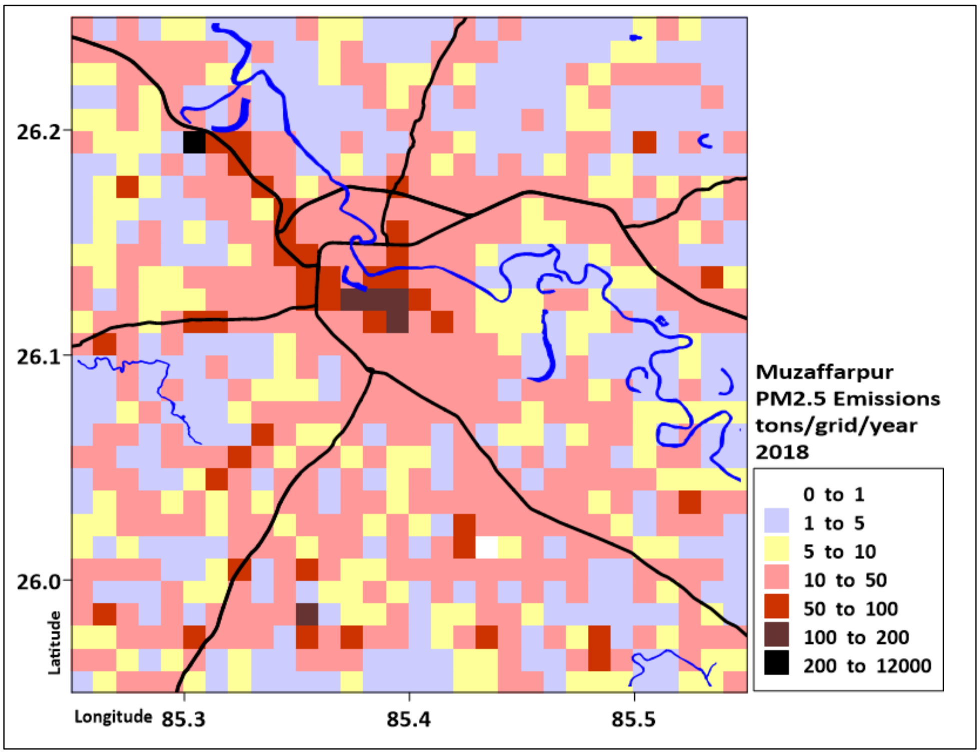


Figure 8: Grid level PM2.5 emissions – (BAU – 2018)

Figure 9, presents the estimated PM2.5 concentration share in Muzaffarpur during 2018 and 2030 for the BAU scenario. During 2018, sources from outside the boundary and transportation sector contributed around 37% and 23% towards the total concentration levels in the city. By 2030, the transportation sector's contribution to the total concentration level is estimated to be maximum at 32%.

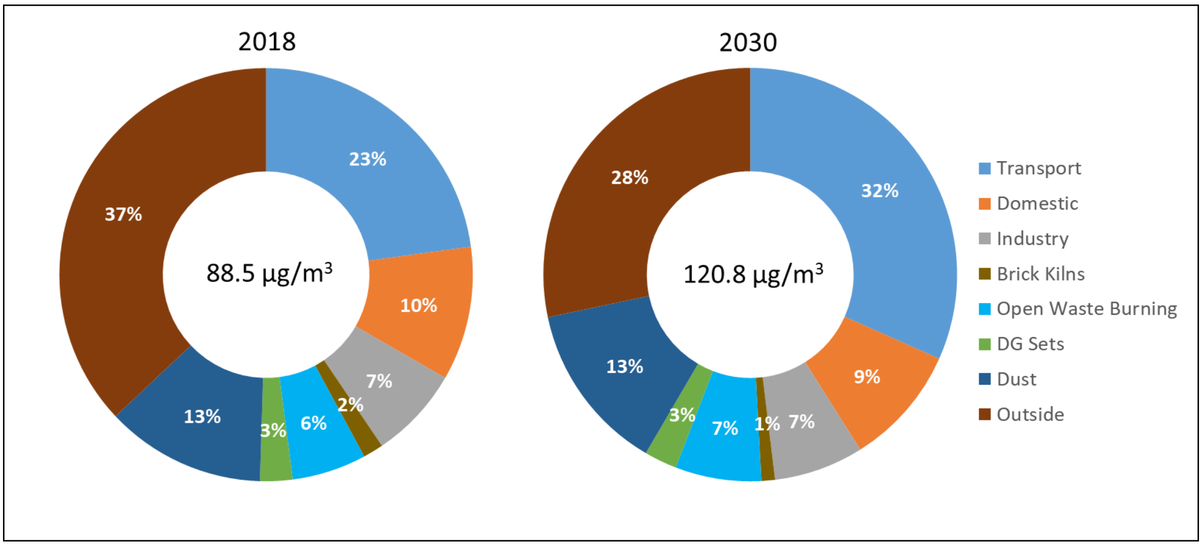
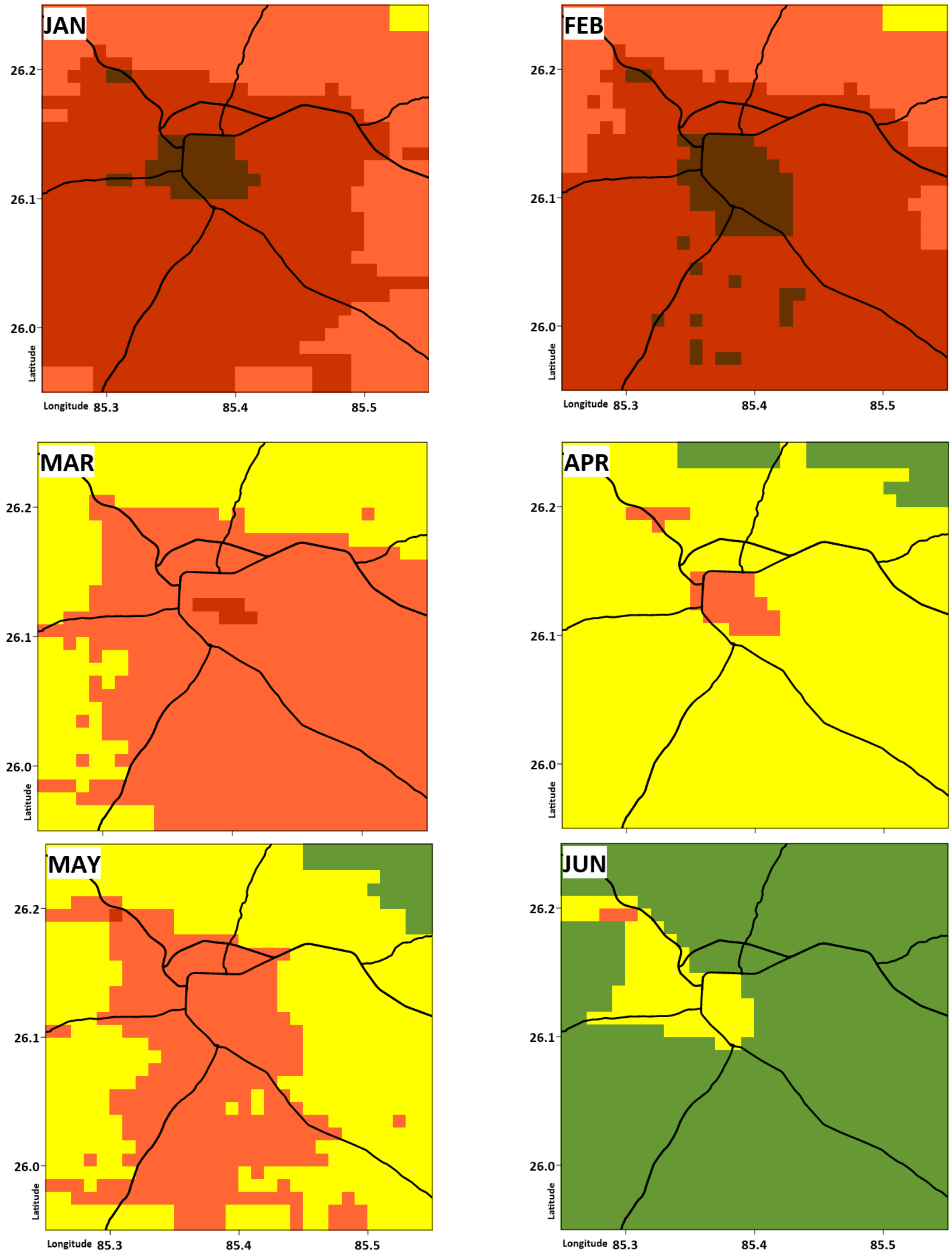


Figure 9: PM2.5 concentration share 2018 vs 2030 (BAU)

Under the BAU scenario, it appears that the transportation, domestic sectors (heating), and dust will have the maximum impact on ambient air quality levels and hence, need serious interventions in terms of policies and mitigation measures to reduce the pollution level. The PM2.5 concentration of Muzaffarpur is expected to reach 120.8 µg/m³ in 2030 from 88.5 µg/m³ in 2018.

Figure 10 presents monthly estimates of PM2.5 concentration levels in Muzaffarpur for 2018 (BAU). It is observed that the concentration levels are high (well over 100 µg/m³) during the winter months (November, December, January, and February). The months of June, July, and August are relatively clean (compared with the winter months) with concentrations in the range of 20 to 50 µg/m³ while other months (March, April, May, September, October) had concentrations ranging between 50 and 100µg/m³



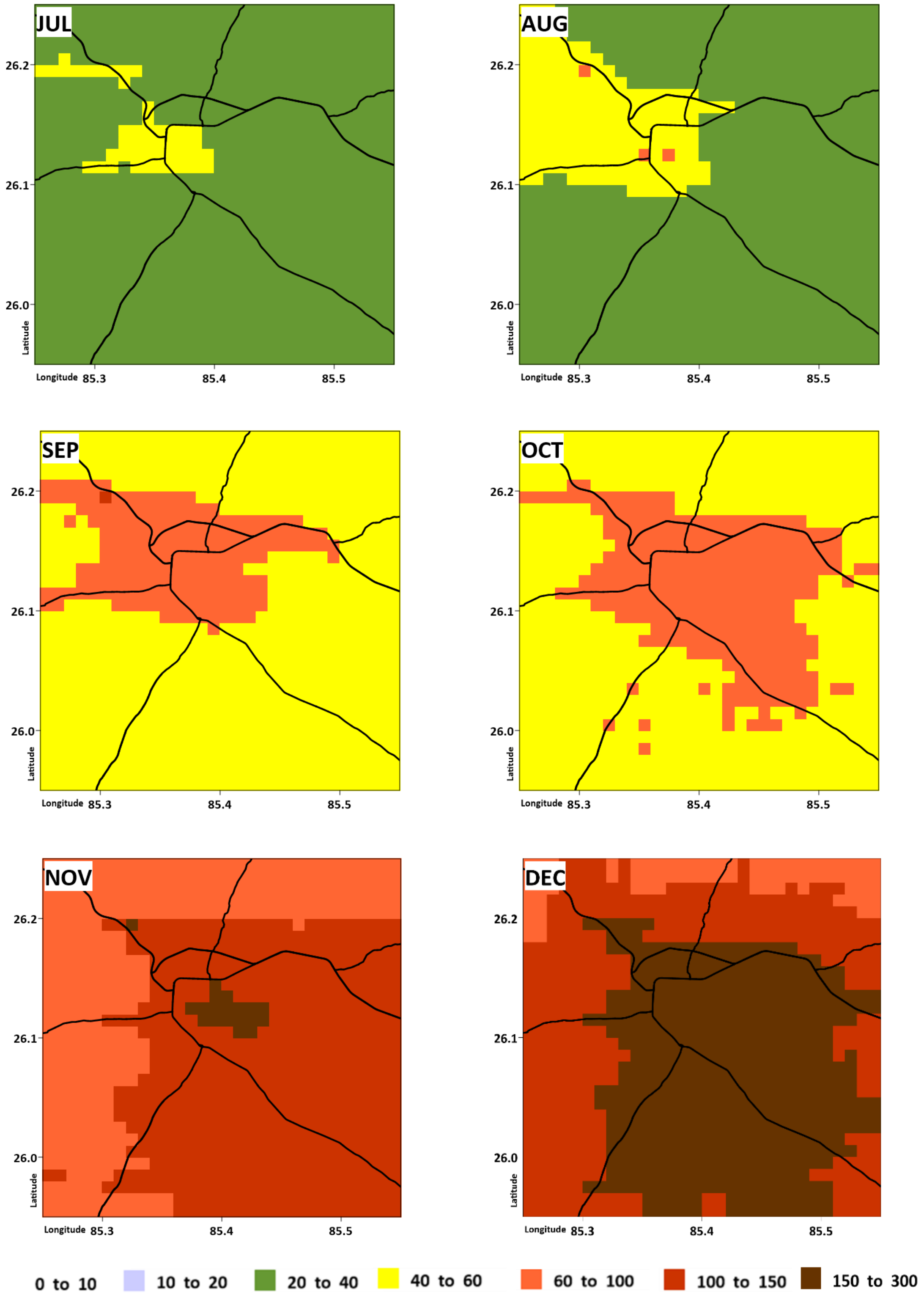


Figure 10: PM2.5 Monthly concentration levels (BAU - 2018) (μg/m³)

3. Sector-Specific Control Measures

The pollution in Muzaffarpur city is predominantly anthropogenic in nature. Tailpipe emission from the transportation sector, industrial emission (stone crushers, manufacturing, and fabrication industries), dust from construction and demolition activities, and household emission (cooking and heating) are the primary contributors to the city's pollution load. Reducing the pollution load of the city will require curbing emissions from these sectors. A list of sector-specific CMs were identified to reduce emission from the sectors.

