WRI INDIA ROSS CENTER

Bloomberg Philanthropies

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Gujarat Pollution Control Board

Surat Municipal Corporation

SURAT CLEAN AIR ACTION PLAN

COMPREHENSIVE REPORT

ABOUT THE REPORT

The Surat Clean Air Action Plan has been prepared as part of the National Clean Air Programme of the Ministry of Environment, Forest and Climate Change by WRI India in collaboration with Surat Municipal Corporation and Gujarat Pollution Control Board with support from Bloomberg Philanthropies and Shakti Sustainable Energy Foundation.

ACKNOWLEDGEMENTS

WRI India would like to thank all collaborating agencies and their teams of researchers and collaborators, especially Bloomberg Philanthropies, Shakti Sustainable Energy Foundation, Surat Municipal Corporation, Gujarat Pollution Control Board, and The Energy Resource Institute. A detailed acknowledgment has been provided at the end of this document.

Cover image credit: Surat Municipal Corporation

Report citation: Nagpure, A.S., Anadkat, V., Sharma, B., Shaikh, Z., Tyagi, V., Ali, S., Wankhade, K., Patidar, R., Ramprasad, V., Krithi, V., Daftardar, C., Kajol, Krishnan, D., Pai.,M. 2021. *Surat Clean Air Action Plan: Comprehensive Report*. World Resources Institute India, New Delhi

ABOUT WRI INDIA

WRI India is a research organization with experts and staff who work closely with leaders to turn big ideas into action to sustain a healthy environment—the foundation of economic opportunity and human well-being. We envision an equitable and prosperous planet driven by the wise management of natural resources.

WRI India works on a unique three-fold approach, as highlighted below:
Count It: We start with the data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies.

Change It: We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

Scale It: We don't think small. Once tested, we engage with decision-makers to carry out our ideas and elevate our impact. WSe measure success through government and business actions that improve people's lives and sustain a healthy environment.

C. R. PAATIL
MEMBER OF PARLIAMENT
LOK SABHA
Chairman
House Committee, Lok Sabha
Member
Urban Development Committee

Dt. 17/12/2021

Message

Air Pollution is a major challenge faced globally, with many detrimental environmental, health and economic impacts. India is at the forefront of the global struggle against air pollution. The Government of India has launched National Clean Air Programme (NCAP) in 2019. Its goal is to tackle air pollution problems in cities of India with a long-term, time-bound strategy to achieve a 20-30% reduction in the Particulate Matter concentrations by year 2024 (taking 2017 as the base). The NCAP has so far identified 132 non-attainment cities. Under the NCAP, these cities need to prepare City Clean Air Action Plans, including mitigation strategies for every air pollution contributing sectors. Surat, the second largest city of Gujarat, is also one of the non-attainment city. Therefore, Surat has also come forward and prepared Surat Clean Air Action Plan.

The Surat Clean Air Action Plan has been an outcome of Source Apportionment study of PM10 & PM2.5 at Surat city for two seasons, primary surveys and involvement of all stakeholders. I am sure that, by implementations of all the mitigation measures mentioned in the action plan, Surat city will have cleaner air. I am also confident that, Surat Clean Air Action Plan would be guiding document to all non-attaintment cities of the country.

I offer my congratulations to World Resources Institute-India (WRI-India), Surat Municipal Corporation and Gujarat Pollution Control Board for preparation this document. I extend my heartiest congratulations to Bloomberg Philanthropies, Shakti Sustainable Energy Foundation for supporting this study and contributing towards improvement of air quality in Surat.

CRPatil

C R Paatil

(AN ISO 9001:2015 Certified Office)
Parliament Office : 141, Parliament House, New Delhi -110001. Tele. : 011-23019598, 23034719
Delhi Office : 501, New M. S. Flats, **'Narmada'**, Dr. B.D. Marg, New Delhi -110001
Telefax : 011-23313371, Delhi Mobile : 09013180249
Surat Office : 9, Amba Nagar, Udhna-Magadalla Road, Surat-395002 (Gujarat) Personal
Mobile : 098241 27694 Toll Free : 1800-2331590, Ph. : 0261-2300000 (100 Lines)
Surat Mobile : 09428822424, Ph. : (0261) 2633467, 2630404, Fax : (0261) 2630405
E-Mail : c_r_patil@yahoo.com, Website : www.crpatil.com

Hemali Boghawala

Mayor,
Surat Municipal Corporation

Message

Surat is the second largest city in Gujarat and one of the biggest commercial and economic centers in western India. It has well-established diamond and textile industries and is a shopping center for apparel and accessories. It is predicted to be the world's fastest-growing city between 2019 and 2035. Due to the pace of development, the city has witnessed the degradation of air quality in the past few years. With the aim to improve the poor quality of air in Surat city, Surat Municipal Corporation has taken several proactive steps and decided to prepare a Clean Air Action Plan for the city.

As the Mayor of Surat city, I am pleased that the Surat Clean Air Action Plan is a comprehensive document that details sector and source contributions, control measures and strategies, techno-economic analysis, micro-planning, etc. I strongly believe that this action plan would help all line agencies and stakeholders to stimulate concrete efforts to combat air pollution in the city,

I am confident that the strategies, control measures, and actions proposed in the Surat Clean Air Action Plan will be implemented by all responsible line agencies. This will help improve the air quality of Surat city.

I congratulate the officials at Surat Municipal Corporation and Gujarat Pollution Control Board on the publication of the Surat Clean Air Action Plan document.

I take this opportunity to thank and acknowledge the support of Bloomberg Philanthropies, Shakti Sustainable Energy Foundation, WRI India and TERI, Gujarat Pollution Control Board, other organizations in Surat city, and the experts' for their contribution in preparing this report.

(Hemali Boghawala)
Mayor
Surat Municipal Corporation

(M): +91 97243 45101 (O) 0261 2422255, Fax : 0261 2411424, mayor@suratmunicipal.org
Address : 37, Nita Society, Tadwadi, Rander Road, Surat.

सत्यमेव जयते

Gujarat Pollution Control Board
Paryavaran Bhavan, Sector-10-A
Gandhinagar - 382 010, Gujarat

Sanjeev Kumar, IAS
Chairman

Foreword

National Clean Air Programme (NCAP) is a flagship programme of MoEF&CC aimed to improve ambient air quality in non-attainment cities of the country. There are four non-attainment cities in the State of Gujarat viz. Ahmedabad, Surat, Vadodara and Rajkot. Under the guidance of MoEF&CC and CPCB, preparation & implementation of Air Action Plan, its review through mechanism of three tier Committee etc. are on full swing. Funding under XV-FC is also allocated to each of the city under this programme for improvement in the ambient air quality which is performance linked.

I appreciate the continuous efforts of Surat Municipal Corporation (SMC), World Resources Institute (WRI, India), Bloomberg Philanthropies and Shakti Sustainable Energy Foundation who have come together and developed this encyclopedic Surat Clean Air Action Plan based on the findings of Source Apportionment Study of Surat City. I do hope this Surat Clean Air Action Plan becomes a benchmark for other non-attainment cities too.

Controlling air pollution is not a one-day exercise and requires constant efforts and periodic updates to tackle polluting activities at the source. Hence, our efforts will always be to keep working towards a clean and better air for all the residents of Surat.

I wish all the success to the Surat city for their future endeavors.

Sanjeev
Gujarat Pollution Control Board

GPCB
Tel.: (O) 079-23222425 E-mail : chairman-gpcb@gujarat.gov.in
web : http://gpcb.gujarat.gov.in

NO-COM./76.
Dt. 17/08/2021.

BANCHHANIDHI PANI, IAS
Commissioner

SURAT MUNICIPAL CORPORATION
MAHANAGAR SEVA SADAN
MUGALISARA, SURAT - 395 003.

Message

Poor air quality is among the most pressing environmental and health challenge of our time. The World Health Organization has warned that air pollution is 'the new tobacco' harming us with every breath we take. On 10 January 2019, the Ministry of Environment, Forest and Climate Change, Government of India, launched the National Clean Air Programme as a five-year strategy to control air pollution levels in a comprehensive and phased manner across the country. As part of this program, each of the 124 non-attainment cities identified by the Central Pollution Control Board needs to develop a city-specific air pollution mitigation action plan. Owing to the high levels of air pollution in the last few years, Surat is among those cities that find a place in the list of non-attainment The Surat Municipal Corporation has continuously strived towards enhancing the quality of life of its citizens and decided to conduct a source apportionment study for Surat city and develop the Surat Clean Air Action Plan. I am pleased to present the Surat Clean Air Action Plan developed as part of the National Clean Air Programme. This action plan has been developed on the basis of the findings of the source apportionment study. The consistent and sincere efforts and involvement of committed stakeholders of Surat made this study possible.

I take this opportunity to acknowledge the support and guidance of the Gujarat Pollution Control Board, Government of Gujarat.

I am incredibly grateful to Bloomberg Philanthropies, Shakti Sustainable Energy Foundation, WRI India, and TERI for facilitating the development of the Surat Clean Air Action Plan.

I am deeply grateful to Shri. Mukesh Puri, IAS, Additional Chief Secretary, Urban Development and Urban Housing Department, Government of Gujarat, who supported the preparation of the plan.

I also gratefully acknowledge and express deep appreciation to the many wonderful people who have made this project possible:

- Hon'ble Mayor, Dy Mayor, Chairman Standing Committee, and leader of the Opposition for their interest

Tel. No. (0261) 2422244 (O) Fax No.(0261) 2422110/2451935 E-mail : commissioner@suratmunicipal.org

SWACHH SURVEKSHAN 2021

SURAT MUNICIPAL CORPORATION
MAHANAGAR SEVA SADAN
MUGALISARA, SURAT - 395 003.

- Local leaders, MPs, MLAs, Heads of NGOs, Chamber of Commerce, Engineering Association, Architect Association, Builder Association, CREDAI members, Textile Association, Industrial Association, SVNIT, CEPT University, Government officials, and seminar participants whose deep sharing and synergy have moved us many levels beyond our own thinking
- All Municipal Councilors of for their valuable suggestions and interest
- The print media and digital/TV media for covering events and encouraging people's participation in the exercise
- My team at Surat Municipal Corporation, all Deputy Commissioners, technical advisors, city engineers, additional city engineers, executive engineers, environment engineers, town planning officers, and my personal staff for their synergy and for going the extra mile.

Last but not the least, I would like to place on record my belief that the document is certain to provide a new road map for providing cleaner air to Surat city and lead to a better and healthier environment for the citizens of Surat city.

(Banchhanidhi Pani)

Tel. No. (0261) 2422244 (O) Fax No.(0261) 2422110/2451935 E-mail : commissioner@suratmunicipal.org

MESSAGE

Bloomberg
Philanthropies

Air pollution is one of the biggest global challenges of our time impacting public health, the environment, and the economy. It is also a complex issue, especially in developing countries, with many different causes and sources — from transport and industry to waste and cooking. Yet, if we look at examples of the progress made on clean air, from cities in different parts of the world, we find that it is a challenge that can be addressed.

At Bloomberg Philanthropies, we support work worldwide to enable better evidence and data, policy action and design, and capacity building to help address climate and environment issues, including air pollution. We are pleased to be working with the Surat Municipal Corporation, the Gujarat State Pollution Control Board, and our partners at WRI India, TERI, and the Shakti Sustainable Energy Foundation to improve air quality in Surat.

This effort is part of Bloomberg Philanthropies' broader partnership with the Indian Ministry of Environment, Forest, and Climate Change on India's National Clean Air Program, supporting air quality work in other Indian cities including Patna, Bangalore, and Mumbai. Our experience shows that cities can learn from one another and have a significant role to play in reducing air pollution. The Surat Clean Air Plan is based on a deep analysis of the sources and causes of air pollution and was developed through stakeholder consultations. We thank the city of Surat and the state of Gujarat for their efforts and leadership.

Surat is a remarkable city, one whose population is growing rapidly. As it grows, local leaders have a unique opportunity to integrate clean air action and adopt sustainable urban development strategies to improve citizens' health, well-being, and quality of life; and become an example for other cities.

Ms Priya Shankar
India Director, Environment and Climate Program
Bloomberg Philanthropies

MESSAGE

Air pollution is a serious threat to public health and communities at large. A 2020 report by IQAir, illustrated that 22 out of 30 of the world's most air polluted cities were in India. Over the years, the Government of India has taken steps to address the issue of rising air pollution levels. Of these initiatives, the National Clean Air Programme (NCAP), launched in 2019, is the most focused and cross-sectoral. NCAP urges cities to formulate a comprehensive plan to tackle the crisis.

Air pollution levels are associated with different sectors including industry, transport, construction, and waste to name a few. Therefore, it is imperative to have multi-sectoral strategies, for air pollution mitigation, in place. The city clean air action plans also need to be context specific as pollution levels in cities may vary depending on geography, meteorology, population density and primary polluting sources. The mitigation measures, therefore, must be designed accordingly.

The comprehensive Surat Clean Air Action Plan, developed by WRI India, follows a sector specific multi-stakeholder approach to provide detailed recommendations on cost-effective ways to address air pollution in Surat. The plan serves as a key guiding document for Surat's officials as they tread on the path towards clean air.

I take this opportunity to thank and acknowledge Bloomberg Philanthropies for their support. A big congratulations to the teams at WRI India and TERI for putting together this comprehensive plan, the officials of Surat Municipal Corporation and Gujarat Pollution Control Board for their support and feedback, and to all the experts and other stakeholders for their valuable inputs.

Dr. Anshu Bharadwaj
Chief Executive Officer
Shakti Sustainable Energy Foundation

MESSAGE

WRI INDIA

Air pollution is a significant risk factor and a major public health challenge for a number of pollution-related diseases, including respiratory infections, heart disease, stroke, and lung cancer, etc. Due to air pollution, various govt officials, policymakers, and decision-makers have been forced to identify sources of air pollution and control measures thereon.

In order to control the pollution, the city-level intervention is essential. In which, especially to identify sources of air pollution such as emissions by vehicles, burning solid waste, dust-earthen emissions from construction activity, emissions from the commercial use of DG sets, continuous emissions through industrial units, burning activities in agricultural farms in the surrounding areas of the city, etc. For which, it is required to carry out source apportionment study and prepare strategies to reduce air pollution in the city. Throughout India, the National Clean Air Programme (NCAP) is being implemented by various State and City administrations under the aegis of the Ministry of Environment, Forests and Climate Change, Government of India, taking into account the problem of rising air pollution.

Considering that, WRI India prepared Surat Clean Air Action Plan as per guidelines and protocols as prescribed by the Ministry of Environment, Forests and Climate Change under the proposed National Clean Air Program (NCAP). This report has been an outcome of the one-to-one meeting, source apportionment study by TERI, primary surveys, series of stakeholder consultation workshops, etc. The report also included emissions from various source categories, major issues relevant to the sector, control measures, strategies to mitigate, micro-level plans to implement the strategies, techno-economic analysis, different impact scenarios, etc.

I firmly believe that this Surat Clean Air Action Plan will help to improve the air quality in Surat city. I am confident that the SCAP report will be a source of inspiration and guide to the stakeholders, scholars, researchers, and students who are working for air pollution-free cities.

WRI India would like to thank Bloomberg Philanthropies, Shakti Sustainable Energy Foundation (SSEF), The Energy and Resources Institute (TERI) for their continuous support to the task of SCAP.

WRI India also acknowledges the cooperation by GPCB officials, SMC officials, Surat Collectorate, Surat RTO, Surat Traffic Police, South Gujarat Industrial Association, Surat Textile Association, CRDEAI, Surat Builders' Association, SVNIT, CEPT University, IUT local chapter, Surat Resilient Society, Surat UHC society, and other organizations who supported the study by their valuable inputs.

Dr. O P Agarwal
Chief Executive Officer
WRI India

EXECUTIVE SUMMARY

INTRODUCTION

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, launched the National Clean Air Programme (NCAP) as a long-term strategy to tackle the air pollution problem across the country in a comprehensive manner, with targets to achieve 20-30% reduction in $PM_{2.5/10}$ concentrations by 2024, keeping 2017 as the base year. Under NCAP, 124 non-attainment cities have been identified across the country based on the air quality data from 2014-2018. These cities do not meet the National Ambient Air Quality Standards (NAAQS) and require focused attention on multiple fronts to deal with the rising air pollution. In the state of Gujarat, the cities Ahmedabad, Surat, and Vadodara were identified as non-attainment cities. As per the NCAP targets, the cities that don't meet the NAAQS standards would have to develop a city-specific clean air action plan detailing the proposed interventions to reduce air pollution emissions from the identified sources in a timebound manner which will serve as a strategy document.

CONTEXT

The Surat Clean Air Action Plan (SCAP) was initiated in a tripartite agreement between Gujarat Pollution Control Board (GPCB) and Surat Municipal Corporation (SMC), with WRI India and The Energy Resources Institute (TERI), New Delhi. The agencies were entrusted with the task of conducting source apportionment studies and preparing city-specific clean air action plans. The SCAP has multiple objectives and proposes cost-effective interventions to reduce emissions from identified air pollution sources.

Since air pollution sources vary by local characteristics of cities, such as land use, agro-climatic conditions, socio-economic profile, demography, industrial profile, and meteorological conditions, each city requires a separate clean air action plan (CAP) for better air quality management. It is expected that the CAP will help the city administration and authorities maintain regulatory compliance; in turn, it will boost the city's economy, give it a competitive edge at the national level, attract growth and development, thus leading to the creation of jobs and a better quality of life for its citizens.

The SMC has been working towards improving its air quality through both regulatory and voluntary measures, such as implementing energy efficiency programs in industrial clusters, improving the green cover by creating an 'oxygen park,' introducing electric mobility options in public transport, and integrating non-motorized transport (NMT) in the city mobility plan. The SCAP is composed of systematic and comprehensive clean air strategies that are robustly specific to the SMC area. In addition, the plan proposes strategies for reducing air pollution by using robust data, models, and other technical tools to evaluate problems in air quality and the potential effectiveness of the proposed interventions in the short, intermediate, and long terms for reducing emissions.

APPROACH

In the process of developing the clean air action plan for the SMC area, a sector-specific multi-stakeholder approach was adopted, including a detailed analysis of local air pollution sources and their emissions contribution. This was followed by a primary survey to identify and quantify various sources contributing to ambient air pollution and designing air quality monitoring networks based on the population density, the meteorology, primary polluting sources, the transport network, the topography, and the available power supply. Air quality monitoring was conducted in strict adherence with the Central Pollution Control Board (CPCB) guidelines to validate these steps. Air quality data were analyzed using Chemical Mass Balance (CMB) receptor modeling to understand the source characteristics. Using an approach based on activity and emissions factors, an emissions inventory has been developed for the SMC area and Surat district to quantify the emission of different pollutants from various sources. The final version of the action plan contains a detailed assessment of air pollution source characteristics evaluated by an emissions inventory, the source apportionment study report, and clean air strategies for different sources based on inputs from stakeholders and local and regional policy-makers.

To refine the assessment, the following steps were observed while developing the sector-specific action plans:

1. The emission inventory and source apportionment results for the baseline year 2019 were studied.
2. The analysis of the current sectoral profile included the baseline year data of the sector.
3. The major issues relevant to the sector were assessed to identify the potential bottlenecks in the proposed mitigation actions.
4. The existing policies and programs at the corporation, state, and central government levels were compiled. These were then considered for their impact on the sectoral assessment.
5. The clean air action strategies of GPCB were assessed specifically to compare the ongoing work with the proposed strategies and programs.
6. Control measures were identified during the opportunity framing workshop, individual stakeholder meetings, and group discussions.
7. The strategies to mitigate air pollution have been proposed after assessing the emissions contribution of different sources based on the source apportionment study, emission inventory results, and an analysis of the existing policies and gaps specific to the SMC area.
8. To implement the micro-level plans for mitigating sectoral air pollution, priority areas were identified at the ward level.
9. The techno-economic analysis and health risk assessment evaluated the financial intricacies for the different sectors.