3.1 Comprehensive list of control measures

A comprehensive list of sector-specific CMs was prepared for an effective action plan for the city. Figure 11 presents the various sector-specific determinants which were selected to identify CMs. The determinants were selected based on the existing scenario of the various sectors in the city of Muzaffarpur.

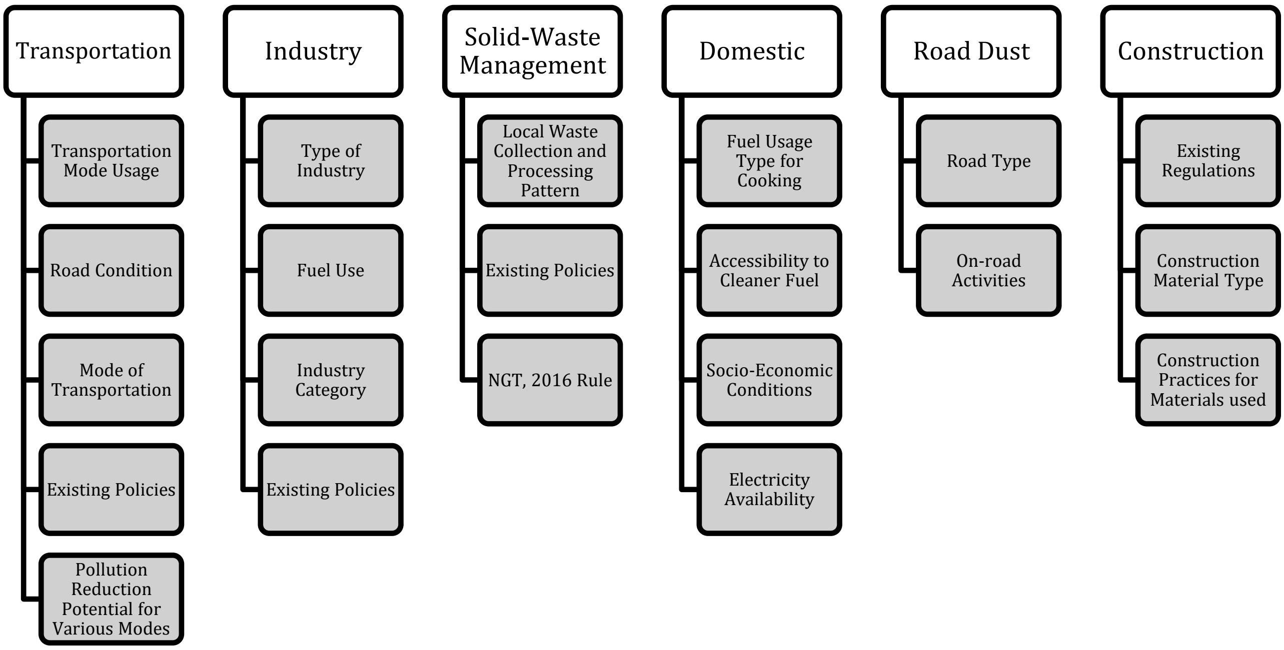


Figure 11: Determinants for source-specific CMs

Transportation Sector: To identify CMs for the transportation sector, determinants such as the existing mode of transportation (i.e., bus, car, auto-rickshaw, 2-wheeler, and non-motorised transport) and modes of transportation used by the public were considered. Moreover, factors such as road condition (road width, paved/unpaved roads) and the pollution-reduction potential of various modes of transportation were considered while determining the CMs. Existing and upcoming emission-reduction policies were also examined to identify CMs.

Industrial Sector: Various determinants were considered for suggesting the CMs, such as type of industries (brick kiln, metal fabrication, smelting, and others), fuel use (biomass, coal, CNG, and diesel), and categorisation (red, orange, green, and white). Apart from the above-mentioned determinants, the existing and upcoming policies relating to air pollution were also considered while selecting the CMs.

Solid-Waste Management (SWM): The sector is governed by various factors such as a) door-to-door waste collection/collection from local dumping place b) frequency of collection c) waste segregation and d) types and quantity of waste processing (if any)

When attempting to determine CMs for solid waste, the aforementioned factors, along with central and state policies of waste management and National Green Tribunal (NGT) rules–2016 (ban on any type of waste burning) were taken into account.

Domestic Sector: Determinants such as the fuel used for cooking/heating (LPG and wood), availability and accessibility to cleaner fuel, socio-economic conditions, and fuel for lighting purpose (because of non-availability of electricity) were taken into account for identifying CMs.

Road Dust: Determinants such as types of road (paved or unpaved), on-road activities (number and type of vehicles plying), construction activities near roads, plantation around the roads, and potholes were considered while determining the CMs.

Construction sector: Selection of the CMs was based on the existing rules and regulations determined by central and state governments to reduce pollution. The construction practices (transportation and storage of material) exercised in the city also helped in defining the CMs.

The determinants helped us identify CMs for various sectors contributing to pollution. The policies introduced by the state and central governments—such as the introduction of BS-VI vehicles and fuel (by the central government), and the introduction of increased LPG use for cooking under the Pradhan Mantri Ujjwala Yojana (PMUY)—were taken into account to determine the CMs.

It was important to understand the various line departments' capability to implement the identified CMs. For this, multiple focussed group discussions were conducted with the line departments and the necessary data was collected (Annexure D).

A comprehensive list of CMs was proposed, based on the polluting sectors and their contributions. Implementation timelines for the CMs (short-, medium-, and long-term) were also suggested based on the availability of infrastructure and the existing policy framework of the various line departments. A Benefit-Cost Ratio (BCR) of the CMs was estimated to help line departments prioritise implementation strategies. The CMs were shortlisted by BSPCB after deliberations with various line departments, based on the BCR and the implementation time.

The short-listed CMs for TEA are listed in Table 1. A detailed list of CMs adopted by BSPCB for Muzaffarpur city has been attached in Annexure A. The list of CMs mentioned in Annexure A has been sent for NGT compliance.

Table 1: Shortlisted control measures for TEA

City Name:- Muzaffarpur						
Sl. No.	**Sectors**	**Action points**	**Technology/Infrastructure Requirement (TR/IR)/ Methods (M)/ Outcome (OC)**	**BCR[15]**	**Implementation Period (Short term – 6 months, Medium term- <2 yrs. Long term – >2 yrs.)**	**Implementation Agency**
1	Transportation	Complete ban on 2-stroke autos and their replacement with EV	TR—E-rickshaws OC—Reduction of emission load from autos	High	Medium-Long	Dept. of. Transport (D.O.T)
		PUC check (every 6 months) and better PUC check infrastructure and management	OC—With better PUC infrastructure and strict pollution norms, emission from private and public vehicle will decrease	Medium	Medium	
		Incentivising the use of cleaner fuels - electric vehicle and (CNG/LPG) for private vehicles	TR—Proper infrastructure to increase the adoption rate of cleaner fuels OC—Reduction of emission load from private vehicles that switched to Electric/CNG/LPG-based vehicle from Petrol/Diesel-based vehicles	Medium	Medium	
		Installation of Diesel Particulate Filter (DPF) in all diesel vehicles	M—Installing DPF filters in existing diesel vehicles OC—Reduction of emission load from diesel vehicles	Medium	Medium	
		Efficient parking facilities near hotspots (railway stations, religious spots, educational institutions, govt. offices, etc.)	M—Improvement in infrastructure at hotspots OC—Reduction in traffic congestion will facilitate faster vehicle movement and reduce tail-pipe emission	Medium	Long	Muzaffarpur Municipal Corporation (MMC)
2	Industry	Introduction and shifting towards cleaner fuels in metal fabrication and food processing industries	TR—Feasible technologies that support cleaner fuel OC—Reduction in emission load from industries	Medium	Medium	Bihar State Pollution Control Board (BSPCB)

[15] - Benefit Cost Ratio (BCR) - Lives saved and cost incurred are the deciding factors for categorizing CMs into high, medium, and low for BCR. The categorisation scale of BCR varies for all the CMs listed.

						Dept. of Industries (Bihar)
		Adapting new technologies for brick kilns	Adapting zigzag technology	Low	Medium	
3	**Solid-Waste Management**	Installing new waste composting plants at city level and/or increasing the capacity of existing composting plants	M—Composting plants OC—Composting waste/garbage will reduce the emission load from garbage burning	Medium	Medium	MMC
		Recycling centres for dry waste	M—Recycling centres for dry waste OC—Proper disposal of dry waste will reduce the emission load from garbage burning	Medium	Medium	
4	**Domestic**	Increasing LPG connections in low-income strata	M—Increase in LPG connection OC—Reduction in emission load	High	Medium	Food And Civil Supplies Department
		Introduction of improved *chulahs* (low-emission *chulahs*)	Identifying areas for using *chulahs,* procuring the *chulahs* OC—Reduction in indoor emission load	Medium	Medium	Food And Civil Supplies Department MMC
		Ban on use of kerosene (Use of solar lanterns)	M—Procuring solar lanterns OC—Reduction in emission load	Medium	Medium	Bihar Renewable Energy Development Agency (BREDA) MMC
		To mandate rooftop solar panel for power back-up and solar water heating	TR—Solar panels and other technological requirements OC—Reduced electricity demand	Medium	Medium	BSPCB MMC
5	**Road Dust**	To take appropriate actions to remove road dust/silt regularly by using mechanical sweepers	Mechanical sweeping, identifying the road stretch with high silt content, procuring mechanical sweepers OC—Reduction in resuspension of dust	High	Medium	MMC

4. Methodology - Techno-Economic Assessment (TEA) of the Control Measures

4.1 Techno-Economic Assessment

TEA is a framework to analyse the economic and technical performance of a process, service or product. Technical feasibility analyses the effectiveness of a particular technology whereas, economic feasibility analyses the cost incurred (capital, operational, maintenance, salvage value, etc.) and the benefits achieved in the form of lives saved due to better air quality. TEA was performed for all the shortlisted CMs identified (Table 1) in each sector.

The following sections talk about sector-specific TEA and the technologies considered for emission reduction and policy solutions.

4.1.1 Transportation

Nathani et al. (2016) state that the total road network of Muzaffarpur is around 73km. The network is jointly managed by the district council, MMC, and public works department (PWD). Nathani et al. (2016) also identified the key issues affecting the transportation sectors as a whole as 1) garbage collection issue 2) illegal encroachment on the sides of the road 3) bottlenecks at several major locations 4) improper placement of electric poles 5) water logging issues 6) unorganised traffic, etc. The paper also stated that just by implementing the existing rules, the current situation of the transportation sector could be drastically improved. Rectifying the above-mentioned issues, alongside the boosting of infrastructure to support public transportation, would result in several benefits, including congestion reduction, reduction in average travel-time, resource conservation, etc., (Dora, 2007).

The following CMs under the transportation sector were considered for Muzaffarpur city to help reduce pollution levels.

Control measure 1: Ban on registration of two-stroke autos

Proposed measure: "Registration of two-stroke autos to be banned; old two-stroke autos to be replaced with either CNG-based autos or Electric-Rickshaws"

Due to the lack of an efficient public transportation system, citizens rely on autos for their transportation needs. Two-stroke autos use a mixture of oil and gasoline and tend to emit more pollutants into the atmosphere in comparison to four-stroke autos. Though the percentage share of two-stroke autos operating in Muzaffarpur is low, the proportion of toxic air pollutants emitted by two-stroke autos is more than twice that of four-stroke autos (Thakur et al., 2018). Potential technologies that could replace existing two-stroke autos were identified. A CBA was performed by comparing the shortlisted technologies. Cost incurred was estimated using their Total Cost of Ownership (TCO) (estimated using equation 4.1.1.1) and benefits achieved were estimated using the additional revenue and potential benefits that these technologies could offer in terms of pollution reduction.

$$TCO = \frac{C + (F * L * D) + [(O + M) * L * D] - S}{L * D} \quad \textbf{(4.1.1.1)}$$

Where,

C - Initial capital cost
F - Fuel cost (INR/km)
L - Lifetime of the considered vehicle (yrs.)
D - Distance travelled by the vehicle in a year (km/yr.)
O&M – Operation and Maintenance cost (INR/km) - Includes battery replacement cost
S - Salvage value (estimated resale value of an asset at the end of its useful life)

It was estimated that the major component of the TCO of auto rickshaws is the operation and the maintenance cost. Table 2 lists the technological options and key parameters considered for the replacement of two-stroke autos.