Based on the sectoral growth, different scenarios have been discussed with regard to air pollution contribution and mitigation actions.

FINDINGS

The emissions of different pollutants from various sectors in the SMC area for 2019, listed below, were estimated using the activity and emission factor-based approach. The emissions inventory data was used in the dispersion-based source apportionment study to understand the source contributions in the SMC area.

1. Particulate matter of a size less than or equal to 10 micrometers **(PM_{10}): 35.5 kt/year**
2. Particulate matter of a size less than or equal to 2.5 micrometers **($PM_{2.5}$): 14.3 kt/year**
3. Sulphur dioxide **(SO_2): 5.23 kt/year**
4. Nitrogen oxides **(NO_x): 38.59 kt/year**
5. Carbon monoxide **(CO): 139.5 kt/year**

The following inferences were made based on the emissions loads given in the above mentioned list: **Sulphur dioxide (SO_2)** is a toxic gas produced during the combustion processes associated with coal, lignite coal, petroleum products, and wood. Industries hold a significant share of SO_2 emissions and account for 69% of the total SO_2 emissions from all the sectors in the SMC area. The SMC area industrial clusters continue to depend on fossil fuels to generate energy for their industrial processes. The industrial clusters sector is followed by the residential sector (23%). The per capita coal consumption in this sector in the SMC area is high as the semi-permanent population (migrant laborers) continues to access coal, wood, and a combination of both for indoor cooking and heating needs. The open MSW burning sector emits 5% SO_2 from non-regulated burning of open waste and intermittent landfill fires.

Nitrogen Oxide (NOx) is a significant gaseous pollutant formed when fossil fuels (coal, oil, gas, or diesel) are burned at high temperatures. NOx is primarily emitted from the transportation sector in the SMC area, which shares 85% of the total emissions, followed by a 12% share from industries. The SMC area has the highest per-capita 2-wheeler population and mode share in the state, and many of these vehicles cause high levels of pollution and are not monitored substantially. In addition, there is a heavy movement of freight vehicles in the city, including those that cross the borders by violating the restriction hours. The large industries in the SMC area rely on natural gas and liquid petroleum products for their production processes, which is a major NOx contributor.

Carbon monoxide (CO) is a colorless, odorless, tasteless, flammable gas emitted from fossil fuels and biomass burning. The transportation sector holds a 62% share in the total CO emissions in the SMC area. Apart from the transportation sector, 29% of CO is emitted by industries and 7% by the residential sector. The reason for this attribution is similar to those for NOx, i.e., the use of fossil fuel-powered vehicles and the unavailability of clean fuel infrastructure in the city. Medium, small, and micro enterprises (MSMEs) are yet to replace biomass (bagasse and firewood) with clean fuel, as does the household cooking sector. The low socio-economic strata still do not access clean cooking fuels, such as LPG, PNG, and electricity-powered induction cookstoves.

Particulate Matter – For the SMC area, road dust re-suspension accounts for a major proportion of PM_{10} and $PM_{2.5}$, followed by transport and industries. The Road dust re-suspension is contributing 55% of the total PM_{10} and 33% of the $PM_{2.5}$. The transportation sector accounts for 12% of PM_{10} and 30% of $PM_{2.5}$, whereas industries account for 23% of PM_{10} and 27% of $PM_{2.5}$ share. Construction activities share about 5% and 2% of the PM_{10} and $PM_{2.5}$ emissions, respectively.

SECTORAL CONTRIBUTIONS AND ABATEMENT OPTIONS

According to emissions inventory data, in 2019, the **transportation** sector contributed about 30% (4.19 kt/year) of $PM_{2.5}$ emissions. The source apportionment study based on the dispersion model revealed that the transportation sector contributes about 16% $PM_{2.5}$ in winters and 6% in summers. The receptor model estimation revealed an average seasonal $PM_{2.5}$ contribution of 16% and 5% in winters and summers, respectively, from the transportation sector. This sector is highly dynamic and significantly dependent upon the ever-changing infrastructure in vehicles, which in turn is governed by many programs and policies related to vehicle types, vintage, road conditions, and mode share up-gradation, and tax/subsidy structures regularly monitored by the state and Central governments for the user base. Thus, the assessment has been done only for the year 2025. With a juggernaut target of reduction in taxes of INR 189 crore and 461 crores by the SMC and State Road Transport Department, respectively, in a time span of five years (2021-2026), some of the interventions that have been proposed as part of this action plan are tax rationalizations, updated parking, policies on electric vehicles (EV) and scrappage of older vehicles, lower emission standard operating vehicles, shifting of mode share of the SMC area from private vehicles to fuel-efficient electric public vehicles, and updated freight carriage policies for the city. In addition, to support the current environment in which cleaner demand-side vehicular infrastructure is developing, the SCAP proposes that the SMC should work on its NMT targets for the year 2026 with an anticipated outcome of an 11% reduction in the baseline emissions of $PM_{2.5}$.

According to the emissions inventory, **the road dust re-suspension or non-exhaust emissions (NEE)** cover a share of 55% PM_{10} and 33% $PM_{2.5}$ emissions for the baseline year 2019. Therefore, it becomes essential for the SMC area to be provided with a robust list of interventions for the NEE. Using the dispersion model, the source apportionment study revealed $PM_{2.5}$ contribution at 7% in winters and 10% in summers from NEE. The receptor model estimated an average seasonal $PM_{2.5}$ contribution of 9% and 33% in winters and summers. The receptor model estimated an average seasonal $PM_{2.5}$ concentration combined with construction and soil dust. While the regulation of NEE is almost negligible, conservation of the SMC area's green cover can reduce the road dust re-suspension most effectively. In addition, an amount of INR 7 crore will have to be spent on one-time mechanized infrastructure measures, such as mechanical sweepers, fogging machines, and sprinkler systems. Such physical infrastructure investment will cover a period of five years of the initial mitigation years; for actions for a longer-term, it is important to focus on the denser zones in the SMC area either by declaring pollution-free zones or by shifting the mode share of the city to public transport through NMT measures. It is anticipated that these interventions will reduce 50% of the load from the baseline emissions of 4.37 kt/year and reduce them to 2.6 kt/year $PM_{2.5}$ and 0.6 kt/year $PM_{2.5}$ by the year 2030.

With a share of 27% (3.87 kt/year) of emissions, **industries** are among the top contributors to air pollution in the SMC area. According to the dispersion model estimates for summer and winter seasons for industries, the contribution to $PM_{2.5}$ concentrations in the SMC area is 17% and 27%, respectively. Since the density of the SMC area's industrial clusters is next only to Ahmedabad in the state, the composition of MSMEs in the region is relatively higher. Most of them operate with textile and related processing and enterprising businesses.

Gujarat Industrial Development Corporation (GIDC) and GPCB are the most critical stakeholders in reducing/altering the air pollution emissions from the sector. For industry, a capital investment of INR 225 crore is required for a period of 10 years to mitigate air pollution with collaboration between

SMC, GIDC, and GPCB. This will reduce the baseline emissions of $PM_{2.5}$ to 69% by 2030. Strategies that can be taken up to mitigate air pollution from the sector include exploring cleaner fuel options, technological interventions for energy efficiency enhancement, having a robust plan for projects such as establishing community boilers, alternative fuel and raw material (AFR), technology transfer, air pollution control device (APCD) retrofitting, and quality industrial unit pollution control options. A more significant long-run investment will be required for this sector with capacity-building and awareness generation initiatives.

The **household polluting cooking fuel** use contributed approximately 5% (0.68 kt/year) to the SMC area's total $PM_{2.5}$ emissions in 2019. In the summer and winter seasons, $PM_{2.5}$ contribution of household cooking fuel in the SMC area was 2% and 15%, respectively, as per the dispersion model. In comparison, it was 15% in summers and 12% in winters, according to the receptor model. To reduce the $PM_{2.5}$ emissions from household cooking fuel use, it is proposed that access to clean fuels be increased for all sections of society through community awareness, expansion of the PNG network, and promotion of mini-LPG cylinders, a 'go kerosene-free' drive, and induction stoves/electricity for cooking.

The cost for community awareness, the 'go kerosene-free' drive, induction stoves/electricity for cooking is estimated to be INR 27.37 crore for 2021-2025. These interventions are estimated to reduce PM emissions by approximately 22% by 2025.

The **open burning of municipal solid waste (MSW)** contributed approximately 2% (0.23kt/year) to the total $PM_{2.5}$ emissions in the year 2019. In the summer and winter seasons, the $PM_{2.5}$ contribution from MSW burning is 0.3% and 1%, respectively, in the SMC area as per the dispersion model. In comparison, it is 2% in winters, according to the receptor model. To reduce the $PM_{2.5}$ emissions from MSW burning, it is crucial to have a well-functioning MSW disposal system with an efficient door-to-door waste collection system. Mitigation measures, including awareness programs, organic waste conversion, utilization of recyclables, monitoring and penalizing the practice of open MSW burning, prevention of textile waste burning, and curbing landfill fires are a few actions proposed for this sector.

The total cost of awareness programs, monitoring of MSW burning, and the scientific closure of the dumping site at Bhatar have been estimated at INR 4 crore, 0.11 crore, and INR 38 crore. In addition, the capital cost estimated for organic waste conversion and the utilization of recyclables (recovery facility) is INR 39.5 crore and INR 22 crore, respectively. With the help of these mitigation measures, MSW burning can be eliminated with no incidents of open MSW burning in the SMC area by the year 2030.

As per the dispersion model, **construction activities** have contributed an average of 1% and 0.3% in summers and winters, respectively, with 0.29 kt/year $PM_{2.5}$ emission for the baseline year 2019. The construction processes in the SMC area would require a total investment of INR 7.17 crore during the period 2021-2030 to implement emission mitigation strategies. The mitigation actions include pilot clean construction practices display sites development, promotion of ready-mix concrete in the SMC area, more stringent implementation of construction and demolition waste management rules, easing out of collaborative actions with the SMC-owned construction and demolition waste processing plant

(SGPPL, Kosad), promotion/mandatory use of engineering controls at construction sites, and proactive assessment of the vulnerabilities of offsite communities affected by construction dust. The best practices in mitigating emissions from construction sites have been collated in the handbook titled The Clean Construction Practices Guidelines for Surat 2020.

The fuels used for cooking, such as LPG, charcoal, and wood, in informal and formal eateries (tandoors/barbeques in hotels, restaurants, *Dhabas,* and small eateries) contributed approximately 0.5% (0.073 kt/year) to the total emissions in the SMC area during the year 2019. The interventions suggested under SCAP for the eateries sector are inventorization of formal and informal restaurants and eateries, replacing polluting fuels with clean cooking fuels, channelizing fugitive emissions, and decongestion and regulation of eateries, promotion of electricity-based tandoor and LPG. The total cost for the proposed interventions is approximately INR 0.51 core which will be spent over a period of 10 years (2021-2030).

Figure 1: $PM_{2.5}$ Emission Load – All Sector Combined

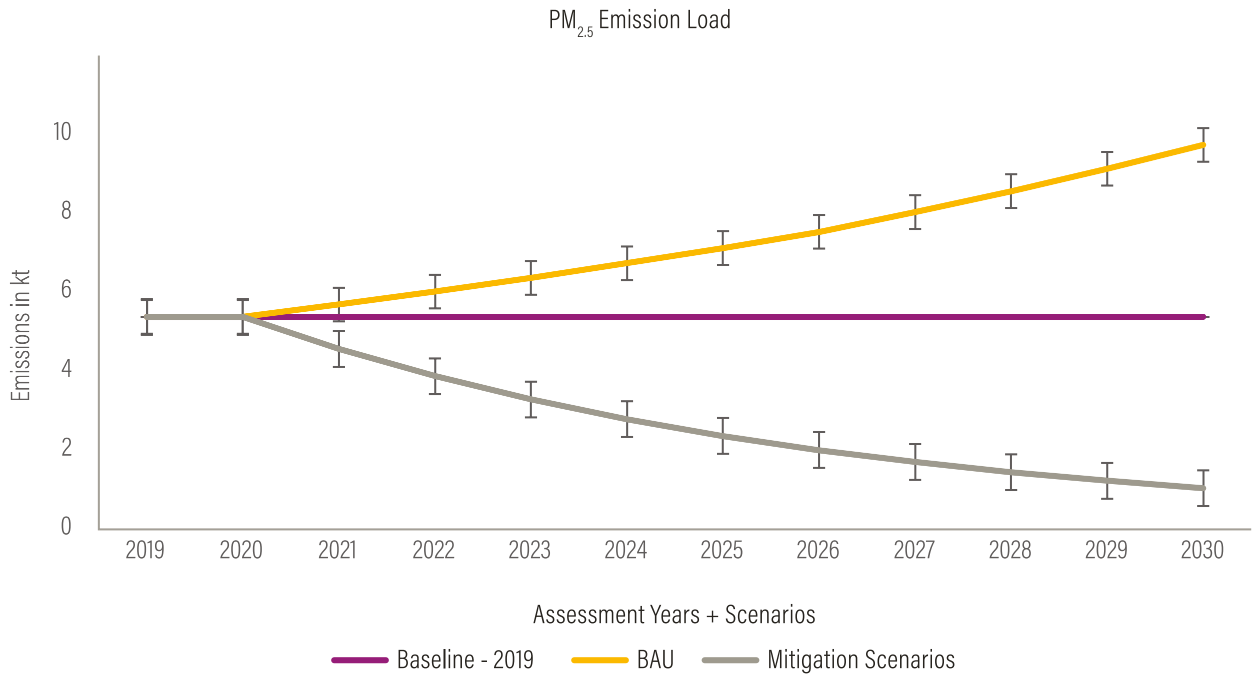


Figure 1 illustrates a comparison of the actions mentioned in this section and shows the emissions reduction potential of different interventions for the business-as-usual (BAU) and mitigation projection scenarios for $PM_{2.5}$ for all the sectors. The mitigation actions for all the sectors and their respective agencies and the estimated cost of implementing these measures are listed in **Table 1.**

MITIGATION ACTION FRAMEWORK AND FINANCIAL ALLOCATIONS

The mitigation framework in **Table 1** lists the various policies with which the emissions load, as presented in **Figure 1**, can be reduced. Approximately INR 560 crore would be spent in a time span of 10 years to achieve the maximum mitigation potential of reducing $PM_{2.5}$ by 60% by implementing the policies listed in **Table 1.**

Table 1: Interventions proposed for achieving maximum reduction potential - 2030 projections

Sr.No.	Proposed Policy or Criteria	Implementation Duration	Implementing Agency/Stakeholder
A	**Residential Cooking Sector – Total cost of implementation – INR 27.37 crore**		
1	Community awareness (LPG cylinder stickers)	2021- 2025	Oil/LPG companies
2	Go kerosene-free	2021- 2025	Food and Civil Supplies Department
3	Promoting induction stoves/electricity for cooking	2021-2022	Industries CSE Bodies, District Administration and SMC
4	Expanding PNG network	2021-2030	PNG companies
5	Promoting mini-LPG cylinders	2021- 2025	Oil/ LPG companies
B	**Construction Sector - Total cost of implementation – INR 7.17 crore**		
6	Preparation and implementation of Ambient Air Quality Monitoring Plan (AAQMP)	2021- 2025	CREDAI
7	Development of construction sector-specific monitoring toolkit	2021- 2025	GPCB, SMC, CREDAI (SMC area level)
8	Creation of pilot prototype site showing best practices	2021- 2025	CREDAI, SMC, GPCB
9	Prototype of best practice of monitoring site	2021- 2025	CREDAI, GPCB, SMC
10	Enclosure provision/Covering of construction site	2021- 2025	CREDAI, SMC, GPCB
11	Proactive disclosure of dust mitigation activities at construction sites	2021- 2025	GPCB, CREDAI, SMC
12	Promotion of procurement of fogging machine	2021-2025	SMC, CREDAI, GPCB, and
13	Promotion of ready-mix concrete	2021- 2025	Competent Agency
14	Air Quality Index Alert System (AQ-IAS) through SMAC center	2021-2025	SMC, CREDAI, Industries Associations
15	Engineering controls monitoring and retrofitting	2021- 2025	SMC, GPCB, CREDAI, Expert Agency
16	HRV assessment of offsite communities surrounding construction sites	2021- 2025	CREDAI, GPCB, SMC, and Expert Individual/ Agency
17	Formation of a central command center	2021-2025	CREDAI, Expert Individual/Agency
18	Increasing monitoring capacity by CAAQMS	2021- 2030	CREDAI, SMC, GPCB
C	**Open MSW Burning Sector - Total cost of implementation – INR 103.61 crore (Excludes the operational cost of INR 85 crore, which can be counted additionally.)**		
19	Organic waste converter for prominent societies, colonies, etc.	2021-2030	SMC (with support from NGOs, SHGs, RWAs, ragpickers)

20	Decentralized waste to compost plant	2021-2030	SMC (with support from NGOs, SHGs, RWAs, ragpickers)
21	Recovery facility	2021-2030	SMC (with support from NGOs, SHGs, RWAs, rag pickers, and private sector)
22	Awareness program	2021-2023	SMC (with the help of NGO's and SHG)
23	Monitoring of open burning of MSW	2021 -2030	SMC
24	Prevention of textile or thread burning (gasification plant)	2021-2030	Industries' Association, GPCB, GIDC, SMC
25	Closure of old dumping site Bhatar	2021-2025	SMC, GPCB
D	**Industries Sector - Total cost of implementation – INR 225 crore**		
26	Retrofitting air pollution control devices	2021-2023	Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC
27	Regular check for resource and energy efficiency improvement	2021-2024	Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC
28	Accelerate technology transformation for automation/ digitization in MSMEs	2021-2024	Industries' Associations, GIDC, GPCB, GEDA, GERMI
29	Revisiting the norms for new installations	2021-2030	Industries' Associations, GIDC, GPCB, GEDA, SMC
30	Promoting cogeneration through monitoring of small boilers	2021-2025	Industries' Associations, GIDC, GPCB, GEDA, District Administration, Directorate of Boilers
31	Carrying capacity assessment	2021-2024	Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC
32	Implementing capacity building module	2021-2023	Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC
34	Shifting towards alternative fuel	2022-2030	Industries' Associations, GIDC, GPCB, GEDA, District Administration
35	Increase efforts in comprehensive control of small-sized boilers	2022-2028	Industries' Associations, GIDC, GPCB, GEDA, District Administration, Directorate of Boilers
36	Provide financial and technical support to reduce emissions	2022-2030	Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, Transport Department, and SSCDL
37	Target to reduce and control emissions from industry	2022-2030	Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, Transport Department, and SSCDL

38	Relocating air polluting industries	2022-2030+	Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, SUDA, Transport Department and SSCDL
E	**Eateries Sector - Total cost of implementation – INR 0.51 crore**		
39	Inventorization of eateries	2021-2023	SMC, District Administration, and Gujarat Government
40	Shifting to cleaner fuel	2021-2030	SMC, District Administration, and Gujarat Government
41	Use of pollution control options in formal eateries such as restaurants	2021-2023	SMC, District Administration and Gujarat Government, GPCB
42	Technological promotion in the operation of eateries through awareness drives	2021-2026	SMC, District Administration, and Gujarat Government
43	Decongest and regulate - All eateries	2021-2023	SMC, District Administration, and Gujarat Government
44	Regular preparation or update of sectoral emissions inventory	2021-2030	SMC, District Administration, and Gujarat Government
F	**Transportation - Total cost of implementation – INR 189 crore and INR 461 crore respectively for SMC and State Transport Department inform of Tax Reductions/Aversions**		
45	The systemic transition of existing and future vehicles to cleaner and more efficient vehicles	2021-2026	RTO, SMC, District Administration
46	Incorporating environmental costs and better monitoring infrastructure implementation	2021-2026	RTO, SMC, District Administration
47	The incentive structure for faster to more efficient and cleaner vehicles	2021-2030	RTO, SMC, District Administration
48	Better PUC centers monitoring and densification process	2021-2026	RTO, SMC, District Administration
49	Implementation of newly introduced scrappage policy	2021-2024	RTO, SMC, District Administration
50	Implementation of EV policy in the city	2021-2024	RTO, SMC, District Administration
51	Re-negotiation of recurring costs on older commercial vehicles by giving up campaign	2021-2026	RTO, SMC, District Administration
52	Alteration of mode share - reduction of private mode share with the more efficient public transport mechanism	2021-2030	RTO, SMC, District Administration
53	Combined strategy to enable mode shift from private to public such that vehicles are operated efficiently and use cleaner fuels	2021-2030	RTO, SMC, District Administration
54	Urban freight policy implementation	2021-2024	RTO, SMC, District Administration
55	Major retrofitting for the implementation of NMT infra-structure and policies	2021-2030	RTO, SMC, District Administration, hand-holding technical expert agencies

56	Creating an inventory of walking infrastructure within the SMC boundary	2021-2026	RTO, SMC, District Administration, hand-holding technical expert agencies
57	Innovative data collection - NMT related infrastructure enhancement and supporting activities	2021-2026	RTO, SMC, District Administration, hand-holding technical expert agencies
58	Congestion management practices	2021-2030	RTO, SMC, District Administration, hand-holding technical expert agencies
G	**Non-Exhaust Emissions - Total cost of implementation – INR 7 crore**		
59	Reduction of SMC area's VKT through mode share transfer and infrastructure development	2021-2030	RTO, SMC, District Administration
60	Recognition of NEE restricted zones through Urban Vehicle Access Restrictions	2021-2030	RTO, SMC, District Administration
61	No implementation of standalone EV and NMT policy	2021-2030	RTO, SMC, District Administration
62	Provision of online app-based integrated ticketing service for the public transport	2021-2025	SMC and RTO
63	Removing or toning down the freight compactness option from the freight transport policy within the SMC area	2021-2030	SMC and RTO
64	Installation of fogging machines and sprinklers at the major junctions of the SMC area	2021-2025	SMC
65	Regeneration of urban forest patches through urban forest scheme (Nagar Van Scheme)	2021-2025	SMC, District Forest Department

WAY FORWARD

The SCAP can be considered as a 'roadmap' to achieve cleaner air in the SMC area. The interventions proposed to necessitate broad support amongst the diverse stakeholders who have participated in developing this action plan. Funding for a few of the interventions in the action plan is currently available, while others will require new public and private investment. However, the cost of implementing new clean air mitigation initiatives is minuscule compared with the public health costs and potential economic impacts that could result if the city fails to address air pollution. Implementation of the strategies in the plan will also require the expansion of existing public-/private-sector partnerships and the creation of new ones. With support from the pollution control board, district administration, other government institutions, and the residents, SMC must work to improve air quality and ensure clean and healthy air for its citizens.

The SCAP is not meant to be a static document. With guidance from the SMC Air Monitoring Cell, the plan should be updated periodically as and when new data is available to revise the strategies and their timelines. This would help the city prepare for newer challenges and maintain clean air.

TABLE OF CONTENT

CHAPTER 6 - INDUSTRIES

CHAPTER 7 - CONSTRUCTION

CHAPTER 8 - EATERIES, HOTELS AND RESTAURANTS

CHAPTER 9 – TRANSPORTATION

CHAPTER 10 – NON-EXHAUST EMISSIONS

CHAPTER 11 - CONCLUSION

ANNEXURES

ACKNOWLEDGEMENT

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AAI	Airports Authority of India
AAQI	Ambient Air Quality Index
AAY	Antodaya Anna Yojana
AC	Area of Construction
ACGIH	American Conference of Governmental Industrial Hygienists (USA)
AERZ	Absolute Emission Restriction Zones
ALRI	Acute Respiratory Lung Infection
ALT	Alternative Scenario
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APCD	Air Pollution Control Device
APF	Assigned Protection Factor
APHRA	Air Pollution Health Risk Assessment
APMC	Agricultural Produce Market Committee
ARAI	Automotive Research Association of India
ATR	Action Taken Report
BAT	Best Available Practices
BAU	Business as Usual
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BPL	Below the Poverty Line
BRTS	Bus Rapid Transit System
BSES	Bharat Stage Emission Standards
BS I	Bharat Stage I
BS II	Bharat Stage II
BS III	Bharat Stage III
BS IV	Bharat Stage IV
BS VI	Bharat Stage VI
C & D	Construction and Demolition
CAAQMS	Continuous Ambient Air Quality Monitoring Station
CAF	Compensatory Afforestation Fund
CAG	Comptroller and Auditor General
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CAP	Clean Air Action Plan
CBO	Community Based Organisation
CBRE	Coldwell Banker Richard Ellis
CBS	Central Bus Station
CCC	Central Command Centre
CCP	Clean Construction Practice
CDP	City Development Plan
CEMS	Continuous Emission Monitoring System
CEPI	Comprehensive Environmental Pollution Index
CEPT	Centre for Environmental Planning and Technology (University)
CETP	Common Effluent Treatment Plant
CFU	Clean Fuel Usage
CMB	Chemical Mass Balance
CMP	Comprehensive Mobility Plan
CMVA	Central Motor Vehicles Act
CNG	Compressed Natural gas
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
CPCB	Central Pollution Control Board
CREDAI	Confederation of Real Estate Developers' Associations of India
CS	Congestion Charging
CSR	Corporate Social Responsibility
CSS-VNSGU	Centre for Social Studies – Veer Narmad South Gujarat University

CTO	Consent to Operate
DALY	Disability Adjusted to Life Years
DBTL	PAHAL Direct Benefit Transfer
DG Sets	Diesel Generator Sets
DGFASLI	Directorate General Factory Advice Service and Labour Institutes (India)
DMIC	Delhi Mumbai Industrial corridor
DPM	Diesel Particulate Matter
DPR	Detailed Project Report
DSO	District Supply Officer
EE	Energy Efficiency
EESL	Energy Efficiency Services Limited
EF	Emission Factor
EIA	Environment Impact Assessment
EPC	Engineering, Procurement, and Construction
EPR	Extended Producer Responsibility
ETS	Emissions Trading Scheme
EV	Electric Vehicle
FICCI	Federation of Indian Chambers of Commerce and Industry
GBD	Global Burden of Diseases
GCC	General Conditions of Contract
GCC	Gross Cost Contract
GDCR	General Development Control Regulation
GDP	Gross Domestic Product
GEDA	Gujarat Energy Development Agency
GERMI	Gujarat Energy Research and Management Institute
GIDC	Gujarat Industrial Development Corporation
GIS	Geographical information system
GoG	Government of Gujarat
GOI	Government of India

GPCB	Gujarat Pollution Control Board
GSRTC	Gujarat State Road Transport Corporation
HC	Hydrocarbons
HCV	High Commercial Vehicle
HCVs	Heavy Commercial Vehicles
HSD	High Speed Diesel
ICT	Information and Communications Technology
IEC	Information, Education and Communication
IER	Integrated Exposure Response Function
IGBC	Indian Green Building Council
IHD	Ischemic Heart Disease
IHME	Institute of Health Metrics and Evaluation (USA)
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
INR	Indian National Rupees
ISO	International Organization for Standardization
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
J-PAL	Abdul Latif Jameel Poverty Action Lab
JRC	Jhuggi Ration Card
KT	Kilo Ton (kt)
L&T	Larsen and Toubro
LC	Lung Cancer
LCV	Light Commercial Vehicle
LDO	Light Diesel Oil
LEED	Leadership in Energy and Environmental Design
LEV	Local Exhaust Ventilation
LEZ	Low Emission Zones
LPG	Liquefied Petroleum Gas
LST	Land Surface Temperature

MCV	Medium Commercial Vehicle
MGSM	Mahatma Gandhi Swachhata Mission
MI	Michigan University (USA)
MNRE	Ministry of New and Renewable Energy
MOEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoPNG	Ministry of Petroleum and Natural Gas
MoRTH	Ministry of Road Transport and Highways
MRF	Material Recovery Facility
MSME	Micro, Small, and Medium Enterprises
MSW	Municipal Solid Waste
MT	Metric Tonnes
MTOE	Mega Tonnes of Oil Equivalent
NAAQS	National Ambient Air Quality Standard
NBC	National Building Code, 2016
NCAP	National Clean Air Programme
NEE	Non-Exhaust Emissions
NGO	Non-Government Organizations
NGT	National Green tribunal
NH	National Highway
NHAI	National Highway Authority of India
NIC	National Informatics Centre
NMT	Non-Motorised Transport
NMVOCs	Non-Methane Volatile Organic Compound
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NSSO	National Sample Survey Organization
NTPC	National Thermal Power Corporation
OECD	Organization for Economic Cooperation and Development
ONGC	Oil and Natural Gas Corporation
OWC	Organic Waste Conversion/Converter
PBS	Public Bicycle Share
PDS	Public Distribution System
PHBL	Public Health Bye Laws
PM	Particulate Matter
PM_{10}	Particulate Matter 10
$PM_{2.5}$	Particulate Matter 2.5
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped Natural Gas
PPE	Personal Protective Equipment
PPP	Public Private Partnership
PT	Public Transport
PUC	Pollution Under Control
RAGAGEP	Recognized and Generally Accepted Good Engineering Practices
RBI	Reserve Bank of India
RCC	Reinforced Cement Concrete
RDF	Refuse Derived Fuel
RERA	Real Estate Regulatory Authority
RM	Rainy Months
RMC	Ready Mix Concrete
RPI	Residential Price Index
RR	Relative Risk
RTO	Regional Transport Office
RTS	Refuse Transfer Station
RUC	Reduce the Usage of Conventional Fuel
RWA	Residential Welfare Association
SBM	Swachh Bharat Mission
SCAP	Surat Clean Air Action Plan

SCBA	Self-Contained Breathing Apparatus/ Respirator
SDG	Sustainable Development Goals
SEIAA	State Level Environment Impact Assessment Authority
SES	Socio Economic Status
SGPPL	Surat Green Precast Private limited
SH	State Highway
SHG	Self Help Group
SMAC	Smart City Centre
SMC	Surat Municipal Corporation
SO_2	Sulphur Dioxide
SOP	Standard Operating Procedures
SPM	Suspended Particulate Matter
SSCDL	Surat Smart City Development Limited
SSEF	Shakti Sustainable Energy Foundation
STD	State Transport Department
STEL	Short Term Exposure Limit
SUDA	Surat Urban Development Authority
SVNIT	Sardar Vallabhbhai National Institute of Technology (Surat),
SWM	Solid Waste Management
TEA	Techno Economic Analysis
TLV-TWA	Threshold Limit Value – Time Weighted Average
TPD	Tonnes Per Day
TPH	Tons Per Hour
TPS	Town Planning Scheme
UCD	Urban Community Department, SMC
ULB	Urban local bodies
UN	United Nations
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USEPA	United States Environmental Protection Agency
UVAR	Urban Vehicle Access Restriction
VGF	Viability Gap Funds
VKT	Vehicle Kilometres Travelled
VOC	Volatile Organic Compound
WB	Waste Burning
WHO	World Health Organizations
WRF-CMAQ	The Weather Research and Forecasting - Community Multiscale Air Quality Modeling
WRI	World Resources Institute

CHAPTER 01

>> INTRODUCTION

1.1. BACKGROUND

In 2019, over 90% of the world's population experienced an annual average particulate matter of 2.5 micrometers (μm) or less in diameter ($PM_{2.5}$) concentrations that exceeded the World Health Organization (WHO) Air Quality Guideline (10 μg/m^3)[1]. The highest annual average exposures were seen in Asia and Africa. Population-weighted $PM_{2.5}$ concentrations exposure represents annual averages across different country regions. It, however, does not represent the considerably higher concentrations observed daily or in certain seasons, especially around cities or significant pollution sources. Inferences from the Global Burden of Diseases (GBD) project indicate that short-term higher exposure can affect health; however, long-term exposures contribute most to disease and mortality from air pollution. The disparities in exposure to $PM_{2.5}$ across Asia and Africa have remained constant over the past decade, with South Asia consistently seeing the highest exposures.

The increasing level of air pollution is one of the leading environmental and human health risk factors worldwide. The impact of rising air pollution is limited to human health and affects agriculture, climate, water cycle, energy, and the economy. Air pollution kills around 7 million people prematurely and drains the global economy of $5 trillion each year worldwide. Air pollution has a more significant impact on low- and middle-income countries than on high-income countries[2].

With rapid economic growth and population increase, India is witnessing cumulative pressure on its existing infrastructure and natural resources. The excessive and inefficient use of infrastructure and natural resources is responsible for the increasing air pollution emissions in the country. In 2017, the WHO observed that India was home to 15 of the top 25 most polluted cities globally in ambient $PM_{2.5}$ concentration levels.

Several studies have shown that the primary sources of air pollution in India are emissions from transportation, construction, industrial activity, biomass burning, etc. There is, however, heterogeneity in source profiles by location and regional characteristics. For instance, biomass use for cooking varies in urban and rural areas; vehicular density differs vastly in various regions. Diverse climatic conditions and landscapes across India also affect the regional and seasonal average ambient air pollution levels. To address this multi-dimensional, multi-sectoral problem, a compelling and considered approach is required.

The Government of India launched the National Clean Air Programme (NCAP) in 2019 as a timebound national-level strategy to tackle the increasing level of air pollution. The NCAP is a mid-term, five-year action plan, with 2017 as the base year. The programme aims to reduce ambient $PM_{2.5}$ and PM_{10} concentration levels by 20-30% by 2024. However, the programme may be extended to a longer time horizon after the mid-term review of NCAP identified 124 non-attainment cities not following the ambient air quality standards consistently. Under NCAP, cities are directed to develop air quality action plans with the following objectives:

---

[1] *Health Effects Institute. (2020). State of Global Air 2020. Special Report. Boston, MA: Health Effects Institute. https://fundacionio.com/wp-content/uploads/2020/10/soga-2020-report.pdf*

[2] *World health statistics overview 2019. Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2019. https://apps.who.int/iris/bitstream/handle/10665/311696/WHO-DAD-2019.1-eng.pdf.*

- To ensure stringent implementation of mitigation measures for prevention, control, and reduction of air pollution
- To augment and evolve effective and proficient ambient air quality monitoring networks across the country for ensuring a comprehensive and reliable database
- To internalize public awareness and capacity-building measures encompassing data dissemination and public outreach programs for inclusive public participation and ensuring trained workforce and infrastructure on air pollution

As part of the programme, it is essential to develop city-level interventions specific to each sector identified as a source of air pollution, with suitable clean air strategies. Surat Municipal Corporation (Surat City/SMC), one of the 124 non-attainment cities in India, is considered one of the world's fastest-growing urban agglomerations. Air pollution has been addressed in a limited manner by the city in its annual list of strategies for providing a better quality of life to its residents. To mitigate air pollution and its associated impacts, the city requires a detailed clean air action plan based on a robust knowledge of air pollution sources, stakeholder engagement, and city-centric interventions, as mandated by NCAP. The Surat Clean Air Action Plan (SCAP) effectively addresses the knowledge gap of managing air pollution emanating from various sources and providing sustainable solutions to mitigate it. The action plan would serve as a guidebook for the city and other officials to understand the sources of air pollution, their contribution to air quality, and health and mitigation measures.

1.2. SURAT CLEAN AIR ACTION PLAN

A clean air action plan intends to improve air quality and public health by identifying cost-effective measures to reduce emissions from air pollution sources, such as transport, industries, and biomass burning. Since air pollution sources vary according to cities' local and regional characteristics, such as land use, agroclimatic conditions/profile, socio-economic profile, demography, industrial profile, city income, and meteorological conditions, each city requires a separate clean air action plan for better air quality management. Developing a clean air action plan depends on the city's needs and capacities to implement air pollution mitigation strategies. In general, the key features of a city-specific clean air action plan include:

- A clear understanding of air pollution contributor sectors and the level of air pollution in the city,
- Instruments and strategies for each sector to comply with air quality and emission standards, which are locally acceptable and mandated by the state and central authorities,
- Adoption and implementation of control measures that can be assessed once the compliance nature of air quality standards has been measured and
- Continuous scope for improvement after the control measures have been assessed and implemented in various sectors gradually with continual pollution control.

The overall objective of implementing a city-specific clean air action plan is 'to generate an interactive platform for various stakeholders to come together by showcasing evidence-based results influencing relevant policies and legislations of cities and countries in the region; and, ultimately, protect public health and the environment against impacts of air pollution.' The inference of SCAP is to improve air quality by implementing science-based strategies for the assessment of emissions generated from various sources, emissions reduction that contributes to public health, and reduced environmental and climate change impacts. This can only be done if the cleanest of air is provided to the residents of the SMC area through the coordinated efforts of all stakeholders, with the lead being taken by SMC.

1.3. APPROACH – SCAP – DESIGN STRATEGIES AND IMPLEMENTATION

WRI India is an international organization that works on protecting the environment and the natural and artificial sources needed for current and future generations' needs and keeping its potential alive. WRI India is inspired by and involved with Global Research Institute, World Resources Institute (WRI). WRI India and India's leading international organization, The Energy and Resource Institute New Delhi (TERI), have been entrusted to carry out a $PM_{2.5}$ and PM_{10} source apportionment study and to prepare the SCAP, with the financial support of Bloomberg Philanthropies and Shakti Sustainable Energy Foundation. The SCAP has been developed in collaboration with Gujarat Pollution Control Board (GPCB) and SMC for Surat city and its surrounding area.

We followed a sector-specific multi-stakeholder approach to develop a clean air action plan for the SMC area, with a detailed analysis of local air pollution activities and sources. We first analyzed the available literature on the air pollution sources, activities, and stakeholders directly or indirectly associated with different source sectors. The final action plan is informed by the detailed air pollution source characteristics by emissions inventories, the source apportionment study conducted by TERI, and inputs from stakeholders and local and regional policymakers from all source sectors. The approach and activities in the process of developing SCAP are presented in chronological order below:

Literature Review: A detailed literature review was conducted to understand the activities causing air pollution, the sources of air pollution, and the impacts thereof in Indian cities, particularly in the SMC area. As part of this review, the sectors that are generally responsible for air pollution in the SMC area and other Indian cities were identified.

Identification of Air Pollution Sources and Activities: Available literature and data were used to identify the possible sources and sectors contributing to in-boundary air pollution in SMC. The literature and data of other cities were used to determine the different methodologies, data gaps, and stakeholder identification. Based on the literature review, the sectors contributing to air pollution were narrowed down into sub-aspects to prepare the study framework wherein city-specific air pollution source characteristics could be integrated into the action plan.

Stakeholders Consultations: One-on-one discussions and group meetings were conducted with the key stakeholders directly and indirectly associated with the sectors contributing to air pollution, city managers, and decision-makers. An extensive round of preliminary discussions was conducted with experts from national and state-level organizations, institutions, and think tanks, and their suggestions were recorded. The second round of discussions included professionals from the city and those who have worked on critical projects and issues. This was more focused, and a specific understanding of direct and parallel issues related to the SMC area was developed. The core team of WRI India traveled to the SMC area to establish linkages and build a network of professionals who would support in actualizing SCAP. Detailed accounts of the meetings conducted by WRI India are presented in **Annexure 2**.