Table 2: Key parameters for technologies considered - Autos

Parameters	Two-Stroke Autos	CNG	Electric
Capital cost (INR Lakhs)	1	1.5	2
Fuel efficiency	18-20 km/l	20-22 km/kg	6.7 km/kWh
Fuel cost (INR/km)	4.2	2.6	1.0
TCO (INR/km)[16]	9.5	6	2.5

Control measure 2: PUC check (every 6/12 months) and better PUC check infrastructure and management

Proposed measure: "To open PUC centres at each petrol pump, and policies like 'No PUC No fuel' shall be enforced"

Key facts:

Total No. of PUC centres in Muzaffarpur – 23

Rogers et al. (2002) suggests that with effective polices and efficient PUC centres, the level of emissions from automobiles will decrease. The total number of PUC centres that need to be installed in the city has been estimated considering (a) the cost to install (equipment cost and the registration fee) and operate (salary and other recurring costs) a PUC centre, (b) number of vehicles operating, (c) average cost to get a PUC certificate, and (d) percentage of vehicles to receive a PUC certificate. A Cost Benefit Analysis (CBA) was performed by estimating the total costs (capital and O&M cost) incurred and the benefits (based on emission reduction) achieved. The equipment required for a PUC centre includes smoke meter, 4-gas analyser, and a computer. In addition to this, training of staff will be a requirement as well.

Control measure 3: Incentivising the use of cleaner fuels (CNG/LPG) and electric vehicles for private use

Proposed measure: "Provide incentives to people to buy CNG/LPG/electric vehicles"

Policies that promote the use of electric vehicles, such as the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) and the National Electric Mobility

[16] Estimated from (Center for infrastructure, sustainable Transportation and Urban planning (CiSTUP), Indian Institute of Science, 2012)

Mission Plan (NEMMP), already exist in India. However, unlike other Indian cities, very few people have benefited from the FAME scheme in Muzaffarpur—only 1.3%[17] of the total vehicles have been sold under the FAME scheme in Bihar. It is anticipated that the transportation sector's emission levels could be reduced by increasing the proportion of vehicles that operate on clean fuels.

The cost incurred for the implementation of this CM took into consideration the incentives for consumers. The government should bear the cost of promotional activities focused on increasing the adoption rate of CNG/LPG/electricity-based vehicles. Such fuels, as a replacement to diesel, could lead to reduced emissions. The benefits achieved by implementing the CMs, in terms of potential lives saved (using the difference in emission load), have been estimated.

Control measure 4: Installation of diesel particulate filter (DPF) in vehicles

Proposed measure: "Create mandates and provide subsidies to diesel vehicles (trucks) to install DPF"

Muzaffarpur plays a key role in the economy of Bihar. Muzaffarpur is the largest producer of mango, litchi, and roses (UD and HD, 2010). Construction activities are common in and around the city. Transportation of construction materials and agricultural outputs have increased the number of heavy vehicles that operate in Muzaffarpur. Emissions from these heavy goods vehicles are relatively high compared with any other mode of transportation.

The installation of DPF filters will help reduce emissions from these vehicles by at least 70% (Tsai et al., 2011) and (CARB-USEPA, 2015). However, installation of DPF will increase the CO_2 emissions from the engine. Pollution caused by diesel vehicles can be curbed using the available filters (Preble et al., 2015). The kind of filters that could be installed in vehicles were identified by taking into account the availability of filters, the vehicle type, and the efficiency of the filters. The capital cost of the filter, the recurring maintenance cost and the pollution reduction factor of the filter were used in order to determine the efficient option. Installing a DPF in a truck is expensive and it does not provide any additional benefits to the driver. It was assumed that at least 10% of the trucks plying in Muzaffarpur will be given incentives to install DPF filters. The major focus will be on trucks that are older than 10 years.

Control measure 5: Efficient parking facilities near hotspots.

Proposed Measure: "Parking facilities will be constructed at hotspots, which will help reduce the number of vehicles parked at unauthorised spaces"

Muzaffarpur is an old and unplanned city with narrow roads, leading to traffic congestion. Inadequate parking spaces near hotspots, slow moving vehicles, etc., add extra burden to the congestion levels in the city. The introduction of parking lots near hotpots and the effective implementation of parking rules will help MMC reduce the number of vehicles that are parked at illegal spaces thereby, reducing the overall congestion levels in the city. Locations where vehicles are parked at unlawful places were identified as a part of the transportation survey.

[17] As per data accessed from https://www.fame-india.gov.in/

4.1.2 Industry

The economy of Muzaffarpur is widely dependent on agricultural industries. Besides that, Muzaffarpur is also an important industrial hub. Annexure C presents the red category industries that are situated in and around Muzaffarpur.

Mentioned below are some of the key facts about the industries located in Muzaffarpur:-

Key facts[18]:

- Total no. of red-category industries – 7 (1 Power Plant; 6 Metal fabrication industries (3 still use coal-fired furnaces)
- Total no. of orange-category industries - 7 (3 Husk-fired boiler; 4 Coal-fired boiler)

The percentage share of emissions from industries in the air-shed region is enormous. However, its impacts on the city's pollution concentration is low as the industries are situated outside the city boundary. Moreover, Government need to consider shifting the industries located inside the city on the city outskirts. Considering the various types of industries present in Muzaffarpur, the following CMs are proposed for reducing pollution levels.

Control measure 1: Adapting efficient technologies for brick kilns

Proposed measure: "Convert all existing brick kilns to zigzag technology", create mandates to convert fixed chimney kilns to advanced technologies

At present, there are 86 operational brick kilns in Muzaffarpur using conventional technology. Despite legal mandates from the Bihar government to adopt zigzag technology, several brick kilns still use FCK. Shifting to zigzag technology will help improve the city's air-quality levels. The cost of converting from FCK to zigzag kilns was estimated by considering the capital cost and opportunity cost (based on productivity loss during the days spent on shifting). Meanwhile, the benefits were estimated in terms of the additional revenue generated (based on improvements in product output), savings in fuel (based on fuel efficiency), and lives saved (based on emission-reduction potential).Table 3 presents the list of parameters (Iqbal, 2016) considered for the adoption of improved technologies for emission reduction in brick kilns.

Table 3: Key parameters considered - Adapting new technologies for brick kilns

Retrofitting Parameters	Induced Zigzag Kiln	Natural Zigzag Kiln	Existing FCK Kilns
Capital required (INR Lakhs)	25	27	-
Days required to shift technologies	60	90	-
Coal consumption (ton) per lakh bricks	12	12	16
Product output	70-80%	70-80%	50 – 60%
Total annual savings (INR Lakhs)	44	44	-
Additional requirements	Draught fan	Chimney	-

Control measure 2: Introduction of and shifting towards cleaner fuels in metal fabrication and food processing industries

Proposed measure: "To promote the use of technologies that use clean fuel"

[18] Data from Industries department - Muzaffarpur

The total number of polluting industries in Muzaffarpur is very low. However, the share of emission from power plants located near Muzaffarpur is enormous. This increases the overall share of emission from industries. Implementing strict emission norms in power plants and shifting metal fabrication industries to the latest furnace technologies such as induction or electric furnace will help reduce coal usage (Krishna et al., 2009).

In this case, the implementation of CMs requires investment from industry owners. To understand the cost of installing these clean technologies and the benefits of doing so, the relevant costs and benefits were calculated. The implementation cost of CMs for industries was estimated by accounting only the capital cost. The benefits were estimated using the savings (in fuel consumed), additional revenue (calculated based on the change in product output), and lives saved (estimated using the emission-reduction potential).

4.1.3 Solid-Waste Management

Muzaffarpur Municipal Corporation (MMC) is working towards creating an efficient solid-waste management plan for the city. MMC has been working closely with several entities on programmes such as 'Well-being out of Waste' to efficiently manage the waste generated. MMC has also organised a workshop "Swachhta Swasthya Samridhi", in collaboration with the Centre for Science and Environment. The city has also banned the use of plastic and has also undertaken several initiatives to efficiently manage solid waste.

Muzaffarpur generates around 180 tonnes of waste per day. It is one of the Indian cities with a high waste segregation level. However, only a part of the segregated waste is treated. The rest gets accumulated in a landfill. After taking into account the annual increase of 1% - 1.33% in per capita waste generation (Shekdar, 1999; CPCB, 2000a; Pappu et al., 2007), the waste generated every year is estimated using the equation (4.1.3.1).

$$S_n = G * P_n \quad \textbf{(4.1.3.1)}$$

Where,

Sn – Solid waste generated for year n
G – Per capita waste generated
P_n – Projected population at year n

Key facts:

- Total municipal waste generated in a day: 180 TPD
- Installed capacity: 14 (Compostable: 7 TPD, Dry waste collection centre: 7 TPD)
- Waste composition: Compostable: 55%; Recyclable: 18%; Non-Compostable: 27%

Control measure: Installation of composting plants at the city level, recycling centres for dry waste & waste-to-energy plants

Proposed measure: "To increase the treatment capacity of solid waste at the city level"

There are several efficient solid-waste composting methods, such as vermicomposting, windrow composting, anaerobic digestion, and stack pile composting (CEDINDIA, 2011). The windrow composting technique (production of compost by piling up compostable waste in long rows) is economically attractive and technically simple.

Around 27% of the generated waste in Muzaffarpur is non-compostable. Hence, establishment of dry-waste collection centres is necessary.

Various composting methods were shortlisted for implementation in Muzaffarpur. While selecting the composting method, a few variables were taken into consideration, such as (a) land-use pattern, (b) solid-waste composition, (c) use of compost, (d) existing practices, and (e) cost required to install composting plants for the waste generated in Muzaffarpur.

The capacity of composting plants and dry waste collection centres that need to be installed every year was estimated using the projected solid-waste generated (estimated using population growth) and the segregation level.

The cost incurred in implementing this CM was estimated using the capital cost (construction cost, machineries, etc.,), O&M (salary, maintenance of machineries, etc.), awareness activity, etc. It is assumed that the land required to build the plant will be arranged by the municipality.

Studies suggest that a proper solid-waste management plan could reduce the amount of waste being burnt, which, in turn, may lead to improved air quality in the city (Guttikunda and Jawahar, 2014). In other words, the benefits of these CMs are directly linked to the potential emission reduction from waste burning. The overall benefits of implementation were estimated keeping in mind the revenue generated (sale of fertilisers and recyclable materials), along with the potential lives saved as a result of emission reduction. Table 4 presents the key parameters for the technologies considered.

Table 4: Key parameters for the methods considered - SWM

Parameters	Windrow composting	Dry waste collection centres
Segregation required	Yes	Yes
Implementation time	< 1yr.	1 – 2yr.
Capital required (per-ton)[19] INR	9 Lakhs	15 Lakhs
O&M cost (per-ton)[19] INR	2.3 Lakhs	9 Lakhs
Output	Fertilisers	Reusable/Recyclable materials

4.1.4 Domestic

In 2015, across India, residential biomass burning was the largest individual contributor (24%) to the deaths attributable to PM2.5 (GBD MAPS Working Group, 2018). Evidence suggests that there is a strong link between indoor air pollution and asthma, tuberculosis, cancer, etc. (Kurmi et al., 2012). Infants and children are more vulnerable because of their immature respiratory defence mechanisms.

Control measure 1: To mandate roof-top solar panel for power back-up and solar water heating.

Proposed measure: "Focus on incentivising the installation of solar panels on rooftops"

Industries and local shops often switch to DG sets during power outages. With the introduction of solar panels, the installed power generation capacity of Muzaffarpur will increase, reducing the use of DG sets completely.

[19] Authors estimate based on (CEDINDIA, 2011) & (Chandran and Narayanan, 2016)

Installation of a 1KW solar plant would cost around INR 70,000 – INR 75,000, for which government provides an incentive of around 30%[20] of the same. Cost incurred by the government for the implementation of this CM was estimated using the incentives that will be provided to the general public for the installation of solar PVs on their rooftops, and the cost incurred by the government to build rooftop panels at government buildings.

Control measure 2, 3 and 4: Introduction of improved chulahs *(Low-emission* chulahs)*, increasing LPG connections in low-income strata, and use of solar lanterns instead of kerosene lanterns*

Proposed measure: "Focus on subsidising the cost of smokeless chulahs*/induction stove and new LPG connection, and promote solar lanterns within the economically lower strata of society"*

By increasing the number of LPG connections and refuelling rate of LPG cylinders, and using smokeless *chulahs* or induction stoves, it is expected that the dependency on solid fuels like wood and biomass will decrease. The emissions level from these solid fuels is higher than that of the emissions from LPG or smokeless *chulahs* (Singh, 2009). The cost to implement this CM was estimated by taking into account the incentives (Annexure C) that will be provided to the citizens. This will motivate people to switch to smokeless *chulahs*/induction stoves or to adopt LPG connections. The benefits of implementation were estimated by considering the emission reduction percentage achieved by implementing the suggested CMs.

Non-notified slums in the city are still dependent on kerosene as a fuel for lighting purposes. By promoting the use of solar lanterns in these slums, it is assumed that kerosene usage will decrease.

4.1.5 Road Dust

Traditionally, all the roads and sidewalks in Muzaffarpur city are swept manually. This method, however, is considered highly inefficient as dust swept from the roads is left on the roadside, with dust getting suspended while sweeping as well. This dust gets re-suspended due to vehicular movement (Kuhns et al., 2008). The Bihar government needs to implement stringent norms to collect roadside dust to curb the resuspension of dust. The installation of mechanical sweepers and end-to-end road pavement could help achieve the goal.