- **Sector-based Approach**: Based on the literature review, the identification of sectors/sources, and individual and focused group discussions with sectoral experts, professionals, senior-level city managers, and engineers from GPCB and SMC, we decided to adopt a sector-based approach to identify the air pollution mitigation measures. In a sector-based approach, rather than capturing the contribution of all sectors in a combined manner, the contribution of each sector is considered individually. In the process, 9 sectors were identified for further assessment. This helped develop the framework of the project and streamline the process of data collection and stakeholder interactions. For example, the first stakeholder consultation on SCAP in which several sectoral experts and city-specific stakeholders were invited had an umbrella plan to discuss. The consultations that followed were more sector-specific, where different professional groups weighed in on poor ambient air quality issues in specific sectors. On average, there were 100 participants in each event, and a consensus was built on the following issues related to the sector-specific contribution to the city's air quality:
    - Data and networking gaps related to air pollution sources need to be identified.
    - Best practices are being implemented by the local authorities for mitigating air pollution from the sectors.
    - There is a potential for policy and program level niches to adopt the existing best practices to deliver improved air quality in the SMC area more efficiently.
    - The mechanism for monitoring and evaluating SCAP in collaboration with the identified partners and other stakeholders needs to be improved in the future.

- **Data Collection**: As a part of secondary and primary data collation processes, data sets were compiled against a specific set of primary and proxy indicators required for each sector contributing to the city's air pollution. Extensive field surveys were conducted to collect primary data on municipal solid waste burning and informal and formal restaurants where no activity data was available. Extensive activities data were collected and compiled through personal interviews, consultations, and secondary databases for other sectors. Partner agencies validated all these data sets for their authenticity and agreement of their usage in the process of the SCAP project.

- **Emissions Inventories and Source Apportionment**: For each identified point, area, and line source, city-level, and district-level gridded emission inventories were generated by TERI and projected on spatial and temporal scales. The emission inventory was prepared for the study area and grid-wise emissions for 2 km X 2 km resolution. The emission inventory is developed on a GIS platform for spatial allocation of emissions and further use in the dispersion model. More details on this are presented in **Chapter 2.**

- **Comprehensive Assessment**: An assessment of sources and activities based on air pollution emissions inventories was made to understand their contribution to air pollution emissions. The assessment was kept as urban local body (ULB) specific as possible. Thus, a specific projection-based platform could be generated on which the proposed interventions and policy measure adjustments could be indicated. Robust, city-specific, and sector-based interventions were prepared to purview each sector's existing programs and policies. The findings from the assessment were validated by local experts and representatives from partner agencies so that the interventions for mitigating sectoral emissions are appropriately designed.
- **Scenario Generation:** After completing the activity and emissions analysis, scenarios were developed based on possible growth in the future and assumptions for different sectors. These assumptions were based on implementing various proposals, potentially reducing the emissions from each sector by applying different policies. Each sector's scenarios and the overall emissions inventories supporting the SCAP have been discussed separately in individual chapters.
- **Experts Review Process**: Once the final assessment for each sector was completed, the chapters were sent to 21 experts for rigorous review. These experts belonged to different strata of expertise at reputed institutions, including Health Effect Institute (Boston, MA, USA), Michigan University (MI, USA), Institute of Health Metrics and Evaluation (Washington DC, USA), UN-HABITAT India office, Sardar Vallabhbhai National Institute of Technology (Surat), Centre for Social Studies, Veer Narmad South Gujarat University (Surat), Climate Change Department, Government of Gujarat (Gandhinagar), Centre for Environmental Planning and Technology University (Ahmedabad), Confederation of Real Estate Developers' Associations of India (CREDAI, Surat Chapter) and Geostone Corporation (Surat). The SMC and GPCB were actively involved in the process of the selection of reviewers. In addition, ten subject matter experts from the WRI India pool gave their inputs on sectoral assessments. The inputs and feedback from all the experts listed in **Annexure 5** were consolidated and assimilated appropriately in relevant chapters.

1.4. SURAT MUNICIPAL CORPORATION – PROFILE

Owing to a prosperous economy and a sizeable contribution to the GDP of the state and country, the SMC area has been receiving a huge migrant population every year, constituting 26% of the city's total population (Census of India, 2011). The city's economy thrives on the corporate chemical and engineering industries, small-scale industries, construction, textile, jari, and diamond industries. Administratively, SMC is divided into 107 municipal corporation wards, including 101 wards of SMC and six wards of the SMC area's outgrowth. Between 2001 and 2011, the city recorded significant growth in its population, from 24,33,835 in 2001 to 44,66,826 in 2011. In 2020-21, the population of the city stood at 69,36,534[3].

[3] *Mid-Year Population Estimates and Comparative of Population of India, Gujarat, Surat District and SMC from 1901 to 2011. Surat Municipal Corporation. https://www.suratmunicipal.gov.in/TheCity/City/Stml7*

Table 2: Interventions proposed for achieving maximum reduction potential - 2030 projections (Source: Surat Municipal Corporation)

Criteria	Details
Year of Establishment of Municipality	**1852**
SMC Area	472 Sq. Km. (as on SMC limit extended during June 2019)
Population	44,66,826 (as per census 2011)
No. of Slum Pockets	334
Governing Body (ULB)	Surat Municipal Corporation
Administrative Zones	**8**
No. of Election Wards	29
No. of Administrative Wards	101
Literacy Rate Total	87.89%
Male Literacy Rate	91.22%
Female Literacy Rate	83.44%
Annual Mean Temperature	350 C
Average Annual Rainfall	1143 mm
GDP (approximate)	INR 266,500 crores ($40 billion)
Energy Consumption (MTOE)[4] 2015	4.3
Energy Consumption (toe)	0.96

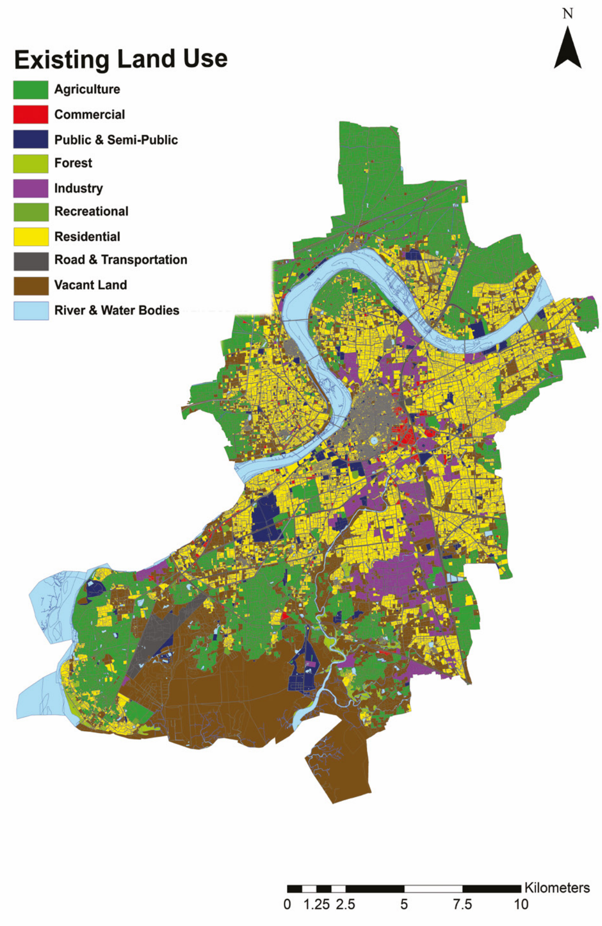
4.1. Land Use

The city's built-up residential area includes housing of different types - detached, semi-detached, row houses, group housing, and basis accounts for approximately 55% of the total urbanized area. The development in the city is taking place in the south and northeast directions, in planned and unplanned colonies. The commercial built-up area covers a significant portion of the city's central, east, north, and southwest parts and accounts for 2% of the total urbanized area. This is mainly because the city has promoted small- and medium-scale production operations within city limits, leading to physical establishments in these areas. The growth potential of small- and medium-scale business units has resulted in a significant rise in the market for residential land in the city. As the business center of the state, large sections of the floating and semi-permanent population have settled within the city limits. Their demand for physical infrastructure led to converting the adjoining agricultural land into

[4] *Ton of oil equivalent (toe) is a unit of energy defined as the amount of energy released by burning one ton of crude oil, approximately 42 gigajoules. Multiples of the toe are used, the mega ton (Mtoe, one million toe)*

residential land, making the city's north, east, central, and south zones the city's most densely populated areas over the years. SMC area is also surrounded by lakes, wetlands, and marshes, as shown on the map in **Figure 2.** The Tapi river divides the city almost perfectly into two halves, northern and southern, and is the primary water source for the residential, commercial, and industrial sectors. Most of the specified industrial zones or notified areas of the city are situated in the south and southwest regions. The commercial and transportation density is the highest in the central, north, and northeast regions **(Figure 2).**

Figure 2: Existing land use and land cover – Development Plan 2035



1.4.2. MSW Generation

In 2002, the SMC area generated 865 metric tons (MT) of municipal solid waste (MSW), which increased to anywhere between 1800 and 2200 MT in 2019[5]. Households and commercial establishments contribute about 70% of the MSW generation. The prevailing door-to-door waste collection system claims to maintain 90% MSW collection efficiency in the city (Swachh Sarvekshan 2020). Additional factors from other approaches increase the efficiency to 98%[6]. The eastern wards, which have a low-income profile, have a lower collection efficiency than the other accessible wards in the north, west, south, and southwest zones.

[5] *Bhakkad, M. (2019). Solid Waste Management: A Case Study of Surat City. International Journal of Management and Applied Science, 5, 34–36.*

[6] *Swachh Survekshan. (2020). Assessment DPR, MoHUA, Government of India.*

1.4.3. Transport

The city's vehicular population has grown significantly over the years. According to SMC and State Transportation Department (STD), about 32.5 million transport and non-transport vehicles have been registered in the SMC area. Of these, 78% are two-wheelers, 13% motor cars, and 4% passenger auto-rickshaws[7] **(Figure 3)**. As per the Census of India 2011, about 44% of households in the city own at least one two-wheeler, and 9% own at least one car in SMC. According to Comprehensive Mobility Plan 2046 data, the share of walk and cycle trips is about 43%, which is quite high and results from compact and mixed land use development in the city. Approximately 36% of the population in the SMC area uses two-wheelers as a mode of travel, and 10% use auto-rickshaws[8] **(Figure 4)**.

Figure 3: Category-wise registered vehicles (Transport & Non-Transport) in Surat Municipal Corporation (SMC) as on 31 March 2015 (Source: data.gov.in, 2019)

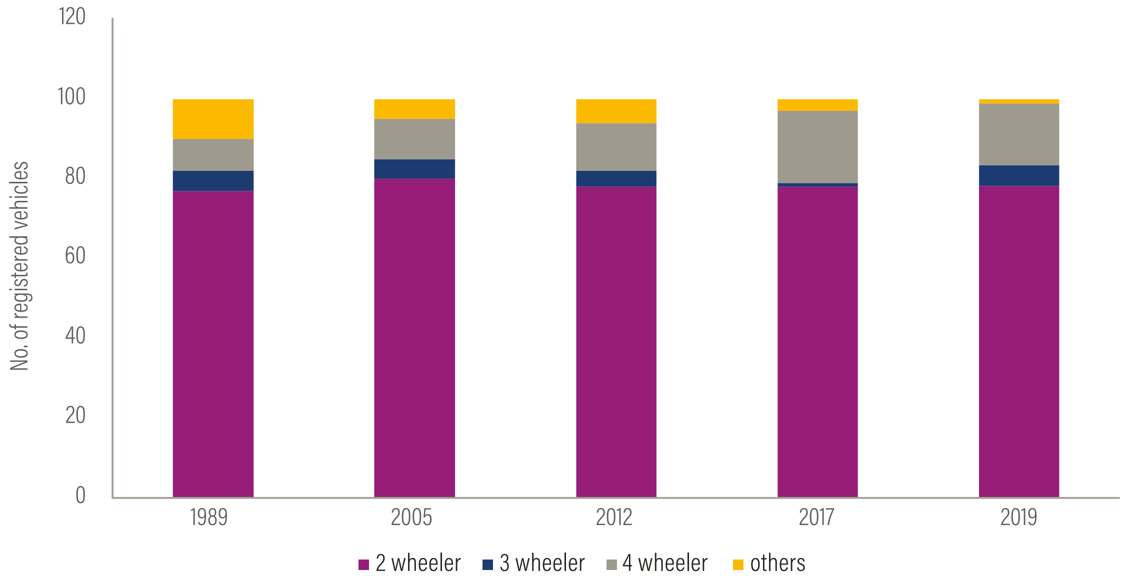
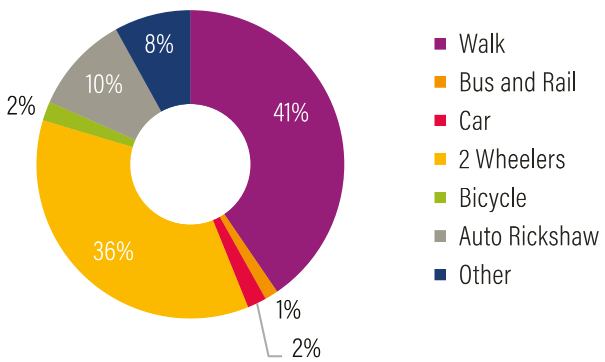


Figure 4: Mode share by SMC population used for traveling to work from home (Source: Comprehensive Mobility Plan 2046)



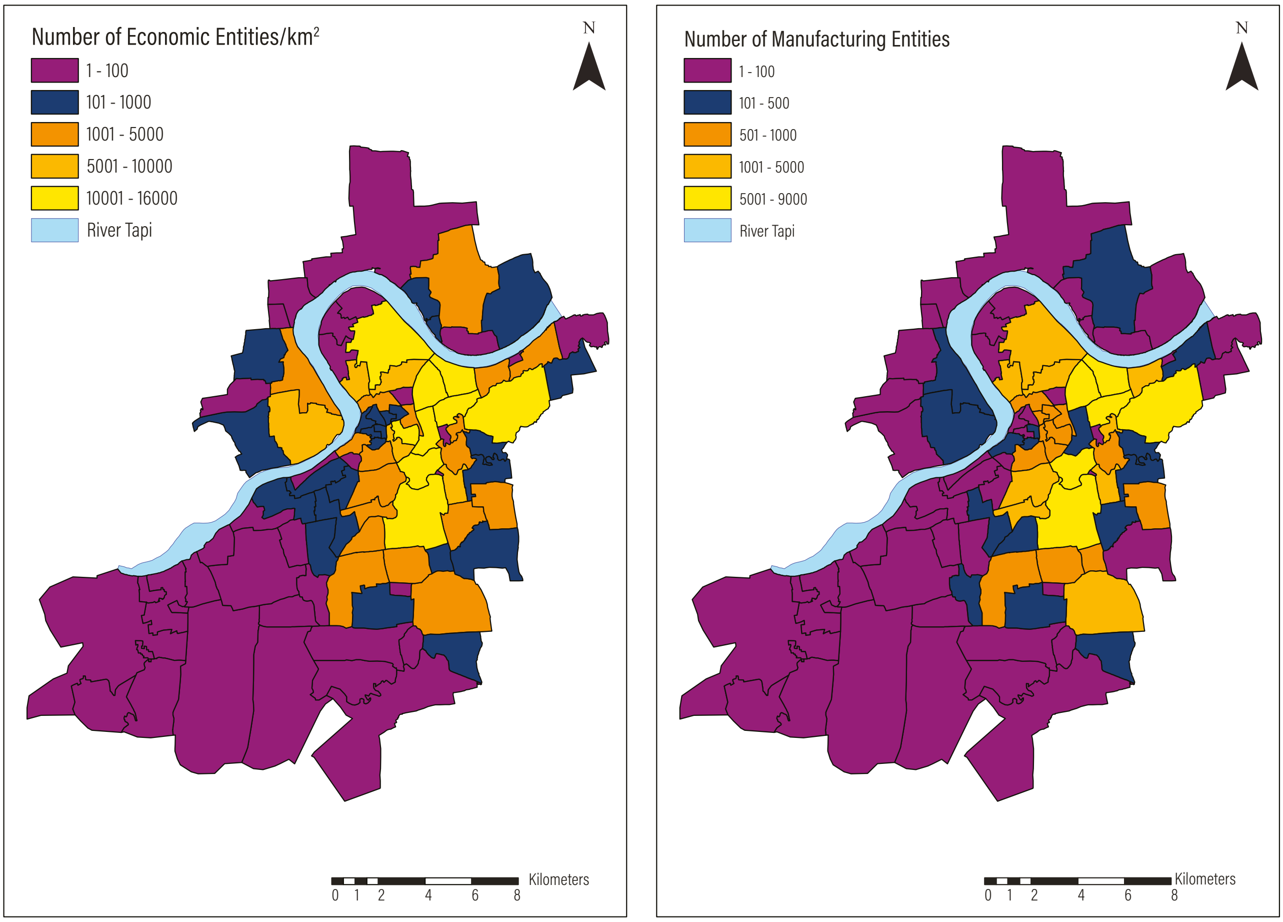
[7] *Comprehensive Mobility Plan 2046 – Surat. (2018). Centre of Excellence (CoE) in Urban Transport, CRDF, CEPT University. http://suratmunicipalcorporation.org:8020/News/6126_1.pdf.*

[8] *Comprehensive Mobility Plan 2046 – Surat. (2018). Centre of Excellence (CoE) in Urban Transport, CRDF, CEPT University. http://suratmunicipalcorporation.org:8020/News/6126_1.pdf.*

1.4.4. Industrial Production

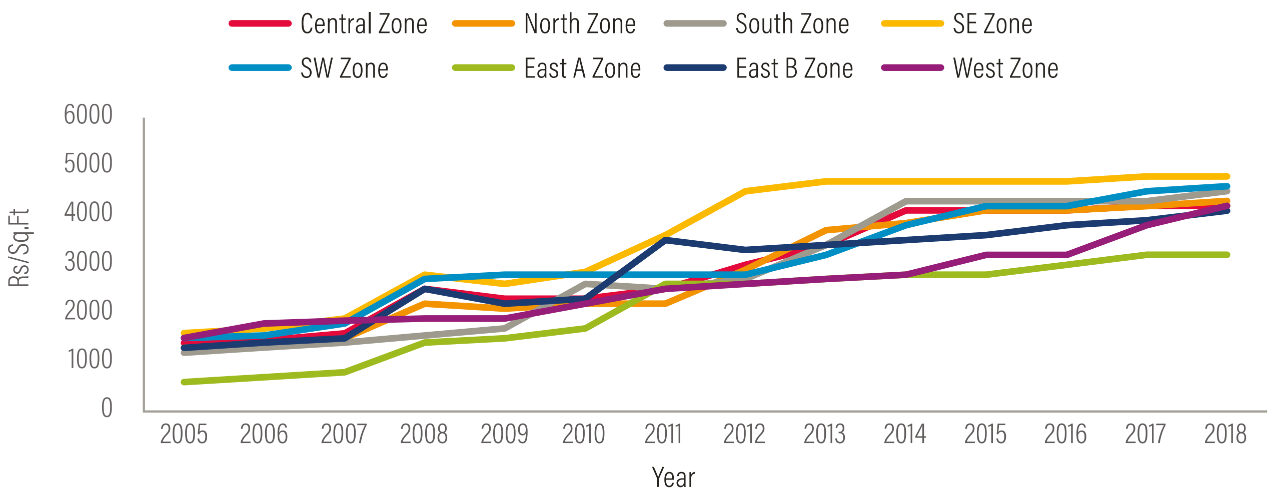
The SMC area has a significant number of industrial clusters in Gujarat. Textile is the dominant industry in the area, employing 57% of the city's primary workers, followed by 31% in other industries that include diamond polishing, chemical engineering, food, and other goods. As depicted in the map **(Figure 5),** most of the city's industrial activity is operational in the south, southwest, and southeast zones.