Control measure: Regular removal of road dust/silt using mechanical sweepers

Proposed measure: "Introduction of mechanical sweepers to control road dust emissions"

Roadside dust can be removed using mechanical sweepers currently available in the market. However, to select a suitable mechanical sweeper for Muzaffarpur, various parameters were considered like (a) road surface condition, (b) content of the debris, (c) area to be swept, and (d) frequency of sweeping. A CBA was performed to check the financial feasibility of the sweeper, considering the key parameters (Kuehl et al., 2008) mentioned in Table 5.

[20] As per the information retrieved from MNRE

Table 5: Key parameters considered – Mechanical sweeper

Parameters	Mechanical Sweeper (MS)	Regenerative-Air Sweeper (RAS)	Vacuum-Assisted Sweeper (VAS)
Capital cost (INR Lakh)	40	48	80
O&M cost per km (INR)	68	31	34
Life (years)	10	12	14

The total number of mechanical sweepers required is estimated using the equation (4.1.5.1) below

$$M_n = L_r/(S * R) \qquad \textbf{(4.1.5.1)}$$

Where,

M_n – Total no. of mechanical sweepers required
L_r – Total length of the roads considered (km)
S – Average speed of the mechanical sweeper (km/hr)
R – Average operational time of the mechanical sweeper (hr)

4.2 Health benefits

Long-term exposure to small particles [10 microns or less in diameter (PM2.5 & PM10)] has been associated with increased mortality and morbidity over time (Srinivasan et al., 2018). When PM concentrations reduce, the related mortality and morbidity levels also go down. The reduced PM concentration helps project the associated health benefits in monetary terms. The clean air action plan's focus is to estimate the mortality avoided due to the reduction in PM2.5 concentration levels.

The following method was adopted to estimate the mortality avoided annually (Pope et al., 2014)

$$M = \Delta \text{ PM2.5} * E_p * \Delta\text{ER} * B_d \quad \textbf{(4.2.1)}$$

Where,

- M – Mortality avoided annually
- $\Delta\ PM2.5$ – Change in PM2.5 concentration levels in 30 km X 30 km grid
- E_p - Exposed Population – Population of Muzaffarpur
- B_d - Baseline death rate (national mortality rate)
- ER (excess risk) – Supra-linear Concentration Response Function (CRF) considered on the basis of GBD assessments. $ER\ (excess\ risk) = 0.4\times \{1 - \exp\ [-0.03\ (PM2.5)^{0.9}\ ]\}$

The method establishes a relationship between the change in PM2.5 concentration and the mortality avoided. According to a study by Pope et al. (2014), the excess risk function can follow either a supra-linear form (rate of change of risk decreases with higher pollution concentration levels) or a linear form (risk increases at the same rate irrespective of pollution levels). However, recent studies consolidated that the ER or the CRF is more likely to be supra-linear at higher levels of exposure (Burnett et al., 2014) (Pope et al., 2014). This implies that the marginal benefits of pollution reduction at lower concertation levels are higher than the benefits in highly polluted areas. Figure 12 describes the difference between the supra-linear curve and the linear curve.

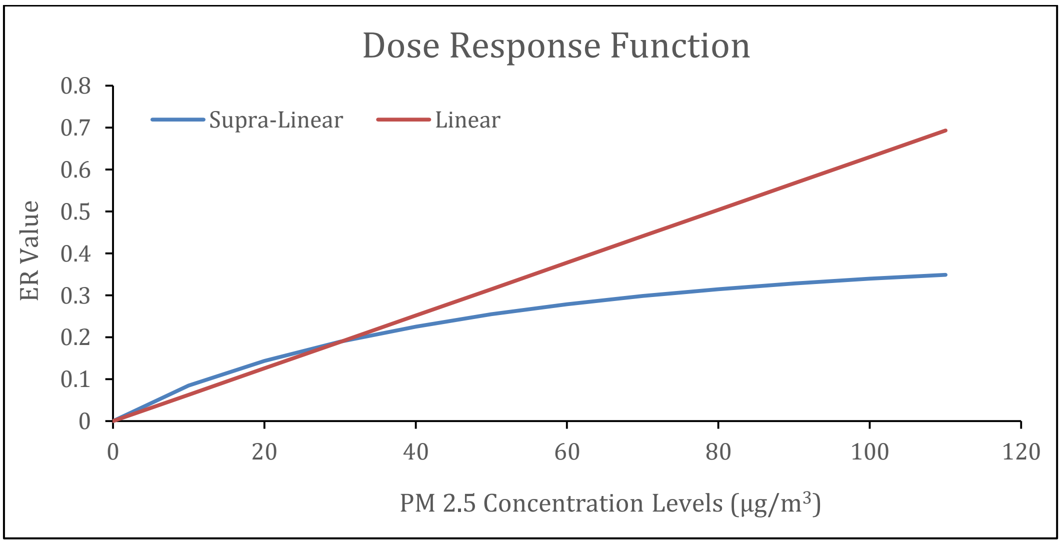


Figure 12: Supra-linear and linear form of ER function

5. Results and Discussion

As per the study's estimate, the total emission load is increasing by 28% (Chapter 2.3.2) under the BAU scenario. Sectors such as transportation, waste burning, and domestic are contributing to this increase in the emission load. Based on these emission concentrations, various scenarios (combination of CMs) were developed with varying levels of pollution reduction targets till 2030. Emission reduction scenarios for the sectors considered in the study have been described below in detail.

5.1 Sector: Transportation

Control measure 1: Ban on registration of two-stroke autos

Under this CM, registration of two-stroke autos will be banned and incentives will be given to two-stroke auto owners to replace their vehicles with E-rickshaws. The introduction of electric autos will help control air pollution.

Key Considerations:

- Total no. of two-strokes to receive incentive: 1010
- Incentives – As per FAME scheme
- Time period: 5 years.

The cost incurred and the benefits achieved under this CM has been provided in Table 6 below.

Table 6: Economic analysis - Replacing two-stroke autos with EV-based autos

Cost and benefits	2019 - 2022	2023 – 2025	2026 – 2030
Cost incurred (INR Cr.)	6	-	-
Total mortality saved (no.)	1	3	11

The study estimates that the adoption of E-rickshaws will reduce pollution levels. However, barriers such as technology, manufacturing capacity, affordability, and driver acceptance have a major impact on the adoption rate of E-Rickshaws (CapaCITIES, 2018). Therefore, considering the varied and substantial potential benefits offered by E-Rickshaws (emission reduction, cost involved, etc.), the government should focus on building new infrastructure and educating drivers to boost the adoption rate.

Control measure 2: PUC check (every 6 months) and better PUC check infrastructure and management

At present, according to CPCB protocol, all vehicles must undergo a PUC every six months. The existing PUC check system needs to be revised and the number of PUC centres and the infrastructure must be improved.

Muzaffarpur city has sufficient PUC centres in place. However, proper monitoring mechanism needs to be implemented to ensure that these PUC centres are operating efficiently. With sufficient infrastructure and strict enforcement of laws, number of vehicles getting PUC certification will increase. We have assumed that the total number of vehicles having valid PUC certificate will increase by at least 30% (TERI, 2017). Muzaffarpur has already established a

PUC network. With proper monitoring mechanisms and strict rules, the city could reduce the emissions from the transportation sector by 1.5%, saving around 9 lives by 2030.

The mere introduction of new PUC centres will not help/encourage vehicle owners to ensure that their vehicles are in good condition. Initiatives like '*No PUC, No fuel'* must be introduced and public awareness about the impact of air pollution must also be escalated.

Delhi has good PUC infrastructure; the city also has proper regulations in place. However, studies indicate (TERI, 2017) that fewer than 30% of vehicles in Delhi have a valid PUC certificate. Lack of public awareness and acceptance is one of the main reasons for these abysmal numbers. Therefore, it is important for various government departments to create public awareness about the importance of vehicle maintenance.

Control measure 3: Incentivising the Use of Electric Vehicles & Cleaner Fuels (CNG/LPG) for Private Vehicles

To bring about any kind of policy change and implement any regulation on-ground, people must be provided with regulations that incentivise them to adopt the suggested change. Hence, for people to use electric vehicles, and clean fuel, a proper incentive-provision channel must be created.

Under this scenario, incentives will be provided to:

- Private vehicle owners who are motivated to retrofit their vehicles with CNG/LPG kits
- Owners purchasing new vehicles that use clean fuel

India already operates schemes that provide incentives to vehicle owners who purchase electric vehicles. Unfortunately, limited awareness about them is one of the major reasons for fewer beneficiaries in Muzaffarpur.

The burden of cost for implementing this CM falls on the government. Under this CM, individuals will be provided incentives only till 2022. It is assumed that around 300 new electric vehicles will be registered by 2022 and around 10% vehicles will be retrofitted with CNG kits. It is estimated that around 2% of the total emissions from the transportation sector can be reduced by this measure. The estimated cost and benefits for the same are listed in Table 7 below.

Table 7: Economic analysis - Incentivising private vehicles

Cost and benefits	2019-2022	2023-2025	2026-2030
Incentives (INR Cr.) - EVs	4	0	0
Incentives (INR Cr.) – CNG	0.5	0	0
Total mortality saved (no.)	0	2	8

Control measure 4: Installation of DPF filters in vehicles

Diesel vehicles emit pollutants that are harmful to human health (New Hampshire Department of Environmental Services, 2014). These emissions can be reduced by retrofitting diesel vehicles with DPF (CARB-USEPA, 2015). BS6 complaint vehicles will come with pre-installed particulate filters and is expected to hit the roads soon. This CM suggests that trucks older than 10 years should have DPF installed.

It was estimated that this scenario would reduce the transportation sector's emissions by around 10%, which would help the government save around 43 lives by 2030. Table 8 presents the total cost incurred (incentives) and the lives saved.

Table 8: Economic analysis - Installation of DPF

Cost and benefits	2019-2022	2023-2025	2026-2030
Incentives (INR Cr.)	2	0	0
Total mortality saved (no.)	3	6	34

Technologies like (a) selective catalytic reduction (SCR) for NOx emission reduction, (b) DPFs for PM reduction, and (c) diesel oxidation catalyst (DOC) for CO & hydrocarbon (HC) reduction (Preble et al., 2015) already exist in the market. Since the primary focus is to reduce the levels of PM, it is recommended that the focus should be on installation of DPFs in diesel vehicles that are older than 10 years.

Control measure 5: Efficient parking facilities near hotspots

Major hotspots, where traffic gets congested due to parking of vehicles at no-parking places, were identified as a part of the transportation survey. The introduction of parking lots that are accessible and affordable will encourage people to utilise such lots. Under this CM, we are proposing to install 4 parking lots with capacity to handle 200[21] cars near 1) Aghoria Bazar Chowk, 2) Saraiya Ganj Tower, 3) Zero Mile and 4) Bhagwanpur Chowk. This would cost the MMC around INR 80 crore.

5.2 Sector: Industry

Control measure 1: Adapting new technologies for brick kilns

This CM recommends the conversion of all the existing FCKs to zigzag technology. Most importantly, the capital cost required to retrofit FCKs to zigzag technologies is much lower than other advanced technologies like Vertical Shaft Brick Kilns (VSBK) or Hybrid Hoffman Kilns (HHK). This CM will help to reduce 40% of emissions from the brick kilns sector, saving around 44 lives by 2030. Below, Table 9 presents the cost of retrofitting all brick kilns from FCK to zigzag technology in Muzaffarpur.

Table 9: Economic analysis - Brick Kilns

Method	Induced Zigzag Kiln	Natural Zigzag Kiln
Additional cost incurred (INR Cr.)	21	21
Additional maintenance cost/year (INR Cr.)	2	-
Savings/year (INR Cr.)	26	28
Total mortality saved (no.)	44	44

Control measure 2: Introduction of technologies using cleaner fuel

Under this CM, it is considered that the industries using traditional/old technology will switch to the latest technology, as per the regulations set by the government. The furnace used in the metal fabrication industry uses coal as its primary fuel, which causes a lot of pollutants. Therefore, it is recommended that mandates be put forth by the industries department to request industries to switch to cleaner fuels.

[21] Assumption based on existing parking lots in tier 2 cities.

5.3 Sector: Solid-Waste Management

Control measure: Installation of composting plants at city level, recycling centres for dry waste & waste to energy (W2E) plants

Scenario:

In 2018, Muzaffarpur generated around 180 tonnes of solid waste per day. Considering the population growth and per-capita waste generation, the city will produce around 287 TPD of waste by 2030.

Key considerations:

- Per-capita waste generation to increase by 1% annually, waste composition to remain constant
- Muzaffarpur's segregation levels to reach 70% by 2030
- It is assumed that setting up a proper solid-waste management plan will reduce the solid-waste burning practices in Muzaffarpur
- A composting plant of capacity 40 TPD will be installed every fourth year and an additional capacity of 30 TPD will be installed in 2027
- Dry waste-collection centre of capacity 10 TPD will be installed every fourth year.