Figure 5: Industrial unit density per km² in SMC (Source: Economic Census of India, 2014)



However, this does not limit the operation of small units within city limits. There are units operational in the east and north zones of the city, which house some of the most populated wards of the SMC. Based on these findings, a separate dataset on the total number of economic entities (commercial and industries) and manufacturing entities located in SMC has been compiled, as indicated in **Figure 5**.

Figure 6: Residential Price Index in different zones of SMC area from 2005 to 2018 (Source: SUDA, Surat)

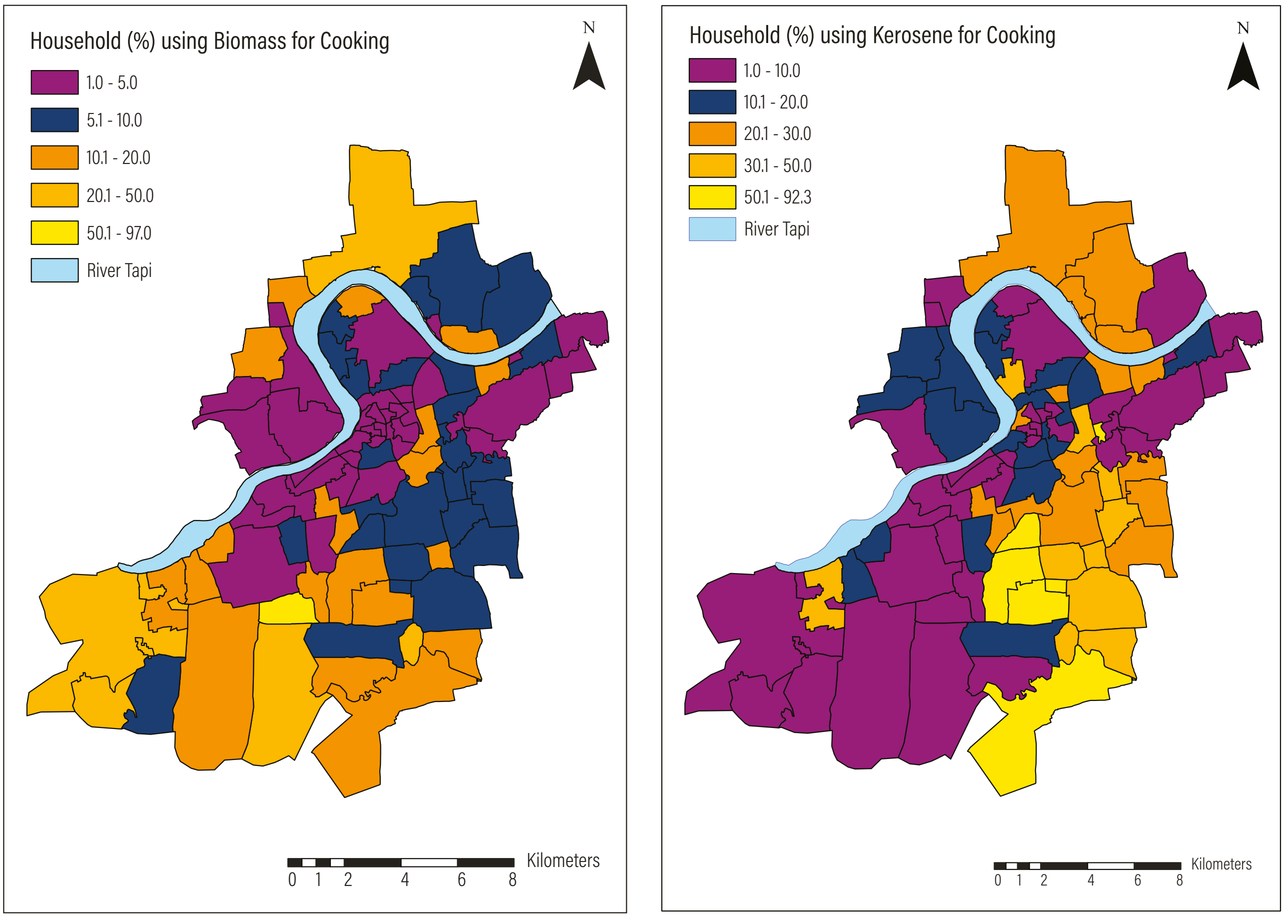


Construction processes: The SMC area has witnessed massive growth in the construction sector during the last few decades owing to economic growth and a continuous rise in the migrant population. **Figure 6** indicates the residential price index (RPI) for different administrative zones of the SMC area. The price index controls the construction and allotment of houses and infrastructure planning in an area of any city. As illustrated in **Figure 6**, the southeast zone of the SMC area has been attracting infrastructure development options and investment from government and private agencies alike due to the newly developing areas, such as Piplod and Vesu. The number of projects in an area also indicates increased or decreased construction activities. The south, southeast, and southwest, along with central zones, continue to lead with their higher RPIs and receive more significant retrofitting projects, if not new developments.

1.4.5. Household Cooking Fuel Use

In 2011, 71.3% of the households were using clean cooking fuel LPG for cooking, followed by 20.4% kerosene and 7% biomass (Census of India, 2011). **Figure 7** shows the ward-wise households' use of biomass and kerosene as cooking fuels in the SMC area for 2011.

Figure 7: Percentage of households using biomass and kerosene for cooking in different wards of SMC



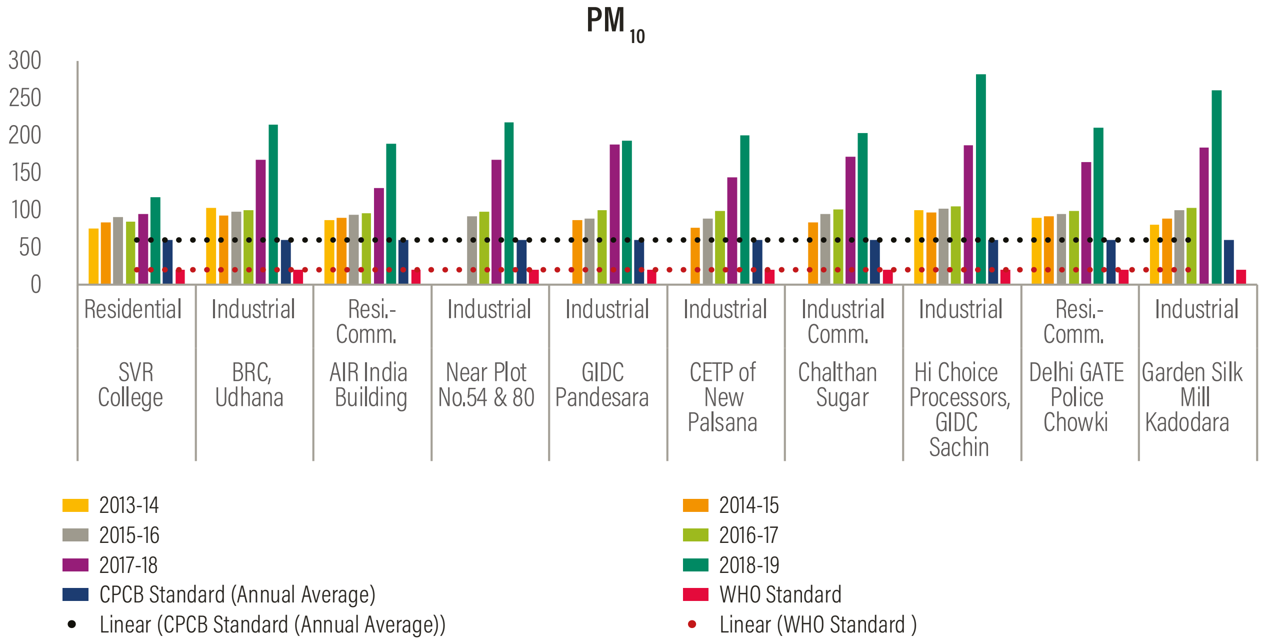
1.4.6. Ambient Air Quality and Emissions Inventories

There are ten continuous and manual air quality monitoring stations located in the SMC area[9]. As indicated in **Figure 8**, most monitoring stations have been violating the Central Pollution Control Board (CPCB) air quality standards for PM_{10} for a long time. Similarly, all the monitoring stations are violating the level of $PM_{2.5}$ from 2017-18. There are limited emissions inventories and source apportionment data available for the SMC area. Guttikunda and Jawahar (2012)[10] developed emission inventories of different criteria pollutants ($PM_{2.5}$, PM_{10}, SO_2, NOx, and CO) for the SMC area for 2010.

[9] *GPCB, Annual Report. Gujarat Pollution Control Board. https://gpcb.gujarat.gov.in/webcontroller/page/annual-report.*

[10] *Guttikunda, S. K., & Jawahar, P. (2012). Application of SIM-air modeling tools to assess air quality in Indian cities. Atmospheric Environment, 62, 551–561. https://doi.org/10.1016/j.atmosenv.2012.08.074.*

Figure 8: Annual average - $PM_{2.5}$ and PM_{10} concentration in different ambient air quality monitoring stations located in the SMC area



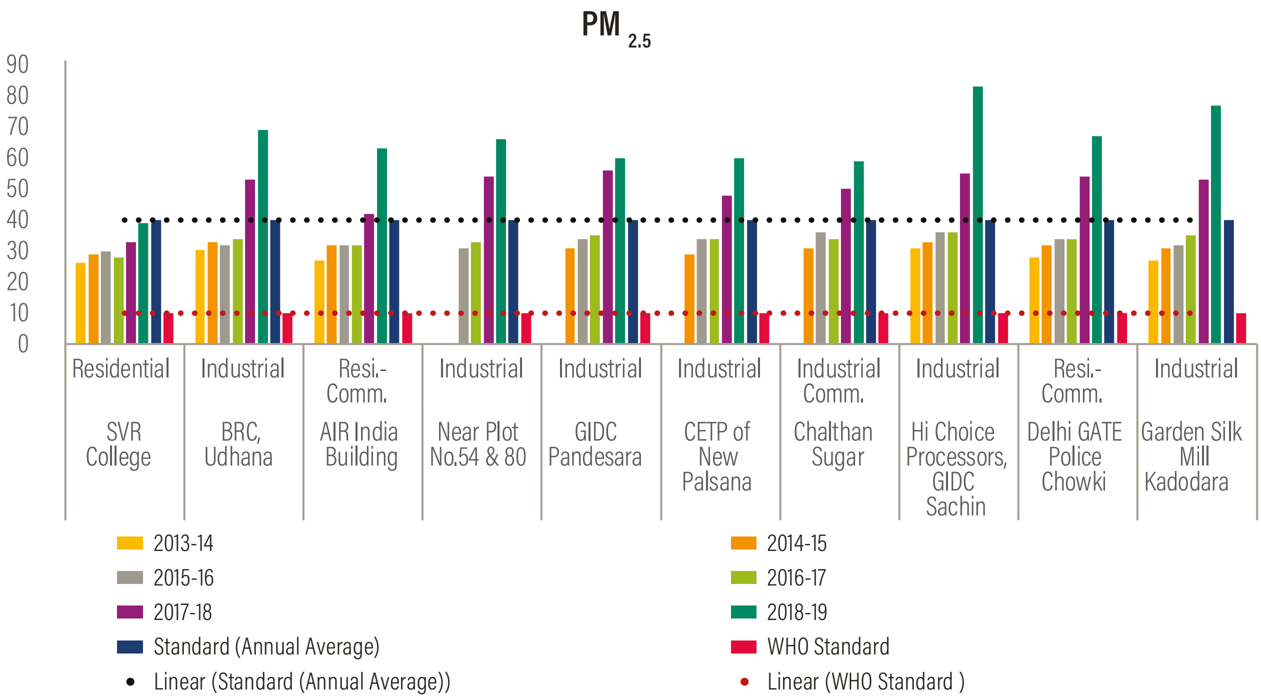
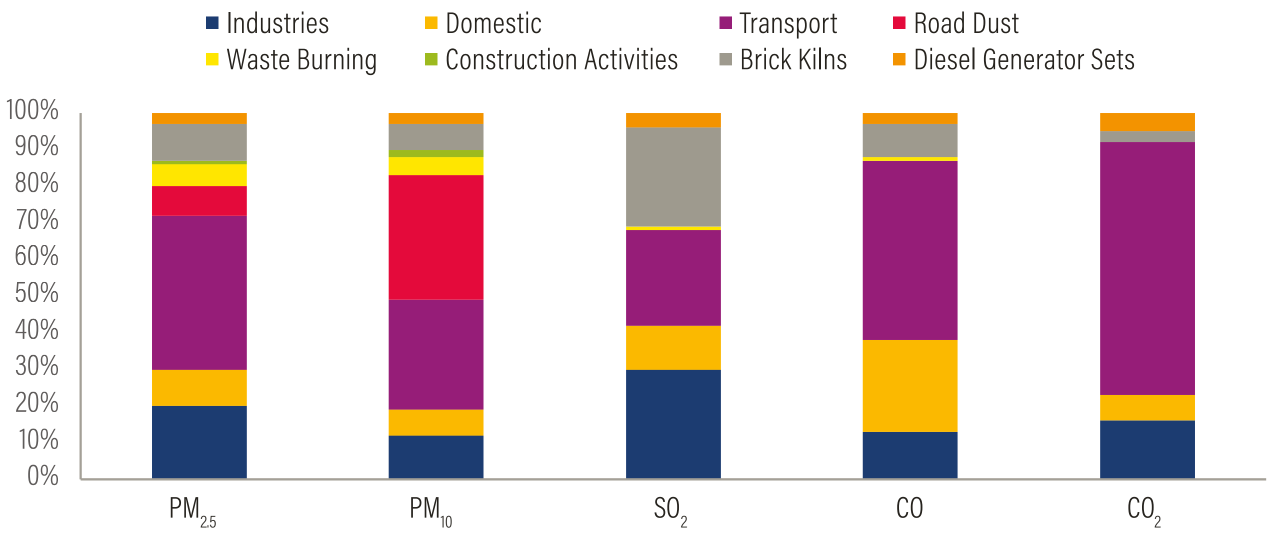


Figure 9: Contribution of different in-boundary sources for various emissions in SMC in 2010 (Source: Guttikunda and Jawahar, 2012)



According to the study, the estimated emissions from vehicle exhaust (passenger and freight), re-suspension of road dust, domestic and industrial fuel combustion, in situ diesel generators, and waste burning, in the SMC area contributed a total of ~20,000 tons of PM_{10}, ~12,000 tons of $PM_{2.5}$, ~3,400 tons of SO_2, ~146,500 of NOx, ~372,000 tons of CO, and ~11.8 million tons of CO_2 in 2010. The source-wise contribution for different pollutants from the cited study is presented in **Figure 9.** For $PM_{2.5}$, the study indicates that transportation, industries, domestic and brick kilns are the most significant contributors, accounting for most air pollutant emissions in the Surat region.

1.5. BRIEF SECTORAL METHODOLOGIES – SCAP

This section briefly discusses the overall approach followed to develop clean air strategies for each sector discussed in detail in individual chapters.

- **Emission inventory and source apportionment results** were depicted for the baseline year 2019.
- **The analysis of the current sectoral profile** included the baseline year numbers pertaining to the sector.
- **Major issues relevant to the sector** were assessed to identify the bottlenecks in the proposed mitigation actions.
- **Existing policies and programs** were compiled for the corporation level and state and Central government levels. These policies and programs were considered for their influence on the sectoral assessment.
- **Clean air action strategies by GPCB** were assessed specifically to compare ongoing works with the proposed policies and programs.

- **Control measures identified during the opportunity workshop/individual stakeholder meeting** were listed for the suggestions made by the main stakeholders during the communication and interactions.
- **Strategies to mitigate air pollution** were proposed after assessing the emissions, source apportionment study results, and analyzing the existing policies and gaps specific to the SMC area.
- **Micro-level plans to implement the strategies** were designed with respect to the ward level influence zones and specific mitigation strategies.
- **A techno-economic analysis** was conducted, and the health risk assessment evaluated the primary stakeholders' financial intricacies to implement the proposed strategies.
- **Scenario building** discussed the projections for the proposed mitigations for the fifth change year, i.e., 2025, and the tenth change year, i.e., 2030.

The following is a snapshot of the methodologies, databases, and criteria used to study mitigating emissions in each sector.

1.5.1. Household Cooking

Kerosene and biomass used for household cooking are significant sources of air pollution in the country[11]. A study conducted in 2012 indicates that household cooking contributes 25% of CO, 10% $PM_{2.5}$, 7% PM_{10}, and 12% SO_2 emissions in the SMC area[12]. **Chapter 4** analyzes the current fuel use patterns in domestic cooking in the households in the SMC area using primary and secondary data. For example, the analysis of the household expenditure of NSSO (2011) and Census of India (2011) data revealed that some households using cleaner fuel (LPG) use traditional fuels, such as fuelwood dung cake and kerosene, as secondary fuel for cooking for various reasons. Currently, clean fuel coverage is 82% in the SMC area due to the continuous efforts made as part of different clean fuel promoting schemes by the state government. The hitch in 100% coverage is due to those stacking other fuels along with LPG, i.e., secondary fuel users. The desired target of reducing the emissions of various pollutants has not been achieved because of these secondary users. With clean fuel coverage to all households moving at the required pace and several central and state government policies in place, what is required is the on-ground implementation of the schemes. Keeping this in mind, we have suggested interventions that will help achieve the outputs expected from various available clean cooking fuel schemes.

1.5.2. Municipal Solid Waste

MSW burning is a significant contributor to air pollution in urban areas. However, owing to the unavailability of waste burning data, almost negligible data is available about the contribution of MSW burning to air pollution emissions. Therefore, the team of WRI India conducted a detailed primary survey at the neighborhood level to assess the proportion of MSW burning in the SMC area. A distance sampling approach called the line transect method was used to estimate the spatial frequency, rough mass, and

[11] *Guttikunda, S. K., Nishadh, K., & Jawahar, P. (2019). Air pollution knowledge assessments (APnA) for 20 Indian cities. Urban Climate, 27, 124–141. https://doi.org/10.1016/j.uclim.2018.11.005.*

[12] *Guttikunda, S. K., & Jawahar, P. (2012). Application of SIM-air modeling tools to assess air quality in Indian cities. Atmospheric Environment, 62, 551–561. https://doi.org/10.1016/j.atmosenv.2012.08.074.*

composition of MSW burning for different city neighborhoods with various socio-economic and land use characteristics. In this method, the observer moves along a line/road and records the objects at a predetermined distance from the transect line (typically, the visible range is used as the distance). The object density is then estimated by the total object count and surveyed area. Fundamentally, it is assumed that all the objects within the transect line of sight are detected.

Emissions of different pollutants were estimated using MSW burning data obtained from primary transect surveys of the city. To develop the possible interventions and policies to mitigate the MSW burning and associated air pollution emissions, an analysis of currently available policies, interventions, and gaps were conducted. The recommendations were finalized after consultations with the stakeholders directly and indirectly associated with MSW burning. The details of this assessment are presented in **Chapter 5**.