The capacity of composting plants and the number of dry waste-collection centres required were determined by considering the waste segregation level, the collection efficiency, and the projected waste generated per year. Table 10 presents the total cost incurred and benefits under this scenario.

Table 10: Economic analysis - SWM

Cost		2019-2022	2023-2025	2026-2030
Composting plants	Capital cost (INR Cr.)	6	7	6
	Operational cost (INR Cr.)	3.7	9.8	27.6
Dry waste-collection centres	Capital cost (INR Cr.)	1.7	1.9	2.2
	Operational cost (INR Cr.)	3	8	22
Total mortality saved (no.)		8	22	97

Under this scenario, we assumed that the amount of waste burnt will decrease with a proposed solid-waste management plan. By achieving a segregation level of 90% and with sufficient waste treatment capacity to treat the collected waste, it is estimated that around 90% of the emissions from burning waste will be reduced. This could save around 300 lives, as result of reduction in pollution levels.

Household-level waste segregation and waste collection are key to developing an efficient solid-waste management system (Bhushan et al., 2018). A proper waste-collection mechanism ensures safe transportation and treatment of the generated waste. Therefore, 100% waste collection needs to be ensured alongside the boosting of installation and capacities of solid-waste treatment facilities.

5.4 Sector: Domestic

Control measure: Reducing the usage of solid fuels

The problem of solid fuel-burning can be reduced by increasing LPG connections and replacing traditional *chulahs* with advanced *chulahs* and induction stoves. This, in turn, will result in reducing the domestic sector's emissions.

Scenario Creation:

Taking into account the percentage of people (Jain, 2017) willing to switch to LPG from traditional *chullahs* and cost of solid fuel, we considered two scenarios. Scenario one considers that around 70% of households upgraded from traditional *chullahs*, while the second scenario considers installing solar PV. Table 11 presents the cost incurred and the benefits achieved under scenario one described in the above paragraph. The smokeless *chullahs* cost around INR 750 – INR 2,500 in the market. In order to achieve the desired reduction in pollution from the sector, the government should provide incentives to citizens. These incentives will range between INR 750 – INR 2,500, based on the cost of the *chulahs* available in the market. Incentives of INR 1,600 will be provided to people who buy new LPG connections. Moreover, three LPG cylinders at a subsidised rate will be given to the beneficiaries.

Table 11: Economic analysis - Domestic sector

Cost And Benefits	2019-2022	2023-2025	2026-2030
Incentives (INR Cr.) – New LPG connection	0.54	0.49	0.72
Incentives (INR Cr.) – Subsidised cylinders	0.62	1.47	4.13
Incentives (INR Cr.) – Smokeless *Chulah*/ Induction stoves	3.57	0.46	0.38
Total mortality saved (no.)	13	30	74

Scenario 2: Solar PV on government building, institutions, industries, and households

So far, no studies have been conducted in Muzaffarpur to identify its solar rooftop potential. As per our estimates, emissions from DG sets contribute to around 3% of the total PM2.5 emissions. DG sets are widely used in industries, hospitals, institutions, mobile towers, and by local vendors. Under this scenario, with an increase in power generation, we expect the installation of solar rooftops to help decrease the usage of DG sets. The government would save around 65 lives if emissions from DG sets are eliminated completely.

5.5 Sector: Road dust

This measure proposes end-to-end road pavement, strict compliance of existing policies and the introduction of mechanical sweepers. This can help reduce suspended road dust particles.

Key considerations:

- Total road length of Muzaffarpur: 550km
- No. of mechanical sweepers to be employed on major roads: 2 by 2020

It is estimated that at least 2 regenerative air sweepers (RAS) will be required to cover its major roads. This will cost around INR 1 crore. Additional measures such as strict implementation of construction regulations and end-to-end road pavement could help the government save 81 lives in 12 years.

5.6 Scenario analysis

The previous section discussed individual interventions and the associated costs and benefits of various CMs. The study also looked into three combination scenario analysis for emission reduction. These scenarios were considered by clubbing various CMs in three buckets of high-emission reduction, medium-emission reduction, and low-emission reduction potentials. The section below details 1) the assumptions considered, 2) the estimated change in pollution levels, and 3) the costs and the benefits.

Scenario combination 1: High-emission reduction potential measures combination

This scenario is designed to achieve maximum emission reduction (best case scenario) by 2030. All the high-emission reduction CMs/technologies from various sectors were clubbed. The interventions under each scenario have predefined targets, described in chapter 6.

The major interventions are 1) increasing percentage share of electric transportation, 2) conversion of all brick kilns and other industries to technology that uses cleaner fuel, 3) complete elimination of DG sets and maximising the use of LPG for cooking needs.

Scenario combination 1:

- Complete ban on two-stroke auto rickshaw registration and replacement of existing two-stroke auto rickshaws with E-rickshaws
- At least 30% of the vehicles that are operating in Muzaffarpur to have a valid PUC certificate
- At least 10% of the trucks to have a DPF installed in them
- Brick kilns that are present in Muzaffarpur are shifted to induced zigzag kiln and promotion of prefabricated bricks
- Composting Plant Capacity: 110 TPD; Dry Waste Collection Centres capacity: 30TPD
- At least 70% of the traditional *chulahs* are replaced by smokeless *chulahs*
- LPG penetration rate – 90%
- Electrification level – 95% - 100%
- No of mechanical road sweepers – 2

Under this scenario, it is expected that the total emission load (PM2.5) will reduce by 35% by 2030 with respect to the BAU scenario and the same has been presented in Figure 13 below. It also presents the sectoral share of emission in 2030. Heavy industries continues to be the most polluting sector (53%) followed by transportation and domestic contributing 14% each under scenario 1.

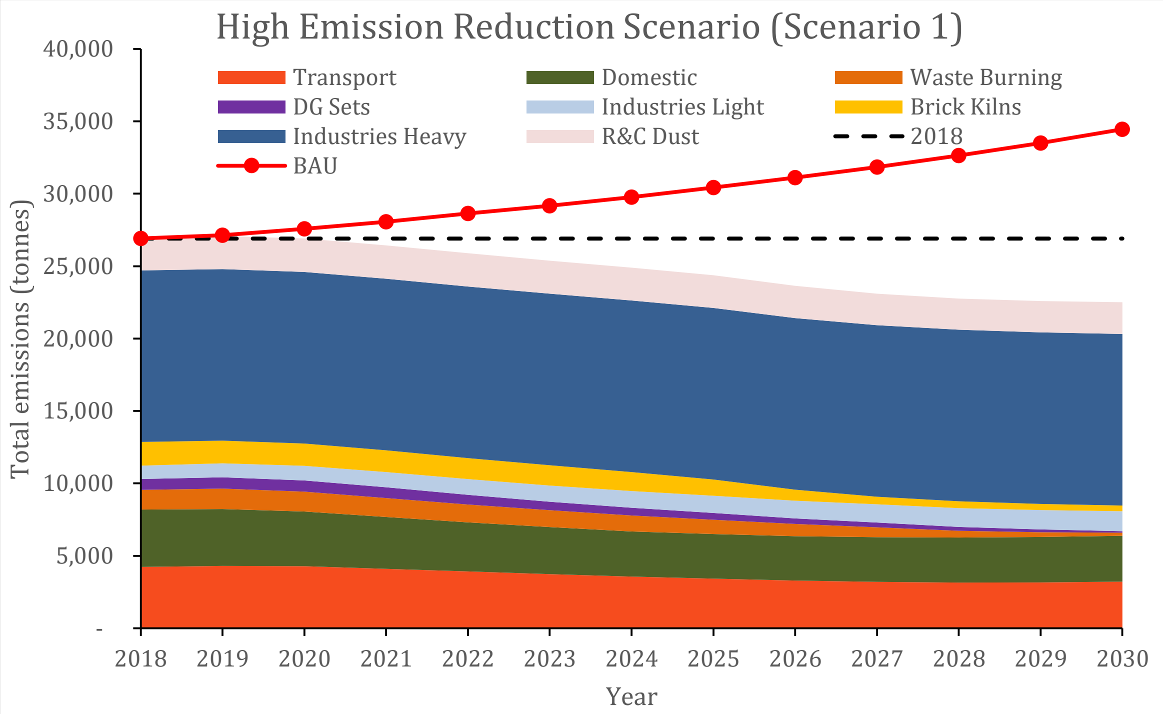


Figure 13: PM2.5 emissions scenario 1 (High emission reduction scenario)

Introduction of solar PV and improvement in the existing power sector infrastructure will decrease pollution from DG sets. Muzaffarpur would also have enough installed solid-waste-treatment capacity to treat all of the waste generated, essentially curtailing the burning of open waste.

Though all the brick kilns are expected to shift to advanced technologies, they are likely to continue contributing to the total emission load, given that they are located within the city. Hence, expecting 100% pollution reduction from the brick kilns sector is unrealistic.

Scenario combination 2: Medium-emission reduction potential measures combination

CMs/technologies with medium-level pollution reduction potential have been grouped under this scenario. It has the potential to reduce the PM2.5 emissions load by 26% by 2030 with respect to the BAU scenario

Scenario combination 2:

- Registration of two-stroke autos are banned completely and all the existing two-stroke autos are replaced by CNG-based autos
- At least 8% of the trucks to have a DPF installed in them
- Brick kilns that are present in Muzaffarpur are shifted to natural zigzag kiln
- Composting Plant Capacity: 40 TPD; Dry Waste Collection Centres capacity: 10 TPD
- At least 50% of the traditional *chulahs* are replaced by smokeless *chulahs*
- LPG penetration rate – 87%
- Electrification level – 90%
- No of mechanical road sweepers -1

Although scenario 2 is similar to scenario 1, it has slightly relaxed targets under each sector. As a result, emissions reduction from each sector is relatively less compared to the first scenario. However, the transportation sector's emission reduction in both scenarios is nearly the same. This is mainly because, in both the scenarios, the number of vehicles (for public transportation) released remains almost the same; only the type of technology used varies. Figure 14 presents the estimated emissions for scenario 2.

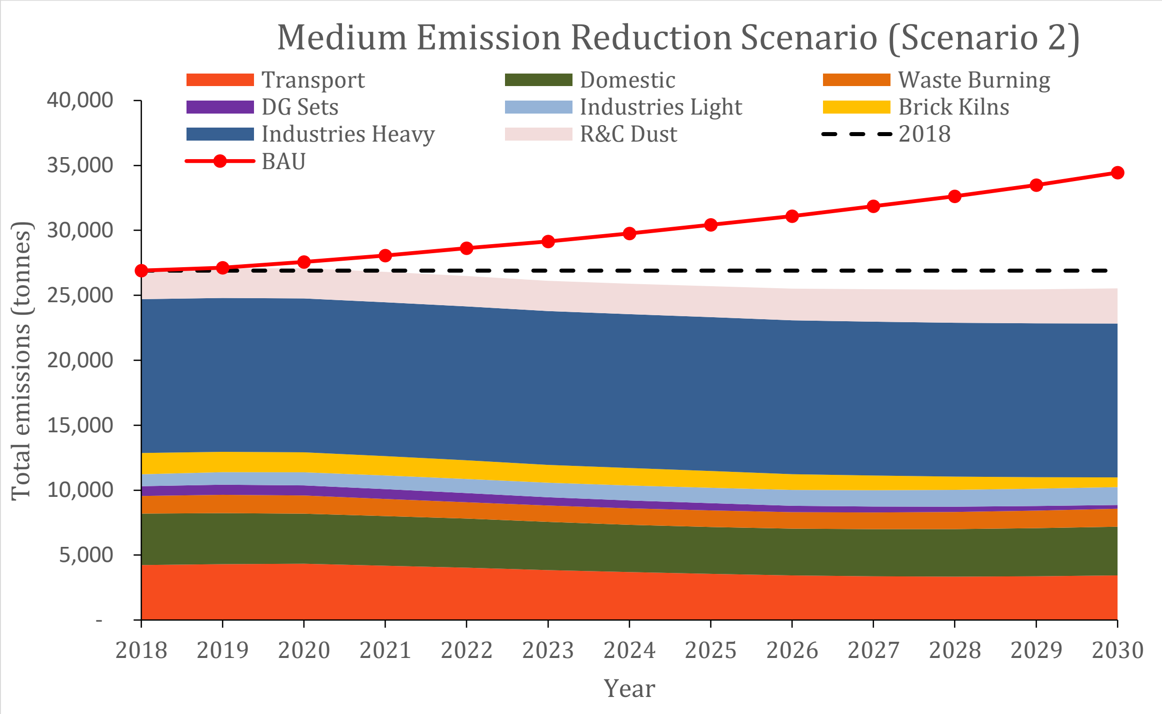


Figure 14: PM2.5 emissions scenario 2 (Medium emission reduction scenario)

Scenario combination 3: Low-emission reduction measure potential combination

This scenario groups all the CMs that a government can implement without any major investments or technology change. Measures such as the introduction of buses (with the majority of new buses being diesel), implementation of existing rules such as the banning of two-stroke auto-rickshaws, shifting to zigzag kilns that use clean technology, etc., will help reduce pollution immediately.