1.5.3. Industrial Processes

Industries have emerged as one of the highest contributors of $PM_{2.5}$ for the SMC area as per the results shared by TERI. A comprehensive analysis of different industrial characteristics, such as fuel use, fuel efficiency, and air pollution control strategies, was conducted to develop clean air strategies for the industrial sector. The industrial characteristics data provided by GPCB was studied to support the current assessment of pollution control devices. The mitigation strategies were designed for the SMC area industrial cluster based on industry emissions contribution, review of existing policies, existing best practices, and consultations with stakeholders. These mitigation measures have been suggested in **Chapter 6**.

1.5.4. Construction Processes

Being one of the fastest growing cities in Asia, there is a considerable increase in construction activities in the SMC area, leading to a significant amount of construction-related air pollution emissions. However, limited work has been done to provide solutions to address air pollution emissions arising from the different construction processes. To develop clean construction practices, we first assessed the current construction profile in the SMC area, reviewed existing policies, consulted stakeholders, conducted best practices analysis, and recommended suitable interventions, which have been elaborated in **Chapter 7**. We also developed clean construction guidelines for the SMC area as a separate document.

1.5.5. Eateries

Eateries (small units, and hotels, and restaurants) contribute to particulate and gaseous pollution. However, no study is available that estimated the contribution of formal and informal eateries for air pollution by using primary data from the SMC area. Therefore, the current study conducted a detailed survey of fuel usage patterns in eateries, restaurants, and *Dhabas* for the SMC area. Based on the primary data, emissions contribution, review of existing policies, and consultants with stakeholders, we have recommended interventions for this sector in **Chapter 8.**

1.5.6. Transportation

The SMC area has the highest per capita private vehicular population in the state, as per the state Regional Transport Office (RTO) data. Considering the sectoral contribution, information from the Comprehensive Mobility Plan (CMP) 2018 was studied. A secondary assessment was made to analyze basic pointers, such as vehicular population, vehicle kilometers traveled, fleet size, vehicle ownership, trip length, and rate. A freight rate assessment was made for the vehicles within the city and those entering or passing through the city. Emissions were calculated for each vehicle type based on their numbers and vintage. Business-as-usual with conventional policy and program implications by the government of Gujarat and SMC were compared with sustainable indicators internalization in different policy and city-specific programs. Specific to this sector, several administrative updates have been suggested to control the vintage vehicular population in the city. This essential infrastructure up-gradation and a redesigning of public engagement with the transportation process have been presented in the section on scenario development in **Chapter 9**.

1.5.7. Non-Exhaust Emissions (NEE)

Non-exhaust emissions (NEE) or re-suspension of particulate matter from road dust in the SMC area is causing a major health concern here. This sector with the highest contribution to PM_{10} and $PM_{2.5}$ is yet to be regulated with specific mitigation measures and monitoring policies. The primary concern with this sector in the SMC area is that since it depends on the vehicles and vehicle kilometers travelled (VKT), it cannot be controlled or reduced in future concentration with a single policy or program. The key lies in controlling the city's vehicular movement and overall motor driving behavior by providing them adequate infrastructure and shifting their mode share towards public transport through administrative regulations, such as 'no pollution zones,' in the city's NEE influenced areas. Based on the source apportionment study, recommendations have been made for the sector and SMC area-specific implementation procedures in **Chapter 10**.

CHAPTER 02

>> EMISSION INVENTORY AND SOURCE APPORTIONMENT

*This chapter has been provided by TERI

2.1. INTRODUCTION

This chapter throws light on the contribution of different sources in the SMC area on air pollution using emissions inventory, dispersion modeling, and receptor-based source apportionment study. Air pollutants emissions inventory is a fundamental tool in air quality management, evaluating air pollution emissions from different sources. It is a critical tool for planning pollution control strategies. Air pollution emissions inventories for the SMC area for different air pollution sources were developed for 2019 using primary and secondary data. This inventory data was then used in air quality dispersion modeling to estimate air pollution source contributions in the SMC area. The modeling framework for this study consists of a meteorological model, an air quality model, and an emissions inventory database, which were integrated to simulate the local and regional atmospheric circulation and estimate the ambient pollutant concentration in the SMC.

The Weather Research and Forecasting (WRF) - Community Multi-scale Air Quality model (CMAQ) combination was used to simulate the SMC area's ambient PM_{10} and $PM_{2.5}$ concentrations. The receptor modeling approach was used to analyze the chemical and physical characteristics of gaseous and particulate pollution in different locations of the SMC area via the Chemical Mass Balance (CMB) model for the receptor-based source apportionment study. To carry out receptor modelling, air pollution ambient concentration data were collected from seven representative monitoring locations of the SMC area. To capture seasonal variation in pollutant concentrations, 24-hour sampling was carried out at each of the selected locations for a period of 15 continuous days covering both summer (May-June 2019) and winter (December 2019 – January 2020) seasons of the year. At the background station, the monitoring was carried out for 30 continuous days during each season. The information presented in this chapter is based on the Source Apportionment Study and Preparation of Air Quality Action Plan for Surat City, TERI, New Delhi (TERI, 2021). For details, refer to the TERI report of 2021.

2.2. EMISSION INVENTORY

The current emissions inventories of particulate matter (PM_{10}, $PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and non-methane volatile organic compound (NMVOCs) from different sources were developed by TERI for the SMC area and Surat district for the year 2019. These emissions inventories are further distributed into 2-km X 2-km grids. The major sectors covered in current emissions inventories are given in **Table 3.**

Table 3: Air pollution source sectors covered in the current emissions inventory

Sr. No.	Type of Source	Sectors
1.	**Line Source**	**Transportation**
		Road dust resuspension from transportation
2.	**Area Sources**	**Residential cooking**
		Crematoria
		Municipal solid waste burning

		Diesel generator sets (DG Sets)
		Construction processes
		Aviation
		Eateries and restaurants
		Landfill open waste burning
3.	**Point Sources**	**Industries**
		Power Plants
		Brick Kilns

Emission estimates for different sources and sectors were based on the air pollution, emission factors, pollution control technologies, and efficiency of the control technologies. For each sector, activity data were collected by primary survey and secondary sources. A primary survey was conducted to fill the data gaps and limitations observed in secondary data for transport, industries, diesel generator (DG) sets, and restaurants/hotels. The estimated emissions from different sectors have been suitably allocated over the study domain as per line, area, and point source categories. The methodologies applied to estimate emissions from different sectors have been described in detail in **Section 2.3**.

2.3. EMISSIONS ESTIMATIONS FROM DIFFERENT SECTORS

2.3.1. Industries

To estimate the emissions from industrial sources, different activity data such as fuel consumption in the industrial processes, fuel type, and type of air pollution control device (APCD) installed in the industry were obtained from the secondary survey and personal communication with GPCB and SMC. The industrial sector emissions were then estimated using fuel consumption, emissions factor, and APCD using the following equation:

$$Ep = Cf \times EF \times (1-\eta)$$

Where Ep is the emission of pollutant p from industrial fuel consumption, EF is the emission factor of the fuel consumed, Cf is the fuel consumed in the industry, and η is the efficiency of the APCD installed in a particular industry.

2.3.2. Transportation

Transport sector emissions have been estimated using vehicle characteristics (VKT) and emission factors based on the vehicle characteristics approach. Data on vehicle characteristics (age, mileage, fuel efficiency) were obtained from traffic count and parking lot surveys at different SMC areas. The following equation was used to estimate the tailpipe emission for the transport sector:

$$E_p = \sum_{c=1}^{n} \sum_{s=1}^{4} VKT_{c,s} \times EF_{c,s,p} \times \varepsilon_{c,s} \times n_c$$

Where Ep is the total emission of a pollutant (p), c is the category of the vehicle, s is the emission control norm (BSI to BSIV) and CNG penetration, VKT is the Vehicle Kilometer Traveled, EF is the emission factor of pollutant p, ε is the percentage of the vehicle under an emission control norm, and n is the total number of vehicles in category c.

The emissions factors for PM_{10}, $PM_{2.5}$, NOx, SOx, hydrocarbon, and CO are adopted primarily from the Automotive Research Association of India (ARAI, 2016). In addition, both VKT and ε are considered based on primary survey results analyzed from the traffic count survey and parking lot survey conducted for the SCAP project.

2.3.3. Road Dust Resuspension or Non-Exhaust Emissions

Emissions from road dust re-suspension due to the movement of vehicles are calculated using United States Environmental Protection Agency (USEPA, AP-42) method. Dust emissions due to vehicle movement vary with the silt loading on the road surface and the average weight of the vehicles plying on the road. Therefore, 38 dust samples were collected from various roads in the study area as per the USEPA method and tested for their silt content. They were then converted into silt loading (g/m^2) and further used to estimate emissions from that sector. A portable vacuum cleaner was used to collect samples from a 1m^2 area in the middle of the road. The filter bag of the vacuum cleaner was emptied and weighed before the sampling. Sampling material was collected only from the portion of the road over which the wheels and carriages travel routinely. PM emissions from the re-suspension of road dust due to the movement of vehicles on paved roads were calculated using the following equation:

$$[E_p]_t = \sum VKT_r \times k \times w^{1.02} \times Mo^{0.91}$$

Where [Ep]t is the fugitive emission of pollutant (p) from the transport sector, r is the type of road (arterial, sub-arterial and local), VKT is Vehicle Kilometer Travelled, k is the function of particle size (0.62 for PM_{10} and 0.15 for $PM_{2.5}$), w is the average weight of vehicle traveling on the road, and Mo is road surface silt (≤ 75 µm in physical diameter) loading in a unit area. The [Ep]t is directly proportional to the silt loading on the road surface and the average weight of the vehicles plying on the road. Therefore, 15% of the [Ep]t was considered $PM_{2.5}$, while 62% was considered PM_{10}.

For Surat, an average value of silt loading was estimated from samples collected from different categories of roads such as arterial, sub-arterial, and local roads. The VKT for Surat was estimated by using the method explained in the transport sector emission estimation. After estimating [Ep]t using the above equation, the effect of rainy days was considered to finalize the fugitive emission (f[Ep]t) from road dust re-suspension using the following equation:

$$f[E_p]_t = [E_p]_t \times (1-D_p)/(4\times365)$$

Where Dp is the number of rainy days in a year, and 112 numbers of days are considered here based on meteorological conditions of the Surat city.

2.3.4. Household Cooking Sector

Data on access to cooking fuel by population, per capita cooking fuel use, and fuel-specific emission factor of different pollutants were used to estimate air pollution emissions. The following basic equation was used to estimate the emissions from the household cooking sector:

$$[E_p]_R = \sum_{a=1}^{2}\sum_{f=1}^{6} Pop_{(a,f)} \times C_{(a,f)} \times EF_{(f,p)}$$

where [Ep]R is the emission of a particular pollutant (p) from the household cooking, Pop(a,f) is the population of Rural (a=1), and Urban (a=2) region in Surat district and SMC using a particular type of fuel (f), C(a,f) is region-specific per capita consumption of a particular fuel, and EF(f,p) is emission factor of the particular pollutant (p) of the particular fuel type (f).

As most fuel access data is available for the year 2011, the projected population using different fuels were estimated using the following equation:

$$Pop_{2019} = Pop_{2011}[1+R\%]^t$$

Where[Pop]2019 is projected population of SMC area, [Pop]2011 is the population of SMC area in 2011, R% is the district-specific population growth rate in rural and urban areas, and t is the period between 2011 and 2019.

Table 4 lists the consumption of different fuels for the SMC area for the base year 2019.

Table 4: Consumption of different types of fuels (kt/year) in residential households of the SMC area

Location	Fuelwood	Crop Residue	Cow Dung Cake	Coal	Kerosene	Kerosene Lightening	LPG
City	59.75	6.41	0.79	71	5.39	0.04	167.06

2.3.5. Municipal Solid Waste Burning

To estimate the air pollution emissions from MSW, primary MSW burning data were first collected by WRI in the primary survey using the survey method developed by Nagpure et al. (2015). The primary MSW burning data were then used to estimate the emissions from MSW burning by multiplying it with the emissions factor from Akagi et al. (2011) and Sharma et al. (2019). The following equation was used for emissions estimation from the open MSW burning sector:

$$E_p = W_B \times E_f$$

Where Ep is the emission of pollutant p, WB is the quantity of MSW burnt, and Ef is the emission factor.

2.3.6. Landfill Emissions – Municipal Solid Waste Burning Sector

Emissions from landfills were estimated based on MSW generation, collection, treatment, and quantity of MSW in landfills. The MSW left untreated finally lands into open sites or landfills. TERI estimated the quantity of MSW on the landfill and assumed that 2% of dumped MSW was burnt every day in the SMC area. The following equation was used to estimate emissions from landfill MSW burning:

$$E_p = 2\% \times W_L \times E_f$$

Where Ep is the emission of pollutants p, WL is the waste collected at the landfill site, and Ef is the emission factor adopted from USEPA, AP-42.

2.3.7. Eateries

To estimate the emissions from hotels, restaurants, and informal and formal eateries, a primary survey was conducted by WRI and TERI to collect fuel consumption data. Data collected in the 12 grids of the SMC area were extrapolated for other grids in the study domain based on population density and land-use patterns. The following equation was used to estimate emissions from hotels, restaurants, and eateries of the SMC area:

$$Ep = C_f \times E_f$$

Where Ep is the emission of pollutant p, Cf is the fuel consumption by the hotel/ restaurant, and Ef is the emission factor of different fuels used in cooking. Emission factors for different fuel types were collected based on a review of published literature.

2.3.8. Construction

To estimate the emissions from the construction sector, high-resolution images using GIS tools were used to identify different construction sites and areas of construction. With the digitization of the identified sites, polygons were created manually with the help of Google Earth's in-built tools. For map creation and post-processing for the polygons marked in Google Earth, ArcGIS software was used to estimate the study domains under construction or earmarked demolition areas. The following equation was used for emission estimation:

$$Ep = A_c \times T \times E_f$$

Where E is the suspended particulate emissions, AC is the area of construction, T is activity duration, i.e., time duration of construction or demolition for a site (Rainy Months (RM) not considered as activity duration, i.e., activity duration considered as (12 – RM), and EF is emission factor (tons/month/acre)). The particulate matter emissions from construction activities were estimated using an emission factor (1.2 tons/acre/month) (USEPA, 2019).

2.3.9. Other Sectors – Aviation, Crematoria, Agriculture Activities, DG Sets, Thermal Power Stations, Brick Kilns

The emissions from aviation, crematoria, agriculture activities, DG sets, thermal power stations, and brick kilns sectors were assessed by TERI. The details of the methodology for each sector can be found in Source Apportionment Study for the SMC area, Gujarat, by TERI (TERI, 2021). These sectors contributed approximately 1% emissions each of PM_{10}, $PM_{2.5}$, NOx, and CO. In comparison, the aviation sector contributed 5% of the SO_2 emissions, and 4% of the NMVOC emissions share was from landfills, crematoria, and aircraft. The sectoral contribution of various pollutants is presented in **Figure 10**.

2.3.10. Total Emissions Estimation

The emission contribution of different sources based on emission inventory in the SMC area is summarized in **Table 5**. The air pollution sources such as industry, transport, road dust resuspension, solid waste burning, DG Sets, residential cooking, eateries, landfills, construction, crematoria, and aircraft together contribute approximately 35.467 kt, 14.248 kt, 5.232 kt, 38.59 kt, and 139.568 kt of PM_{10}, $PM_{2.5}$, SO_2, NOx and CO emissions, respectively, in the SMC area.

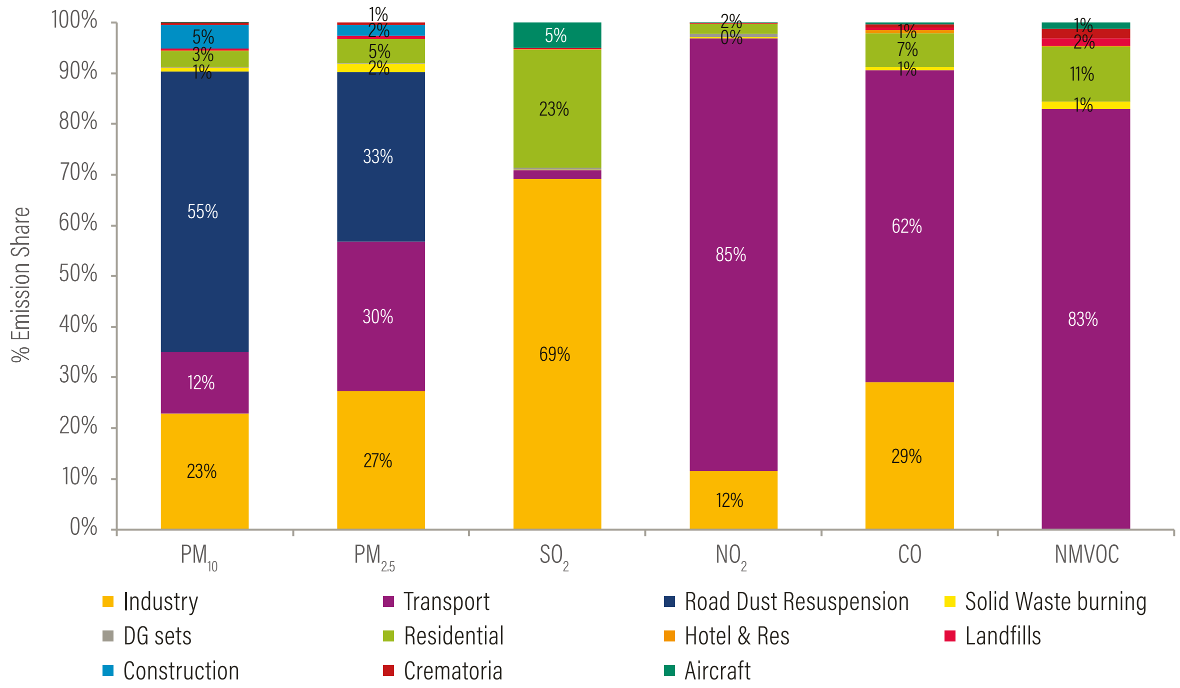
Table 5: Total emissions from pollutants in the SMC area

Sector	Emissions (kt/year)				
	PM_{10}	$PM_{2.5}$	SO_2	NO_X	CO
Industry	8.1	3.87	3.59	4.46	40.42
Transport	4.31	4.19	0.09	32.86	85.78
Road dust resuspension	19.55	4.73	-	-	-
Solid waste burning	0.27	0.23	0.01	0.09	0.87
DG sets	0.02	0.015	0.017	0.258	0.056
Residential cooking	1.14	0.68	1.21	0.76	9.29
Eateries	0.111	0.073	0.042	0.072	1.14
Landfills	0.13	0.089	0.008	0.049	0.686
Construction	1.67	0.29	-	-	-
Crematoria	0.156	0.077	0.003	0.021	0.783
Aircraft	0.004	0.004	0.262	0.02	0.543
Total	**35.461**	**14.248**	**5.232**	**38.59**	**139.568**

Figure 10 shows emissions allocations to different sectors affecting the SMC's air quality**.** It is evident from **Figure 10** that industries hold the major share of SO_2 and accounts for 69% of the total emissions, followed by the residential sector (23%). Similarly, NOx pollution is largely emitted from the transport sector, which shares 85% of the total NOx emissions, followed by a 12% share from industries. Transport holds a 62% share in the total CO emissions, and industries contribute about 29%. As per the emissions inventory data, road dust re-suspension accounts for a major proportion of PM_{10} and $PM_{2.5}$, followed by transport exhaust emissions and industries. Road dust re-suspension in the SMC area accounts for 55% of the total PM_{10} and 33% of the total $PM_{2.5}$. Transport exhaust emissions account for 12% PM_{10} and 30% $PM_{2.5,}$ whereas industries account for 23% PM_{10} and 27% $PM_{2.5}$. NMVOC is mainly emitted by the residential sector (63%), followed by crematoria (11%) and landfills (9%). Apart

from the transport sector, 29% of CO is emitted by industries and 7% from the residential sector. Construction activities share about 5% and 2% of the PM_{10} and $PM_{2.5}$ emissions, respectively. The aviation sector emits 5% SO_2 and 1% NMVOC. The transport sector emits 83% NMVOC.