Scenario combination 3:

- Registration of two-stroke autos is banned completely
- At least 10% of the vehicles that are operating in Muzaffarpur to have a valid PUC certificate
- Brick kilns that are present in Muzaffarpur are shifted to natural zigzag kiln
- Composting Plant Capacity: 20 TPD; Dry Waste Collection Centres capacity: 5 TPD
- Installed solar rooftop Capacity – 10 MW
- At least 30% of the traditional *chulahs* are replaced by smokeless *chulahs*
- LPG penetration rate – 85%
- Electrification level – 80%
- No of mechanical road sweepers – 0

Under this scenario it is expected that the total emission load (PM2.5) will only reduce by 19% by 2030 with respect to the BAU scenario and the total emission load (PM2.5) in 2030 will be more than the present levels (2018). The same has been presented in Figure 15 below. We can observe a major contribution in PM2.5 emission reduction in sectors like transport (69%), followed by brick kilns (31%), and other sectors contributing to less than 25% reduction.

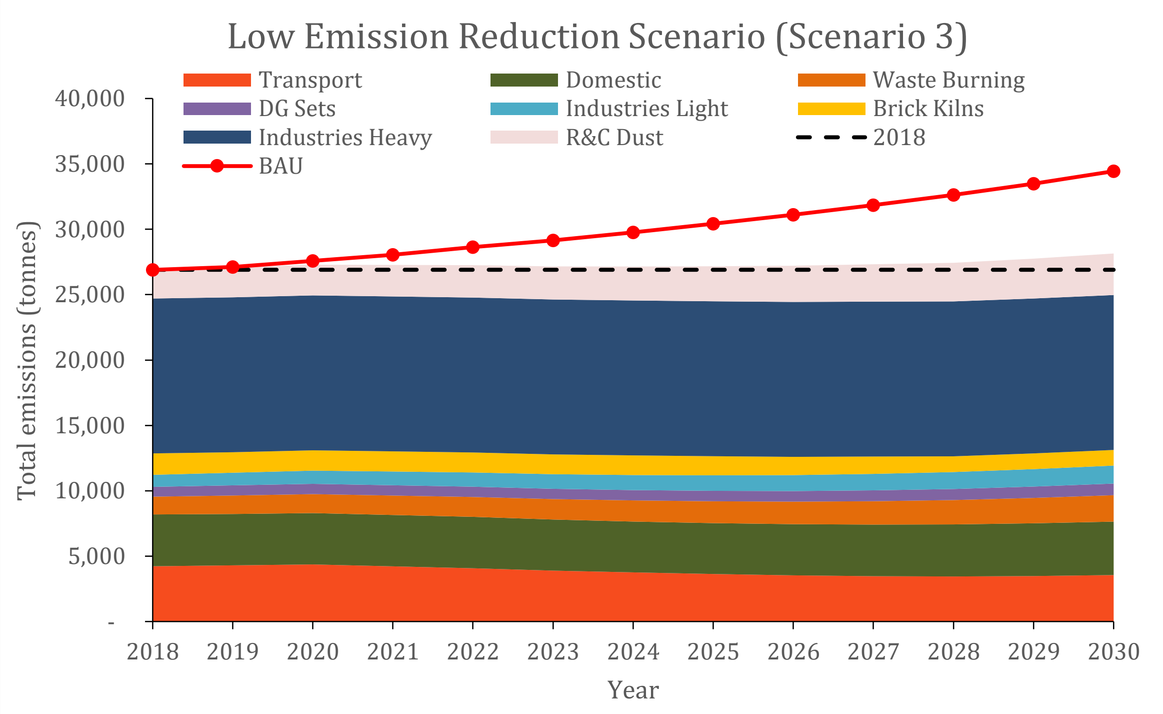


Figure 15: PM2.5 emissions scenario 3 (Low emission reduction scenario)

Economic analysis: scenario combination 1 vs scenario combination 2 vs scenario combination 3

Figure 16 presents the total PM2.5 emission load for high-, low-, and medium-pollution reduction scenarios with respect to baseline (2018) and the BAU scenario.

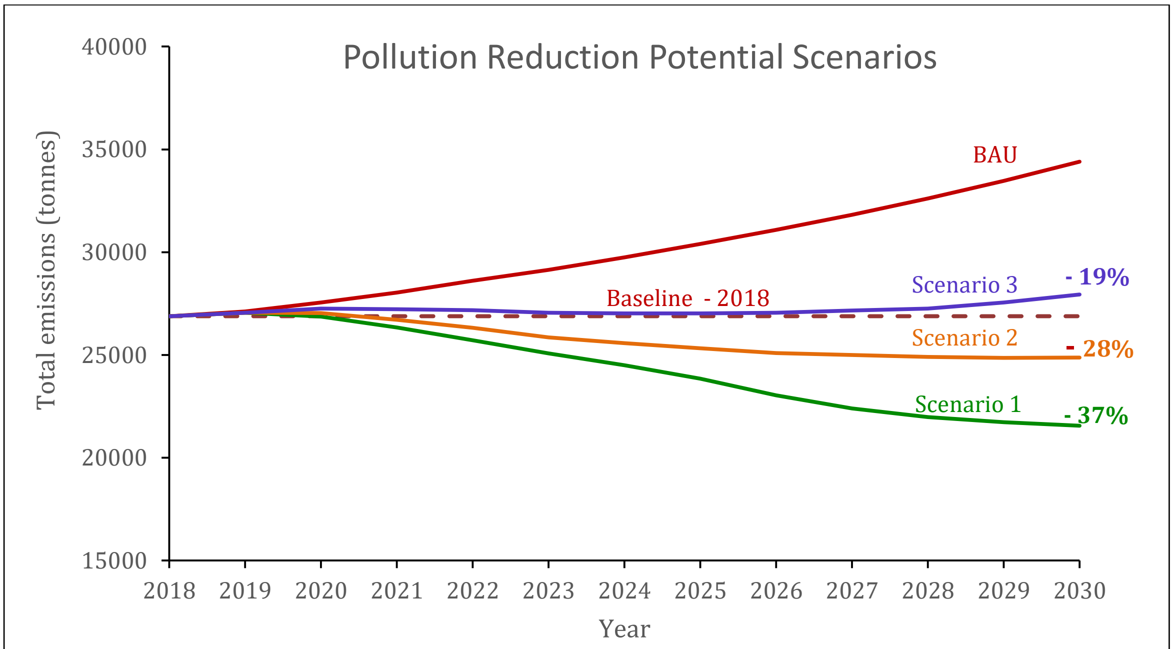


Figure 16: Scenarios— A comparison on emission reduction potential

High-pollution reduction scenario would result in pollution reduction of 37%. The medium- and low-pollution reduction scenarios would result in pollution reduction by 28% and 19% respectively.

Table 12 presents the estimated cost incurred and the potential lives saved under each scenario.

Table 12: Economic analysis (scenario 1 vs scenario 2 vs scenario 3)

Sectors	Private owners	Departments	Cost incurred (INR Cr.)		
			Scenario combo 1	Scenario combo 2	Scenario combo 3
Transport		Traffic Police	0.5	0.5	0.5
		D.O.T[22]	11	10	9
		MMC[23]	80	60	40
Industry	Metal Fabrication		20	20	20
	Brick kilns		22	22	22
SWM		MMC[24]	105	47	30
Domestic		FCS[25]	15	10	8
Solar rooftop		SBPDCL	175	150	75
Road Dust		UD	2.5	1.5	1
		BSPCB	0.4	0.4	0.4
		MMC	90	44	26.5
Lives Saved (No.)			804	603	421
Total			521	365	232

The transportation and solid-waste management sectors require a larger budget allocation for additional machines, vehicles, and new infrastructure to improve the existing practices. However, for other sectors, the cost is either in the form of incentives and implementation cost, or is borne by the private players. Hence, the government's cost burden is reduced.

The cost incurred (INR 521 crore) and the lives saved (804) for scenario 1 is high in comparison to the other two scenarios as described in Table 12. The cost incurred and the benefits are estimated over a period of 11 years (2019 – 2030)

[22] Includes incentives provided for EVs, CNGs, DPFs.
[23] Includes cost incurred to build parking lots
[24] Includes capital & operational cost of the treatment plants and additional vehicles for waste management
[25] Includes incentives provided for new LPG connections, smokeless chulah/ induction stoves, and subsidised cylinders.

6. Recommendations, Implementation Strategy, and Target Setting

Air-pollution management needs a collaborative approach from all concerned departments across Muzaffarpur. Various measures suggested in the study and existing policies must be implemented for effective reduction of the city's pollution levels. The formation of a project management and audit unit is also vital in ensuring time-bound implementation of policies and control measures (CMs). Appropriate indicators to measure the effective implementation of the CMs and progress of the implementation strategy need to be devised.

Based on the techno-economic assessment of the shortlisted CMs for the city of Muzaffarpur, the following policies are recommended:

1. *Muzaffarpur should introduce green public transport (EVs/CNG):* Muzaffarpur city needs to strengthen its existing public transportation. At present, people prefer autos and their own private vehicles as mode of transportation. Old two-stroke autos should be phased out and replaced by electric autos. Electric autos will help reduce tail-pipe exhaust emissions to a major extent.

2. *Vehicle fitness certificate and PUC certificate should be made mandatory for fuel refilling:* Tailpipe emissions from poorly-maintained vehicles are way high in comparison with vehicles that run on ideal conditions. By introducing policies like "No PUC no Fuel" vehicle owners will be more inclined to get the vehicle serviced.

3. *Trucks (diesel) plying in Muzaffarpur must be retrofitted with DPF:* This will cut down tailpipe emission load by around 60% to 80%.

4. *Open dumping of solid waste should be penalised and the municipality should not collect waste if it has not been segregated at the household level:* MMC should ensure 100% door–to-door collection of municipal solid waste. MMC should also develop a mechanism to penalise people who dump their solid waste in open sites. These steps will ensure that waste is collected and treated properly.

5. *Financial incentives (as reduced electricity unit cost) for houses with grid-connected rooftop photovoltaic systems (RTPV):* Muzaffarpur's residents should be encouraged and rewarded for setting up grid-connected RTPV. Unit price of electricity consumption can be reduced, based on solar power generation capacity and household consumption patterns.

6. *LPG distributors should be encouraged to provide 100% door-to-door LPG distribution service: A* robust supply infrastructure (or more LPG distributors) must be set up to ensure door-to-door supply. Increasing the number of LPG distributing centres and workforce will ensure proper door-to-door supply and reduce the use of solid fuel.

7. *Muzaffarpur's city civic body should ensure end-to-end paving of the city's roads based on the examination of local ecological conditions:* Dust on roads must also be removed to ensure road-dust suppression. These measures along with road-side green belt will prevent, to a large extent, dust collection on roads.

6.1 Roadmap, time frame, and essential levers of the plan

This section describes the recommendations, targets, and strategies that should be adopted to ensure effective implementation of the suggested CMs. This section also discusses the various existing schemes in accordance with the suggested CMs. These schemes could be a potential source to financially support the related CMs.

Sector: Transportation

Transportation is one of the major contributors to pollution, contributing 32% to the total pollution concentration in Muzaffarpur. Reducing transportation sector emissions can be a complex process. Table 13 presents the strategies to be followed for implementing CMs.

Table 13: Strategic roadmap - Transportation Sector

S. No	**Strategy**	**Similar funding schemes available**	**Target**			**Implementing agency**
			2022 (Short term)	**2025 (Medium term)**	**2030 (Long term)**	
CM 1	**Complete ban on 2-stroke autos and replacing it with CNG- based vehicle or EV**					
1.1	Ban on 2-stroke autos	-	Complete Ban			D.O.T
1.2	Replacing existing two-stroke autos with E-Rickshaws	-	100%			
1.3	Setting up scrapping centres for old autos (no)	-	1	-	-	
CM 2	**PUC check (every 6 months) and better PUC check infrastructure and management**					
2.1	Setting up PUC centres	-	None			Private owners
2.2	Spreading awareness	-	Awareness programmes			
CM 3	**Incentivising the use of electric vehicles and cleaner fuels (CNG/LPG) for private vehicles**					
3.1	Setting up of incentives for different types of vehicles	FAME scheme	Incentives mechanism already in place			D.O.T
CM 4	**Installation of DPF filters in vehicles**					
4.1	Installation levels of DPFs (in trucks)	-	Upto 10%	-	-	
CM 5	**Efficient parking facilities near hotspots**					
5.1	Installation of parking lot (no)	-	4			D.O.T/MMC

Awareness programmes with a wide public outreach need to be created for promoting acceptance for new modes of transportation.

Sector: Industry

Unlike the transportation sector, emission reduction from the industry sector is directly associated with the kind of technology this sector uses. Policies that enable industries to adopt advanced technologies and fuel need to be enforced. Audit systems need to be set up to monitor the emission from industries. Table 14 lists the strategies that should be followed to ensure implementation of the CMs mentioned above.

Table 14: Strategic roadmap - Industry

S. No	Strategy	Similar funding schemes available	Targets			Implementing agency
			2022 (Short term)	2025 (Medium term)	2030 (Long term)	
CM 1	**Adapting new technologies for brick kilns**					
1.1	Conversion of FCKs to Zig Zag Technology	-	100%			BSPCB Dept. of Industries (Bihar)

Sector: Solid-waste management.