Figure 10: Total emissions in the SMC area – Source wise percentage share



2.4. PROJECTION OF SECTORAL EMISSIONS (BUSINESS-AS-USUAL)

Scenario analysis for the future was carried out to understand how growth in different sectors would contribute to air pollution in the region. In this regard, possible future growth scenarios were prepared for 2025 and 2030. A business-as-usual (BAU) scenario was developed, which considered the growth trajectories in various sectors and the policies and interventions that have already been notified for air pollution control. To assess the potential of various strategies to control air pollution, interventions in different sectors were tested on the air quality model. Strategies that could provide significant air quality benefits were identified for constructing an alternative scenario (ALT) to reduce the air pollution towards meeting their prescribed National Ambient Air Quality Standards (NAAQS) for those by 2030.

2.4.1. Business-as-Usual Considerations for the SMC Area

The BAU scenario depicts changes, both growth, and controls, taking place in different sectors, such as transportation, industries, domestic, open burning, crematoria, and restaurants up until the year 2030. This scenario does not account for any additional interventions to manage air quality, and the growth rates of different sectors have been adopted through a review of published literature. The growth rate in energy consumption in industries in the SMC area is projected to be 5.9%, as per the 2012 Surat solar city master plan of the Ministry of New and Renewable Energy, Government of India. The annual average growth rates of 6.33% and 1.82% in coal and gas in industries were also projected based on the Surat solar city master plan by the Ministry of New and Renewable Energy, Government of India, 2012. The hotels/restaurants sector is projected to grow at a rate of 11.2% in 2025 and 2030, on the basis of the growth rate of district gross domestic product (GDP) of hotels and restaurants in Gujarat during the last five years (India Statistical Handbook, 2020). However, for small unorganized eateries, a growth rate of 7% was projected (FICCI, 2017). In the crematoria sector, based on previous trends in the crude death rate of SMC for the last five years, the crude death rate for the urban population is estimated to be 4.14 per 1,000 inhabitants by 2030. For the rural population, the crude death rate is estimated based on previous trends in the crude death rate of the rural population for Gujarat state (Census of India, 2001 and 2011). It is estimated as 6.1 per 1,000 inhabitants by 2030. As power cuts are already rare in the SMC area and are projected to be negligible by 2025 (as Surat is one of the Smart cities in India), it is projected that there will be no usage of DG sets in 2025 and 2030. Based on the GDP of construction activities in Gujarat during the year 2011-2018, the compound annual growth rate of this sector is projected to be 3.07% (RBI handbook, 2019) for both 2025 and 2030.

Different vehicle registration growth rates in the transport sector are obtained from the statistical yearbook for the road transport sector (MoRTH, 2019). Accordingly, the vehicular sector is projected to grow at 7% up until 2025 and at a rate of 4% post-2025. Furthermore, as notified, BS-VI emission norms are to be effective from 2020.

In the domestic sector, a population growth rate of 4.93% per annum has been projected for 2025 and 2030, based on the decadal growth rate of population in the SMC area as per census data (Census of India, 2001 2011). The annual growth rate of domestic LPG connections in the SMC area was estimated at 3.75%. The annual PNG growth rate in the SMC area was estimated at 7.65%, following the Ministry of New and Renewable Energy (MNRE, 2014). The annual growth rate of kerosene for cooking was estimated at -6.5% (a decline). It is also expected that kerosene will cease to be used for lighting purposes in the SMC area by 2025 and 2030. A 2% growth rate is projected for electricity use for cooking purposes. Simultaneously, the number of fuelwood and kerosene-consuming households would fall by 5.75%. The number of crop residue, dung cake, and coal-consuming households is projected to fall by 1.25% annually by distributing the 3.75% annual growth rate of LPG-consuming households among the three fuels equally. The brick kiln sector is expected to grow at 7.5% annually based on the Centre for Science and Environment data (2017). It is expected that no new coal-based power plants will be installed in the district for the power sector, and accordingly, no growth in emissions in power plants has been projected for 2025 and 2030. In the aviation sector, the number of flights from Surat airport is projected to increase due to increased passenger counts for various national and international destinations. Based on the data from 2015 to 2019 and the growth trends in the number of flights, the annual growth rate for the aviation sector is projected to be 9.46% for 2025 and 2030. Based on the trends in waste disposed at landfills in the SMC area during 2012-19 (SMC, 2021), an 8% increase is projected in the disposal of waste at the landfill site both for 2025 and 2030. For the refuse sector, the SMC area population growth rate of 4.93% per annum is projected for both 2025 and 2030. Also, according to the SMC database, the per capita waste generation and collection efficiency in the SMC area during 2019 was reported as 0.45 kg/day and 97.7%, respectively. The quantity of non-biodegradable waste generated in the SMC area was reported as 35% in the same year. Therefore, similar projections have been made for the emissions from this sector for 2025 and 2030.

The growth rates adopted for projections of various sectors under the BAU scenario are summarized in **Table 6**. The BAU scenario has been developed based on the growth rates under various sectors, and emission loads for different pollutants like PM_{10}, $PM_{2.5}$, SO_2, and NOx have been estimated.

Table 6: Growth rate adopted for various sectors under BAU scenario

Sector	Growth Rate	Reasoning	Controls Assumed
Transport/ Road Dust	7% growth rate up to 2025, after that 4%	Based on the past trends of different types of vehicle registrations in Surat (MoRTH, 2019)	BSVI norms from 2020 No further control for road dust
Crematoria	The crude death rate for the rural population is 6.1% in both 2025 and 2030, and for the urban population, 4.14% in both 2025 and 2030	Based on past trends of the crude death rate of Gujarat state in India Census (2001,2011)	No further control
Restaurants	11.2% in both 2025 and 2030 and for unorganized eateries, 7% in both 2025 and 2030	Based on the growth rate of gross district domestic product of hotels and restaurants in Gujarat during the last 5 years and for unorganized sector FICCI report, 2017	No further control
DG sets	No DG sets in 2025 and 2030	DG set usage is presently very low and is expected to further decline with improve-ment in the power situation.	
Construction	3.07% for both 2025 and 2030	Based on the gross domestic product of construction activities in Gujarat during the year 2011-2018. RBI Handbook, 2019	No further control
Industries	5.9% for other fuels, 6.33% for coal, and 1.82% for Natural gas in both 2025 and 2030	Based on the growth rate in energy con-sumption in industries in Surat as per the Surat solar city master plan by the Ministry of New and Renewable Energy	No further control
Domestic	The annual population growth rate of 4.93% in 2025 and LPG pene-tration will increase at the rate of 3.75% in Surat and annual PNG growth rate of 7.65 % in both 2025 and 2030	Based on the decadal growth rate of population in Surat as per census data 2030 (India Census 2001, 2011) MNRE report 2014	100% LPG penetration by 2030
Brick kiln	The annual growth rate of 7.5% for both 2025 and 2030	Based on Rajaratnam et al. 2014 & Presen-tation by J. S. Kimora (Director, CPCB) in Anil Agarwal Dialogue 2015, CSE & Surat action plan	50% kilns will be converted into Induced draught in 2025, and 100% kilns will be converted into Induced draught in 2030
Power plants	Same as in 2019 for both 2025 and 2030	No new power plants will be installed in the district and hence not projected to grow any further in future	100% implementation of Power Plant emission norms by 2025
Aviation	The annual growth rate of 9.46% in both 2025 and 2030	Based on the annual growth rate in the number of flights during the last 5 years as per Airport Authority of India statistics	No further control
Landfill	The annual growth rate of 8% for both 2025 and 2030	Based on the past years (2012-2019) trend in waste disposed at landfills in SMC areas.	No further control

2.5. AIR QUALITY DISPERSION MODELING AND SOURCE APPORTIONMENT

In this study, using dispersion modeling, the validated model was used to estimate the share of different sources of emissions in the prevailing PM_{10} and $PM_{2.5}$ concentrations in the SMC area. The modeling framework for this study consists of a meteorological model, an air quality model, and an emission inventory database, which were integrated to simulate the local and regional atmospheric circulation and estimate the ambient pollutant concentration in the SMC area. The WRF-CMAQ modeling combination was used to simulate the ambient PM_{10} and $PM_{2.5}$ concentrations. In addition, the CMAQ version 5.3.1 model has been used in the study to estimate the chemical transport of pollutant species under prevailing meteorological conditions.

The source sensitivity analysis was performed to estimate the contributions from different sources impacting the PM concentrations in the SMC area using the validated WRF-CMAQ modeling setup. The simulation has been performed for the same time during which monitoring was performed in Surat by TERI. The results of source apportionment derived using the dispersion modeling approach are presented in **Table 7**. The winter season is averaged from December 2019 to January 2020, while summer is from May 2019 to June 2019.

Table 7: Seasonal averaged source contribution to PM_{10} and $PM_{2.5}$ concentrations in Surat

Sector	Winter		Summer	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Residential	14%	15%	1%	2%
Industry	25%	27%	12%	17%
Transport	13%	16%	4%	6%
Thermal power plants	9%	10%	1%	1%
Brick kilns	3%	3%	0.1%	0.1%
Waste burning	1%	1%	0.3%	0.3%
DG sets	0.2%	0.2%	0.2%	0.2%
Road dust	14%	7%	12%	10%
Construction	1%	0.3%	2%	1%
Agriculture residue burning	2%	3%	0%	0%
Transboundary sources	8%	8%	64%	57%
Others	10%	9%	5%	6%

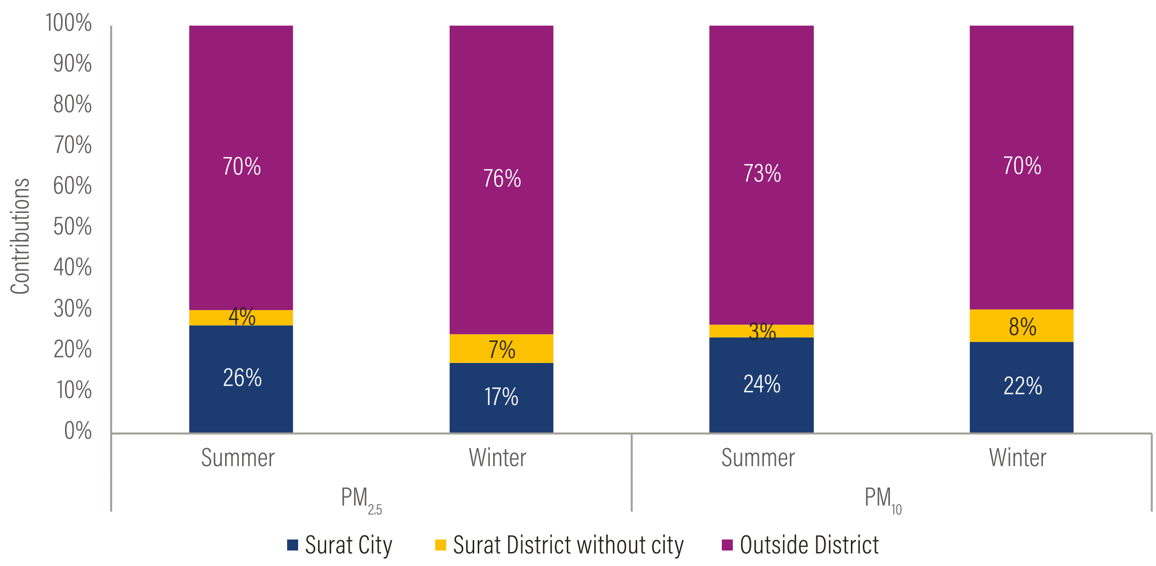
**Others include Crematoria, Surat port, landfills, biogenic and NH_3. The contributions to PM levels in the SMC area given above are different sectors with contributions from various geographical regions, not just from sources within the SMC area.*

Industrial sources emerge as the major contributor in both seasons, with contributions ranging from 17% to 27% for $PM_{2.5}$ and from 12% to 25% for PM_{10}. This is followed by road dust and the transport sector. The contribution from road dust in ambient $PM_{2.5}$ concentration ranges from 7% to 10%, and in PM_{10} concentration, it ranges from 12% to 14%. In the transport sector, the contribution of $PM_{2.5}$ ranges from 6% to 16%, and in $PM_{10,}$ it ranges from 4% to 13%. In the case of ambient PM_{10} concentration, the significant contributors are the residential sector (1- 14%), others (5- 10%), and the power (1- 9%) sector. The ambient $PM_{2.5}$ contribution from transboundary sources varies from 57% in summers when the wind speed is high and blowing from the western direction and drops down as low as 8% in winters when the wind speed is reduced and the wind direction is reversed. The transboundary contribution to ambient PM_{10} concentration varies from 8% to 64%. It is evident that agriculture residue burning is not a prominent sector causing deterioration in the air quality of Surat, with contributions ranging between 2% and 3% in the winter season and negligible contributions in summers for both PM_{10} and $PM_{2.5}$ ambient concentration, respectively.

2.5.1. Geographical Contributions of PM Concentration in Surat

The model has also been used to estimate the geographical contributions of ambient $PM_{2.5}$ and PM_{10} concentrations in the SMC area. The geographical contributions vary as per prevailing wind directions and meteorological conditions. The contribution in SMC area's ambient PM_{10} and $PM_{2.5}$ concentration from the city's own emissions in summer has been estimated to be about 24% and 26%, respectively, while in winters, it is estimated to be 22% and 17%, respectively. **Figure 11** shows the contributions of different regions towards PM_{10} and $PM_{2.5}$ concentrations in the SMC area in the summer and winter seasons. The outside India contributions are higher in summers for both $PM_{2.5}$ (57%) and PM_{10} (64%), while it decreases to about 8% for both pollutants in winters. This is due to the prevailing windy conditions in the summers, which transport dust and other pollutants from outside the boundary of India and influence the air quality of the city.

Figure 11: Geographical contribution of PM_{10} and $PM_{2.5}$ concentrations in Surat



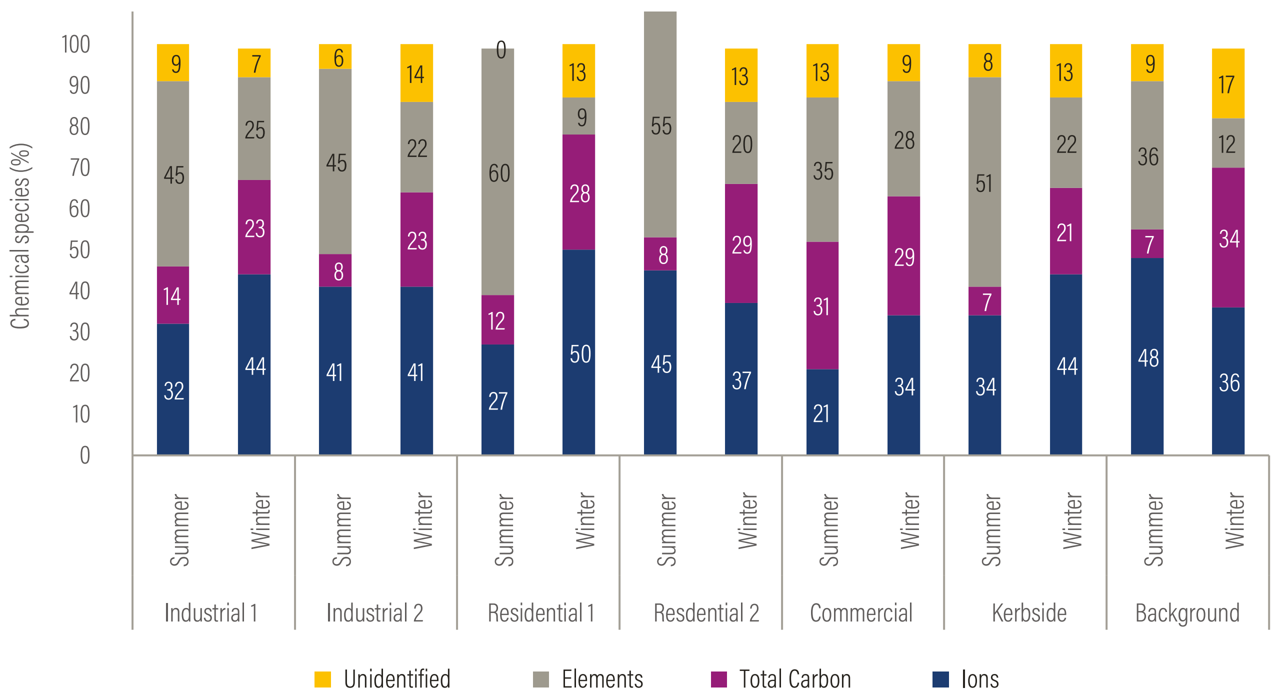
From **Figure 11**, it may be inferred that the contribution from the rest of India is dominant during the winter months when the wind direction is reversed, and the pollutants from upwind of the SMC area have a higher impact on the air quality of the city.

2.6. CHEMICAL CHARACTERIZATION OF PARTICULATE MATTER

The chemical composition of particulate matter provides useful information about the formation, aging, reaction mechanism, and the source it originates from. Therefore, the ambient particulate matter collected on different filter media from seven locations in the SMC area during both seasons was analyzed for their chemical characteristics, namely, carbon, ions, and elements. The following critical observations were made for PM_{10} and $PM_{2.5}$:

PM_{10}: Elements were identified as the most abundant chemical constituent in ambient PM_{10} across all the monitoring locations during the summer season. On the other hand, ions were the most abundant chemical constituent in ambient PM_{10} at different monitoring locations during the winter season. Irrespective of monitoring locations, Si, Al, Fe, Ca, Na, and S were identified as the most dominating element species during the summer and winter seasons, depicting significant contributions from dust and industrial sources. On the other hand, $NH4^{+}$, Ca^{2+}, Na^{+}, Cl^{-}, $SO4^{2-}$ and $NO3^{-}$ were identified as the most dominating ionic species across different monitoring locations during summer and winter seasons, depicting significant contributions from chemically formed inorganic secondary particles from long-range transport and sea salt. The proportion of energy consumption ranged between 12% and 47% and between 25% and 35% of total carbon in PM_{10} amongst different monitoring locations during the summer and winter seasons.