Open waste burning contributes to around 7% of the total emission in Muzaffarpur. Studies suggest that an efficient solid-waste management system can reduce the amount of waste burnt. Table 15 presents the targets and strategies that should be followed to achieve maximum pollution reduction from the solid-waste sector.

Table 15: Strategic roadmap - Solid-Waste Management

S. No	Strategy	Target			Implementing agency
		2022 (Short term)	2025 (Medium term)	2030 (Long term)	
CM 1	**Introduction of composting plants and dry waste collection centre**				
1.1	Setting up laws/ Incentivising mechanism to improve segregation at household level	Awareness programs and policy initiatives to increase the segregation level			
1.2	Level of segregation	70%	75%	80%	
1.3	Installation of composting plants(TPD)	40	40	30	MMC
1.4	Installation of dry waste collection centre(TPD)	10	10	10	

The government should establish stringent regulations to control waste burning during winters. It is observed that roadside dwellers burn leaves and dry waste to dispose them and generate heat to shield themselves from the cold in winters. Therefore, alternative solutions for roadside dwellers need to be provided to discourage them from burning waste.

Sector: Domestic

Wood and biomass (solid fuel) usage for cooking is a major contributor to domestic sector emissions, which can be reduced either by increasing LPG connections or by introducing smokeless *chulahs* / induction stoves. Table 16 details the various targets and strategies that can help ensure the highest levels of pollution reduction from the domestic sector.

Table 16: Strategic roadmap - Domestic sector

S. No	Strategy	Similar funding schemes available	Target			Implementing agency
			2022 (Short term)	2025 (Medium term)	2030 (Long term)	
CM 1	**Introduction of improved *chulahs* (Smokeless chulahs)**					
1.1	Setting up incentivising mechanism	Unnatt *Chulah* Abhiyan (UCA)				Food And Civil Supplies Department, MMC
1.2	Replacement of traditional *chulahs*		50%	+15%	+15%	
CM 2	**Increasing the LPG connections in low-income strata**					
2.1	Setting up new LPG refuelling centre	PAHAL, Ujjwala Yojana	20	+5	+5	Food And Civil Supplies Department
2.2	Increasing the LPG penetration rate		90%	+2%	+2%	
CM 3	**Replacing kerosene with an alternate fuel**					
3.1	Increasing the electricity connectivity	Saubhagya	90%	+6%	+4%	Bihar Renewable Energy Development Agency (BREDA) MMC

Sector: Road Dust

Construction activities, resuspension of dust, unpaved roads, transportation of uncovered material, and uncoordinated roadworks are some of the activities that result in the increase of suspended particles in the atmosphere. Because the sources of road dust are linked to activities of various departments, it is important to have a coordinated approach among various departments to reduce the emission from suspended particles.

Mechanical sweepers need to be adopted and end-to-end road pavements should be constructed to control the resuspension of dust. The strategy that should be followed, under this sector, is described in Table 17.

Table 17: Strategic roadmap - C&D and road Dust

Si. No	Strategy	Target			Implementing agency
		2022 (Short term)	2025 (Medium term)	2030 (Long term)	
CM 1	**To take appropriate action to remove road dust/silt regularly by using either mechanical sweepers / road paving**				
1.1	Road paving (either by laying roads / green cover) – Major roads	80%	90%	100%	MMC
1.2	Addition of new mechanical sweeper of capacity 5-8 tonnes	1	-	-	

Communication and Implementation Strategy:

A task force committee with representation from various line departments needs to be formed, to monitor and implement the CMs. The air-quality monitoring committee should keep a check on the functioning of the task force committee. The task force committee should be headed by the Chief Secretary of the state. The main objective of the committee will be "to reduce the emissions levels in Muzaffarpur region to the target set by NCAP".

The committee should meet every quarter to discuss the a) implementation status of the CMs, b) new policy changes, and c) required future steps. Representatives from line departments should coordinate the implementation strategies within their departments within the stipulated time.

Alongside other stakeholders and funders, various available schemes at the central level need to be considered for creating the corpus needed to implement the action plan.

6.2 Emergency response actions

Despite our best efforts, there may be episodes where pollution levels may increase drastically due to anthropogenic and natural phenomena.

To control this unexpected increase in pollution levels, CMs are suggested in Table 18. These measures, if implemented on an emergency basis, could safeguard our environment.

Table 18: Emergency response action plan

Severe Pollution (ambient PM2.5 concentration values of 250µg/m3 and above)	**Agency responsible/ Implementation agency**
Temporarily stop all construction activities	Bihar State Pollution Control Board (BSPCB)
Temporarily shut down brick kilns, and hot mix plants	BSPCB
Temporarily shut down schools and colleges	
Very poor Pollution (ambient PM2.5 concentration values of 121-250µg/m3)	**Agency responsible/ Implementation agency**
Increase frequency of mechanised cleaning of the road and sprinkling of water on the unpaved section of the road	Muzaffarpur Municipal Corporation (MMC)
Increase public transport frequency and restrict operation of diesel autos	Department of Transport, Govt. of Bihar
Increase parking fee 3-4 times the current value	MMC
Strict vigilance and no tolerance for visible emissions—stop operations of visibly polluting vehicles by putting heavy fines	Traffic police
Stringently enforce all pollution control regulations in brick kilns and industries	BSPCB
Moderate to poor (ambient PM2.5 concentration values of 61-120µg/m3)	**Agency responsible/ Implementation agency**
Strict vigilance and enforcing of PUC norms	Traffic police
Stop burning of solid waste	MMC, and BSPCB
Periodic mechanised sweeping and water sprinkling on the unpaved roads	MMC

6.3 Way forward

Development plays an important role in shaping a city's economy. Although Muzaffarpur has developed at a rapid rate, this development has come at the cost of deteriorated air quality. Unfortunately, the resultant increase in air pollution has had tremendous health impacts. Muzaffarpur's rising air-pollution levels require immediate action and implementation of mitigation measures. Various environmental consequences and the social well-being of people have to be considered while implementing these mitigation measures. Future infrastructural development and growth of the city should be planned only after evaluating the impacts and consequences of the potential environmental damage.

Our study indicates that the mortality benefits [value of a human life—around INR 2.8 crore (Madheswaran, 2007)] of implementing CMs that focus on improving environmental quality far outweigh the costs. Such measures could end up saving hundreds of lives and prevent insurmountable environmental damage.

The effective implementation of pollution-mitigation policies hinges on various considerations, such as various government departments coming to a consensus and adopting a solution-driven approach.

Curbing pollution requires a combined effort from government bodies, local community groups, and citizens. Policies such as increasing the mode share of public transportation, and switching to cleaner fuels will be effective only if the community actively participates in adoption and implementation of these measures. Moreover, a project management and audit unit is to be set up to ensure that the above mentioned strategies are effectively implemented as per the provided roadmap and time frame.

Muzaffarpur already has several institutional requirements in place. The level of waste segregation, support towards plastic ban, etc., show the willingness of the public to improve the situation. Proactive actions from the city municipality in implementing the suggested CMs will help improve the quality of air in the city.

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Appendix:

Annexure A:

Clean Air Action Plan submitted to NGT

Sl. No	Sector	Action Points	Technology/Infrastructure requirement (TR/IR)/ Methods (M)/ Outcome (OC)	Implementation period (Short – 6 months, Med- <2 yrs.), long – (>2 yrs.)	Implementation agency	Time target for implementation
1	Transportation	Restriction on plying and phasing out of 15 year old commercial diesel driven vehicles[26]*	OC- Reduction In black carbon emissions M- Policy reforms	Medium	Transport Dept. Govt. of Bihar	December 2019
		Complete ban on 2-stroke autos and replacing them with EV	TR—E-rickshaws OC—Reduction of emission load from autos	Medium - Long		December-2022
		PUC check (every 6 months) and Better PUC check infrastructure and management (Hon'ble Supreme court of India in W.P.(C) no 13029/1985 said that pollution testing centres should be set up within premises of all petrol pumps)	OC—With better PUC infrastructure and strict pollution norms emission from private and public vehicles will decrease	Medium		December-2020
		Incentivising the use of cleaner fuels - electric vehicle and (CNG/LPG) for private vehicles	TR—Proper infrastructure to increase the adoption rate of cleaner fuels OC—Reduction of emission load from private vehicles which switched	Long		December-2022

[26] Subject to clearance from Honourable High court

			to Electric/CNG/LPG based vehicle from Petrol/Diesel based vehicles			
		Installation of Diesel Particulate Filter (DPF) in all the diesel vehicles[27]	M—Installing DPF filters to existing diesel vehicles OC—Reduction of emission load from diesel vehicles	Medium	Transport Dept. Govt. of Bihar	December-2020
		Good traffic management including re-direction of traffic movement to avoid congestion.	OC- Reduction in emission due to non-congestion TR- Policy intervention	Medium	Traffic police	December 2020
		Demarcated lanes for E rickshaw's plying for public commuting	OC- Reduction in emission due to non-congestion TR- Policy Intervention	Short	Traffic police	Immediate
		Development of Multi level parking	OC- Traffic congestion & road encroachment reduction, emission reduction M- Land space demarcation around public transportation hotspots	Long	MMC	December 2023
		Monitoring of Vehicle fitness	OC- Reduction in emission M- Audit systems	Short-Medium	Transport & Traffic dept.	December 2019
		Checking on fuel adulteration	OC- Reduction in emission M- Audit systems	Short	District Administration & Oil companies	April 2019
		Periodic calibration test of vehicular emission monitoring instrument.	OC- Reduction in emission M- Audit systems	Short	BSPCB & Transport	April 2019
		Complete ban of carriage transport, heavy vehicles, during peak hours (8:00 -11:00 am & 5:00 - 8 pm).	OC—Reduction in peak hour traffic will facilitate faster vehicle	Short	Traffic police	April 2019

[27] Policy decision – MV Act doesn't have provision for installing DPF.

		(Arranging alternate routes to all carriage transports between	movement and reduce tail- pipe emission			
		Launch drive against any vehicle with visible smoke coming out of it and ensure strict compliances		Short	Traffic police	April 2019
2	**Industry**	Adapting new technologies for Brick kilns	Adapting Cleaner technology	Medium	Bihar State Pollution Control Board (BSPCB) Dept. of Industries (Bihar)	December 2019
		Random auditing for 1) Air pollution measures 2) Online reporting systems in the industries	Setting up of policies and institutions that conduct random auditing for air pollution control measures Prevents opening up of new industries that fall under Red Category and Orange Category.	Medium		December 2019
		Introduction and shifting towards cleaner fuels in induction and casting industries	M- Regulatory requirements	Medium		December 2019
		Ban on Polluting Industries	M- Regulatory requirements	Short		June 2019
3	**Biomass & Garbage Burning**	Check Stubble burning	OC- Reduction in emission from stubble burnings M- Regulatory as well as awareness sensitisation	Medium	Dept. Of Agriculture	December 2020
		Identify garbage burning locations and strict enforcement of NGT (2016) rules regarding prohibition of garbage burning.	OC—Reduction in emission load from garbage burning OC—Reduction in emission load from SWM	Short	MMC	Immediate

		1) Installing new waste composting plants at city level and/or increase the capacity of existing composting plants 2) Recycling plants for dry waste.	M – Composting plants OC – Composting waste/garbage will reduce the emission load from garbage burning	Medium	MMC	December 2019
4	**Domestic**	Increasing the LPG connections in low income strata. To mandate LPG/Bio gas in commercial eateries.	M—Increase in LPG connection OC—Reduction in emission load	Medium	Food And Civil Supplies Department	December 2020
		Introduction of improved *chulahs* (Low emission *Chulahs*)	1) Identifying areas for using *chulahs* 2) Procuring the *chulahs* OC – Reduction in indoor emission load	Medium	Food And Civil Supplies Department	December 2020
		Ensuring uninterrupted electric supply within the city.	OC—Reduction in total emission load from kerosene lamps (as power cut backup will not be required)	Medium	South Bihar Power Distribution Company Limited	December 2019
		Ensure easy availability of affordable cleaner cooking fuels (LPG in urban areas & biogas in rural areas)	M—Improvement in LPG/Bio gas infrastructure	Medium	Food & Civil supplies Dept.	December 2020
5	**Construction & Demolition**	Construction materials should be transported in covered vehicles	OC—Reduction in emission load from dust	Short	Traffic Police	Immediate
		To mandate facility of tar road inside the construction site for movement of vehicles carrying construction material	OC—Reduction in emission load from dust	Medium	MMC	December 2019
		Promotion of the use of prefabricated blocks for building construction	OC—Reduction in emission load from dust	Long		December 2020

		Strict enforcement of CPCB guidelines for construction (use of green screens, side covering of digging sites, etc.)	OC—Reduction in emission load from dust	Short	BSPCB	Immediate
		Demolition & construction Sites should be covered from all sides	OC- Reduction in Road dust	Short	MMC	Immediate
		Restriction on storage of construction materials along the road.	OC- Reduction in road dust	Short	MMC	Immediate
6	**Road Dust**	To take appropriate action to remove road dust/silt regularly by using mechanical sweepers	Mechanical sweeping Identifying the road stretch with high silt content Procuring the mechanical sweepers	Short	MMC & Urban Development Dept.	Immediate
		End to end road pavement	OC—Reduction in resuspension of dust M—Improvement in infrastructure	Medium		
		Creating green buffer along the roads.				
7	**Power Plant**	Strict enforcement of CPCB emission rules	OC – Reduction in emissions	Medium	BSPCB	December 2019
8	**Strengthening of AAQ monitoring**	Installation of four CAAQMS at Muzaffarpur. a) Two CAAQM stations under CSR funds of CPSU through CPCB at Eco-Park. b) Two CAAQM stations under State Govt. financial assistance.	OC- Proper evidence on sectorial contributions with primary baseline surveys to update the emissions inventory.	Short	BSPCB	June 2019

		Source apportionment study (Dispersion +Receptor) Modelling	OC- identification of pollutants	Medium	BSPCB	December 2019
9	**Public Awareness**	Issue of advisory to public for prevention and control of air pollution	OC- Awareness and better implementation of policy	Short	BSPCB MMC & Dept. of Environment, forest & Climate Change	Immediate
		Launch public awareness programme campaign to control air pollution	OC—Through awareness, public participation for air pollution reduction will increase	Short		Immediate
9	**Others**	Compliance of guidelines on DG sets and action against violation	OC- Reduction in black carbon TR- DPF (Diesel Particulate Filters installation)	Short	BSPCB & MMC	Immediate
		Help line to oversee non-compliances on aforesaid issues.	OC- Awareness and better implementation of policy	Short	BSPCB & MMC	Immediate
		Hospital incinerators for bio-medical incineration	OC—Reduction in bio-hazardous materials being dumped in to the landfill	Short	BSPCB & MMC Dept. of Health (Govt. of Bihar)	Immediate
		City wise cap on coal use	OC—Reduction in coal consumption will reduce the emission load	Medium	BSPCB FCS	December 2019
		Polluter pay principle	OC—Will act as a deterrent against polluters	Medium	BSPCB	December 2019
		Transportation of municipal solid wastes, construction materials and debris in covered system.	OC- Minimization in road dust M- Monitoring of Implementation	Short	MMC	Immediate
		Immediate lifting of solid wastes generated from de-silting and cleaning of municipal drains for its disposal.	OC- Minimisation of road dust M- Monitoring of Implementation	Short	MMC	April 2019

Annexure B:

Total emissions for Muzaffarpur for the base year 2018 (Tonnes)

	PM2.5	PM10	BC	OC	NOx	CO	VOC	SO_2	CO_2
Transport	4,235	4,458	1,729	1,357	6,366	54,864	15,096	102	14,60,619
Cooking	1,310	1,379	202	669	288	20,594	2,331	145	1,75,209
Lighting	171	180	164	1	0	23	2	17	5,633
Heating	2,479	2,610	326	1,361	272	25,888	4,154	170	86,120
Open Waste Burning	1,358	1,429	101	819	33	6,525	1,314	35	8,700
Construction Dust	865	4899	-	-	-	-	-	-	-
DG sets	752	792	442	141	7,048	1,873	180	71	3,20,185
Industrial Light	920	929	332	184	557	1,189	116	240	74,226
Brick Kilns	1,637	1,653	467	705	819	22,064	2,596	492	83,031
Industry Heavy	11,843	12,736	595	356	18,480	16,521	2,903	234	5,580
Road Dust	1,332	8,880	-	-	-	-	-	-	-
Total	**26,902**	**39,945**	**4,357**	**5,592**	**33,863**	**1,49,540**	**28,692**	**1,504**	**22,19,304**

Total emissions for Muzaffarpur for year 2030 (Tonnes)

	PM2.5	PM10	BC	OC	NOx	CO	VOC	SO_2	CO_2
Transport	8,118	8,545	2,993	2,672	9,681	1,09,742	34,876	28	27,47,246
Cooking	1,454	1,531	226	742	318	22,999	2,588	174	2,24,782
Lighting	188	198	180	1	-	25	2	18	6,180
Heating	2,993	3,150	394	1,644	327	31,187	4,989	204	1,01,681
Open Waste Burning	2,251	2,370	167	1,358	54	10,819	2,179	58	14,425
Construction Dust	1,321	7,484	-	-	-	-	-	-	-
DG sets	1,147	1,208	674	214	10,753	2,857	274	108	4,88,498
Industrial light	1,376	1,390	497	276	833	1,779	173	358	1,11,054
Brick Kilns	1,645	1,662	469	709	824	22,174	2,609	494	83,446
Industry Heavy	11,843	12,736	595	356	18,480	16,521	2,903	234	5,580
Road Dust	2,100	14,000	-	-	-	-	-	-	-
Total	**34,436**	**54,272**	**6,195**	**7,972**	**41,271**	**2,18,103**	**50,595**	**1,676**	**37,82,892**

Annexure C: Sector wise formulas, data considered and assumptions

Key Macro-Economic Variables

Variable	Value
Inflation Rate (CPI)	4.30%
Average Person per household	5.9
Population (2018) (Lakhs)	5.2
Population (2030) (Lakhs)	7.3

A) Sector: Transportation

1) Vehicle characteristics in Muzaffarpur (2018)

Total vehicle fleet: 7,40,059 (District), 1,05,925 (city)

Vehicle type	% share
Truck	4%
Bus	1%
Car	4.6%
Taxi	2.3%
Jeep	1.6%
Three-wheelers	3.3%
Two-wheelers	78.1%
Tractor	3.6%
Trailer	1%

Source: Data from Transportation Department

2) Incentives provided to autos

Autos	EV
Incentives (INR)	61000

3) Incentives provided to buy CNG/LPG/Electric vehicles (FAME Scheme)

Type	Incentive (INR)
Electric Vehicles	As per the FAME scheme
CNG retrofitting	20000 – 30000

4) Petrol bunks in Muzaffarpur

Petrol bunks & PUC's		
Total No of petrol bunks in Muzaffarpur	12	
Total No of PUC centres	34	8 with valid licence

B) Sector: Industry

Brick kilns in Muzaffarpur	
Total	86

1) Most polluting industries (Red Category) in Muzaffarpur

Name & address	Fuel consumed
M/S Unique foods, At-Patahi, Rewa Road, Muzaffarpur	Coal- 300 kg/day
M/S Ganesh foundary & Casting Ltd., At-Sipahpur, P.O- Bhkhanpur, Muzaffarpur	Coal- 80 MT/day
Tirhut dugdh utpadak sahkari sangh ltd., Muzaffarpur	Coal- 1.5 MT/day
M/s Mehrotra engg works pvt. Ltd. Phase-1, Industrial estate, Bela, Muzaffarpur	Diesel- 7 kl/month
M/S Legend alloys pvt ltd, Industrial Area, Bela, Muzaffarpur	Coal- 6 MT/day Wood- 200 kg/ day
M/S Maa bhagwati sponge irone pvt. ltd, at-Ramtomha, P.O- pipraha, P.S-Minapur, Muzaffarpur	Coal
Kanti bijlee utpadan nigam limited, Kanti, Muzaffarpur	Coal- 2500 MT/ day

2) Casting technologies considered for metal fabrication industries.

Furnace technology	Fuel used	Cost (INR)
Gas-fired cupola	Gas	Total operating Cost/Metric Ton of molten metal : INR 30,000; Capital Cost: INR 46 Lakhs
Induction	Electricity	Total operating Cost/Metric Ton of molten metal : INR 35,000; Capital Cost: INR 30 Lakhs
Rotary	Light Diesel Oil	Total operating Cost/Metric Ton of molten metal : INR 34,000; Capital Cost: INR 10 Lakhs

Source: (Krishna et al., 2009)

C) Sector: Solid Waste Management

1) Waste Composition

Compostable	Recyclable	Non- Compostable
55%	18%	27%

2) Projected solid waste generation

Projected values		
Year	Projected Population	Solid waste Generation (TPD)
2018	5,21,090	180
2019	5,39,050	188
2020	5,57,010	196
2021	5,74,970	205
2022	5,92,930	213
2023	6,10,890	222
2024	6,28,850	231
2025	6,46,809	240
2026	6,64,769	249
2027	6,82,729	258
2028	7,00,689	267
2029	7,18,649	277
2030	7,36,609	287

3) Proposed waste segregation level

	Assumptions	Estimates		
Year	Proposed waste segregation level	Segregated compostable waste (TPD)	Segregated recyclable waste (TPD)	Non compostable + Unsegregated (TPD)
2018	0	0	0	180
2019	70%	51	17	121
2020	70%	57	19	121
2021	72%	61	20	124
2022	72%	68	22	124
2023	75%	73	24	125
2024	75%	76	25	130
2025	75%	84	27	128
2026	77%	90	29	130
2027	77%	98	32	127
2028	77%	102	33	132
2029	77%	106	35	137
2030	80%	120	39	128

4) Proposed waste treatment plants (TPD)

Year	Addition of new Composting plants	Composting Plant Capacity	Addition of new Dry Waste Collection centres	Dry Waste Collection Centre	W2E Plants
2019	0	7	0	7	0
2020	0	7	0	7	0
2021	30	47	10	17	0
2022	0	47	0	17	0
2023	0	47	0	17	0
2024	40	87	10	27	0
2025	0	87	0	27	0
2026	0	87	0	27	0
2027	0	87	0	27	0
2028	30	117	10	37	0
2029	0	117	0	37	0
2030	0	117	0	37	0

D) Sector: Domestic

Incentives provided

CMs	Incentives provided (INR)
New LPG connection	1600
Smokeless *Chulah*	750 – 2500
Purchasing a cylinder	300

Annexure D:

Data requirement form

S. no	Sector	Concerned Departments	Data Required
1	Transportation	Transport Department, Govt. of Bihar	1) Number of vehicles (buses/ Autos (2 strokes, E-Rickshaw and 4 strokes)/ two wheelers/ Cars/taxis/Heavy vehicles) plying in Muzaffarpur 2) Vehicles registration details for the past 15 years (Yearly data for all vehicles) 3) Number of new buses proposed for public transportation in the city (if any) and type of buses 4) Total number of existing and proposed charging infrastructure for EVs.
		Bihar State Pollution Control Board (BSPCB)	1) Number of Pollution Under Control (PUC) centres (Operational and Non-operational centres) 2) Year of calibration (last) for the PUC units
		Bihar State Food & Civil Supplies Corporation Ltd.	1) Total number of existing and proposed charging/ fuelling infrastructure for CNG/LPG 2) Number of parking facilities (Public/Private) that are available in the city and their vehicle parking capacity 3) Number of petrol stations carrying out fuel adulteration
		Muzaffarpur Municipal Corporation (MMC)	1) Number of petrol pumps and the amount of fuel sold and types of fuel sold 2) Total road length in the city, types of road and road width
2	Industries	BSPCB, Bihar Industrial Area Development Authority (BIADA)	1) Total no. of Industries in Muzaffarpur (Segregated based on Industry Type/ Fuel Used/ Location-inside city/ outside city, emission details if monitored by BSPCB) 2) Total number of brick kilns in Muzaffarpur (Segregated based on technology used/ fuel they use/ location-inside city/outside city) 3) List of Metal fabrication industries that use clean technologies 4) Number of industries that meet the standards set by CPCB 5) List of industry with waste disposal facilities, their waste treatment technology and their treatment capacities 6) An estimate on the total number of DG sets (industrial) that are used in Muzaffarpur 7) Average running hours
3	Diesel Generator sets		1) Estimate of number of DG sets used for commercial and domestic purpose 2) Average running duration (hrs./day) 3) Capacity of the DG sets (KVA)
4	Health	Health Department, Govt. of Bihar	1) Total number of respiratory health diseases registered in various hospitals (details for at least one year)

			2) Average cost that is spent on one person on respiratory health diseases 3) Average number of days a person stays in a hospital for cases related to respiratory health diseases
		BSPCB	1) Total number of hospitals with incineration facility (Total/Operational) 2) Amount of medical waste that is generated in Muzaffarpur hospitals (tonnes/day) 3) Number of medical waste processing units
5	Solid Waste Management	BSPCB, MMC	1) Total solid waste generated in the city (tonnes/day)-domestic 2) Total solid waste collected and treated per day 3) Total waste burned on daily basis 4) Total number of solid waste treatment plants (composting/ recycling/ waste to energy plants) in Muzaffarpur and their treatment capacity. 5) Total amount of waste that is (generated by the industries (tonnes/day)/ treated by the industries (tonnes/day)/ disposed by the industries (tonnes/day))
6	Domestic, Institution & commercial.	MMC, BSPCB	1) Total urban, rural and slum population in the city 2) Number of slums inside the city 3) Mode of cooking and fuel used by the slum people (biomass burning, *chulahs*, dung cakes etc.) 4) Total number of households that use *chulahs*. 5) Percentage of households that have access to electricity 6) Type of fuel used in households (cooking-LPG, kerosene, and lighting-electricity. Kerosene for lamps etc.)
7	Road side vendors/eateries		1) Total number of roadside vendors that use DG sets 2) Type and amount of fuel used for (Cooking / DG sets)
8	Others	Finance Department, Govt. of Bihar	Average income of a person in Muzaffarpur
		MMC	Average land cost in Muzaffarpur