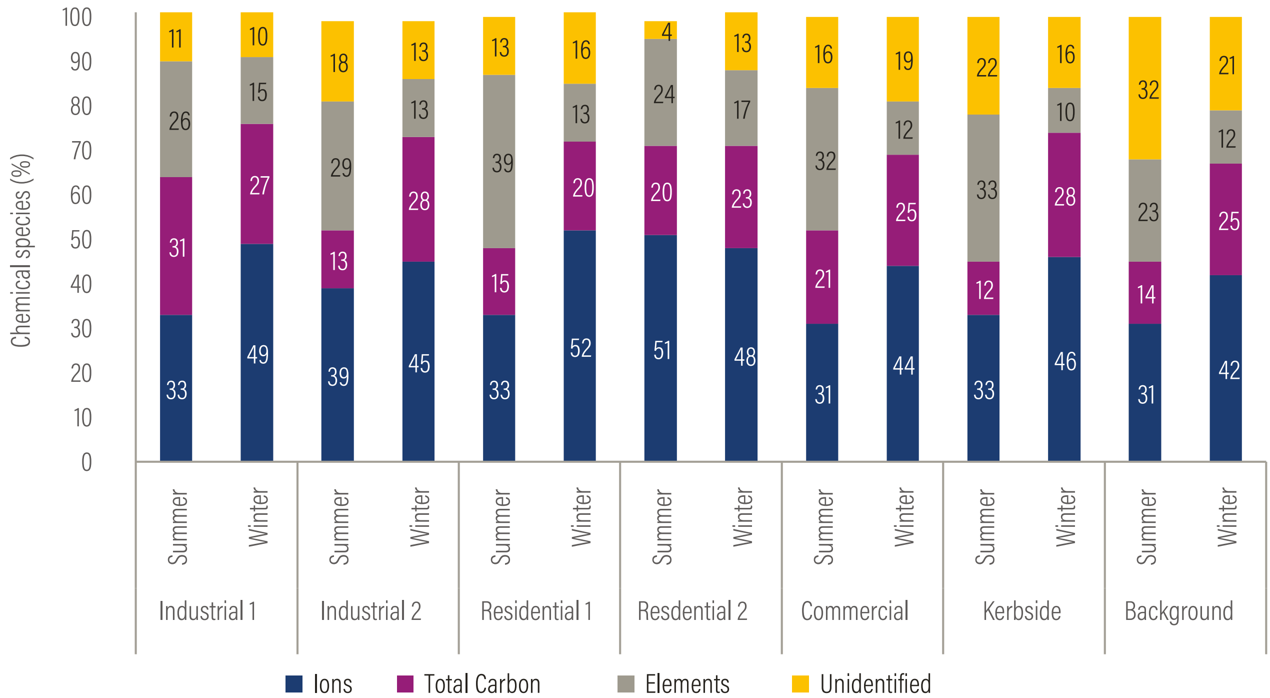
Figure 12: Seasonal variation in chemical characterization of ambient PM_{10} at different monitoring locations



** The unidentified portion (reconstructed mass under the estimated gravimetric mass showed as less than 100%) includes organic matter associated with organic carbon, oxygen associated with the oxides of metals, and other unidentified species that are not analyzed. This discrepancy could also be attributed to some loss of organic compounds due to volatilization. On the other hand, the unidentified (reconstructed mass over estimated gravimetric mass showed as exceeding 100%) may be attributed to measurement errors, missing sources, and/or particle-bound water.*

$PM_{2.5}$: Ions were the most dominating chemical constituents across the monitoring locations during summers and winters. Elements were the next most dominating chemical species in ambient $PM_{2.5}$ among different monitoring locations during the summer season, while carbon was the next most dominating chemical species during the winter season. The winter season showed higher shares of carbon, depicting the dominance of combustion-based sources. Across monitoring locations, Si, Al, Fe, Ca, Na, Cl, and S were identified as the most dominating element species during the summer and winter seasons, depicting significant contributions from dust and industrial sources. $NH4^{+}$, Ca^{2+}, Na^{+}, Cl^{-}, $SO4^{2-}$ and $NO3^{-}$ were identified as the most dominating ionic species in ambient $PM_{2.5}$ across monitoring locations during summer and winter seasons, depicting significant contributions from chemically formed inorganic secondary particles from long-range transport and sea salt. The proportion of EC ranged between 10% and 18% and 28% and 37% of total carbon in $PM_{2.5}$ amongst different monitoring locations during the summer and winter seasons. Higher shares of EC in winters indicate the dominance of diesel and biomass-based combustion, a rich source of elemental carbon emissions.

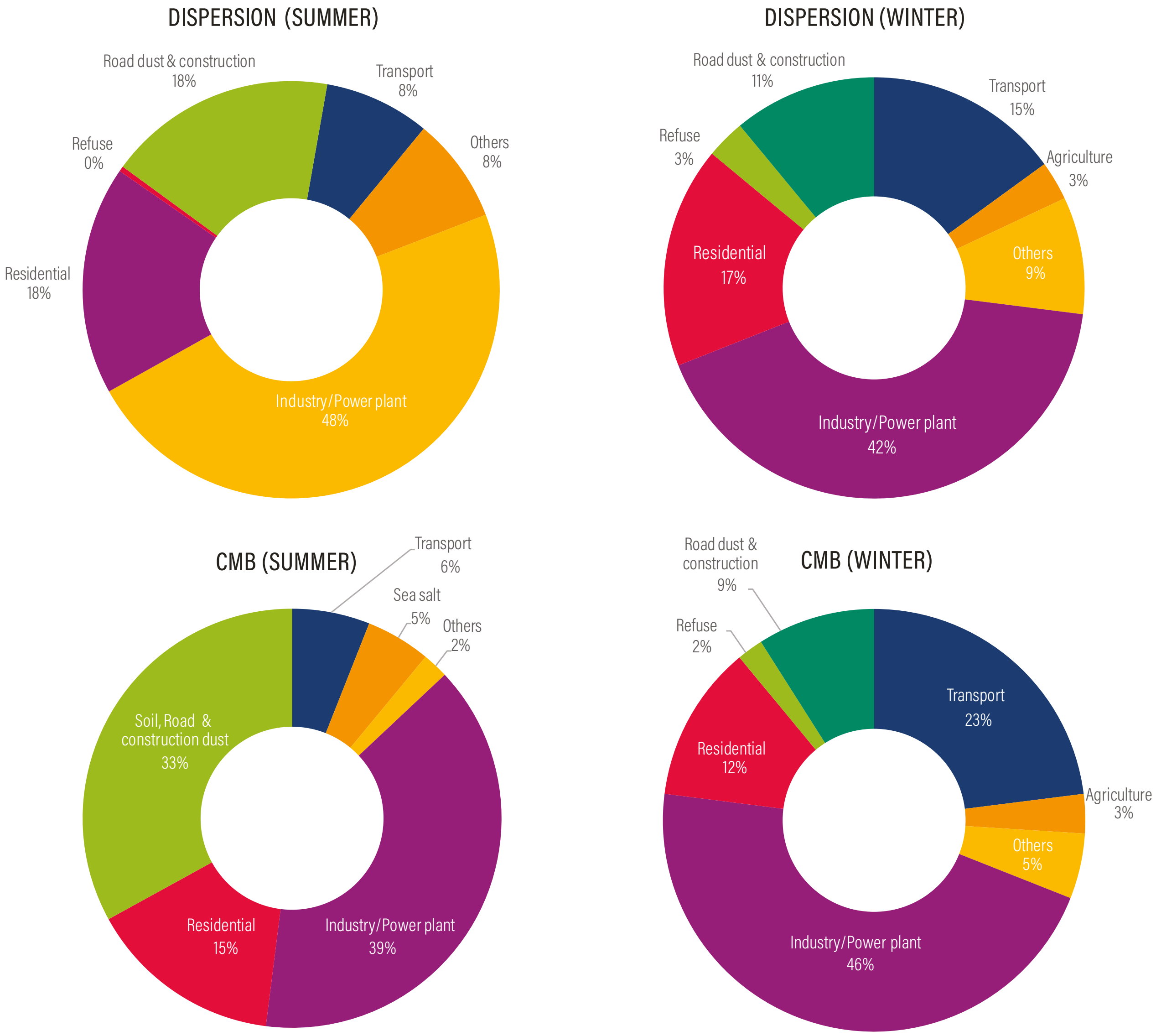
Figure 13: Seasonal variations in chemical characterization of ambient $PM_{2.5}$ at different monitoring locations



2.7. COMPARATIVE ANALYSIS OF RECEPTOR MODELING AND DISPERTION MODELING RESULTS

On comparing the average city-wide results that emerged from the receptor modeling carried out in this study with the outputs of dispersion modeling, it was noted that the results in the former show sectoral contributions of primary PM and secondary particulates separately. Secondary particulates are not apportioned to contributing sectors as these are contributed by the reactions of gases emitted from different sectors. Therefore, the dispersion model could assess the contributions of different sectors to secondary particulates along with the primary fractions.

Figure 14: Comparative analysis of receptor modeling and dispersion modeling estimates of sources contributions towards ambient $PM_{2.5}$ concentrations in the SMC area



*** In the receptor model, results show sectoral contributions for primary particles and do not apportion secondary particulates separately. The dispersion model was used to assess contributions of different sectors to secondary particulates used to distribute the secondary contribution in the receptor model.*

In order to make a more effective comparison, secondary particulates in the results of receptor modeling were allocated based on their apportionment in the dispersion modeling approach. The comparative results for the two techniques are shown for $PM_{2.5}$. Overall, source apportionment results from the two approaches seem directionally consistent for most sectors, as shown in **Figure 14**.

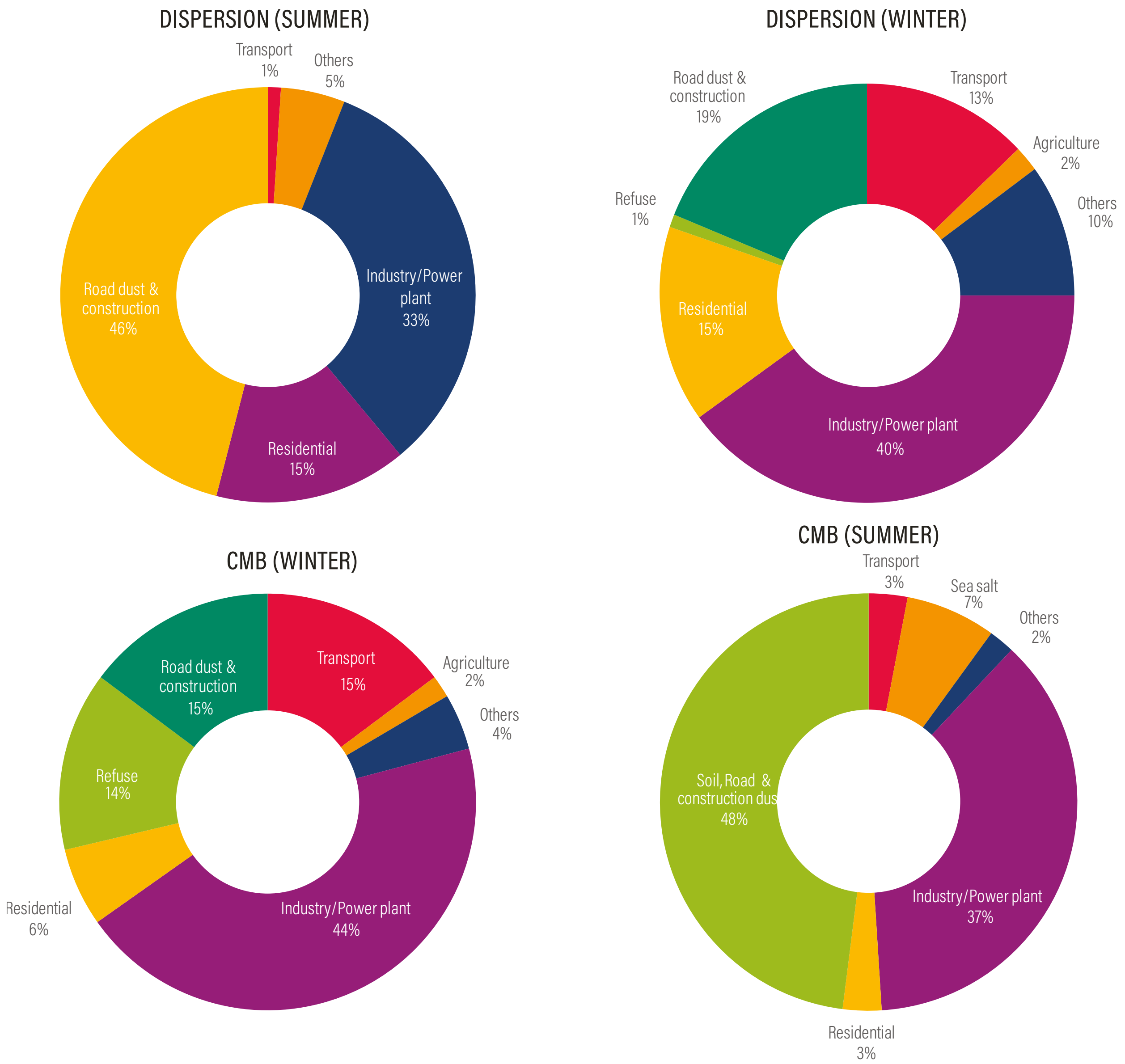
Both the source apportionment approaches indicate that the industrial (along with power plants) sector is the major contributor to the ambient $PM_{2.5}$ concentrations in both seasons, winter and summer. In winter, the industry contributes 46% and 42% of $PM_{2.5}$ with respect to receptor and dispersion approaches, respectively. The contributions estimated for other sectors to the winter $PM_{2.5}$ concentrations in SMC area are indicating to be at 23% and 15% contribution from the transport sector, 12% and 17% contribution from the residential sector, 9% and 11% contribution from dust (road, soil, and construction), 2% and 3% contribution from refuse burning, 3% contribution from both approaches, 5% and 9% contribution from agriculture residue burning and others for receptor and dispersion models, respectively.

In summers, the industrial sector contributes 39% and 35% of ambient $PM_{2.5}$ for receptor and dispersion modeling approaches, respectively. This is followed by dust (road, soil, and construction), which contributes 33% and 40% $PM_{2.5}$, the residential sector contributes 15% and 13% $PM_{2.5}$, the transport sector contributes 6% $PM_{2.5}$ in both approaches, and 2% and 6% $PM_{2.5}$ contribution from other sectors to the ambient $PM_{2.5}$ concentrations of SMC area for receptor and dispersion modeling approaches, respectively.

In winters, the contribution of transport is found to be somewhat higher in the receptor modeling approach. This can be attributed to the proximity of monitoring stations to the local sources such as transport, which depict higher contributions in the receptor modeling approach, especially in relatively calmer conditions observed in winters. In this study, the dispersion model works at a 2km X 2km resolution and presents average sectoral contributions for the entire grid. Hence, somewhat lower contributions are estimated for local sources such as vehicles. Conclusively, the outcomes from both approaches are within close range for most of the sectors and provide decision-makers a clear indication to take specific actions.

A comparative analysis of dispersion modeling with receptor modeling results for PM_{10} concentration is illustrated in **Figure 15**. Overall, source apportionment results from the two approaches seem to be directionally consistent for most sectors. In the summer season, dust is a major contributing source with 48% and 46% PM_{10} for receptor and dispersion modeling approaches. Dust includes contributions from road dust re-suspension, construction activities, and transboundary contributions.

Figure 15: Comparative analysis of receptor modeling and dispersion modeling estimates of sources contributions towards ambient PM_{10} concentrations in the SMC area



Based on the assessment of species, it can be concluded that in summers, transboundary contributions are mainly composed of dust. The second major contributing source is the industrial sector, with a contribution of 37% and 33% PM_{10} for receptor and dispersion modeling, respectively, followed by 3% and 15% PM_{10} contribution from the residential sector, 3% and 1% PM_{10} contribution from transport, and 2% and 5% contribution from others to the ambient PM_{10} concentrations of the SMC area. The contribution to ambient PM_{10} concentrations from sea salt is also observed during the summer season, with about 7% contribution as derived from the receptor modeling approach. Contributions were significant in summers as the dominant wind direction (south-west) was found to be from the seaside only.

In the winter season, the industry is a major contributing source, with PM_{10} contribution of 51% and 40% from receptor and dispersion modeling approaches, respectively, followed by 16% and 19% contribution from dust (dust soil and construction), 17%, and 13% contribution from the transport sector, 7% and 15% contribution from the residential sector, 1% and 2% contribution from refuse burning, 3% contribution from agriculture burning and 5% and 10% contribution from other sectors to the ambient PM_{10} concentrations of the SMC area. In the dispersion modeling approach, the industrial sector, which appears to be overestimated, includes biomass as an industrial fuel, which seems to be underestimated by the receptor modeling technique for the residential sector (shown as a dotted line).

2.8. CONCLUSION

The emissions estimations for the SMC area reveal that road dust is the highest contributor, with 55% and 33% of the PM_{10} and $PM_{2.5}$ emissions, followed by the industrial and transport sector. Transport exhaust emissions are the highest contributor for NOx and CO, whereas the industry contributes the largest share of SO_2. The source apportionment of ambient particulate matter was done using dispersion and receptor models. In the dispersion-based modeling, the industrial sector and power plant emerged as the top contributors of $PM_{2.5}$ in the winter season, whereas dust from construction and road is the most significant contributor to $PM_{2.5}$ during the summer season. After dust and industry, residential and transport exhaust emissions together cause a major share of the air pollution in the SMC area during both summers and winters. The air quality results in the receptor-based chemical mass balance modeling analysis of SMC are similar to that in the dispersion-based source apportionment study. The receptor-based source apportionment study also points to industry-power plants, dust pollution, residential and transport as the significant sources of air pollution in the SMC area.

CHAPTER 03

>> HEALTH RISK ASSESSMENT

3.1. INTRODUCTION

Air pollution (indoor and outdoor) is one of the leading risk factors for premature mortality in India and caused about 1.5 million premature deaths in 2019[13]. Besides endangering human health and longevity, air pollution adversely affects economic productivity. Thus, cities must assess the impact of air pollution on their citizens. The assessment of the health risks of air pollution and its associated economic costs can help make citizens and policymakers aware of the severity of the problem.

Health risk assessment and associated cost analysis for different pollutants from various clean air action plan sectors help understand the health and economic gains from targeted interventions. These measures help policymakers identify and target the most vulnerable population at risk in the city. These also alert and motivate policymakers, planners, and citizens to implement interventions efficiently.

We first reviewed the existing literature to estimate the health risk associated with air pollution from different sources in the SMC area. Based on the review, it was concluded that exposure to pollutants such as $PM_{2.5}$ has a strong association with the deteriorating health of the exposed population. To assess the health risk for the SMC population, we used the concentration-response or exposure-response-based method suggested by WHO and Global Burden of Diseases[14]. The method assesses the health risk and impacts specific to the pollutant and does not calculate the synergistic effects of two or more pollutants, nutritional profile of the affected population, and age-gender aspect of the affected population health risk assessment for the SMC area given in the following sections.

3.2. METHODOLOGY

3.2.1. Health Risk Assessment

The health risk or premature mortality associated with air pollution in the SMC area was quantified using population attributable fraction (PAF). PAF is the reduction in premature mortality that would occur if air pollution exposure were reduced to the threshold level. PAF was calculated for ischemic heart disease (IHD), cerebrovascular disease (stroke), chronic obstructive pulmonary disease (COPD), and lung cancer (LC) for adults of the SMC area aged more than 25 years and Acute Respiratory Infection (ARI) for children under five.

$$PAF = \frac{\sum\{[RR(c)-1] \text{ X } p(c)\}}{\sum[RR(c) \text{ X } p(c)]}$$

Where P(c) – the proportion of the population exposed to concentration c and RR(c) is the estimated relative risk at particular $PM_{2.5}$ concentration (c) exposure for premature mortality associated with five diseases, IHD, stroke, COPD, and LC for adults, and ARI for children, by using integrated exposure-response (IER) functions. More details of relative risk and IER function are available in Apte et al. (2015).

[13] *Balakrishnan, K., Dey, S., Gupta, T., Dhaliwal, R. S., Brauer, M., Cohen, A. J., & Dandona, L. (2019). The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017. The Lancet Planetary Health, 3(1), e26-e39.*

[14] *WHO. (2003). The World health report: 2003: Shaping the future. World Health Organization.*

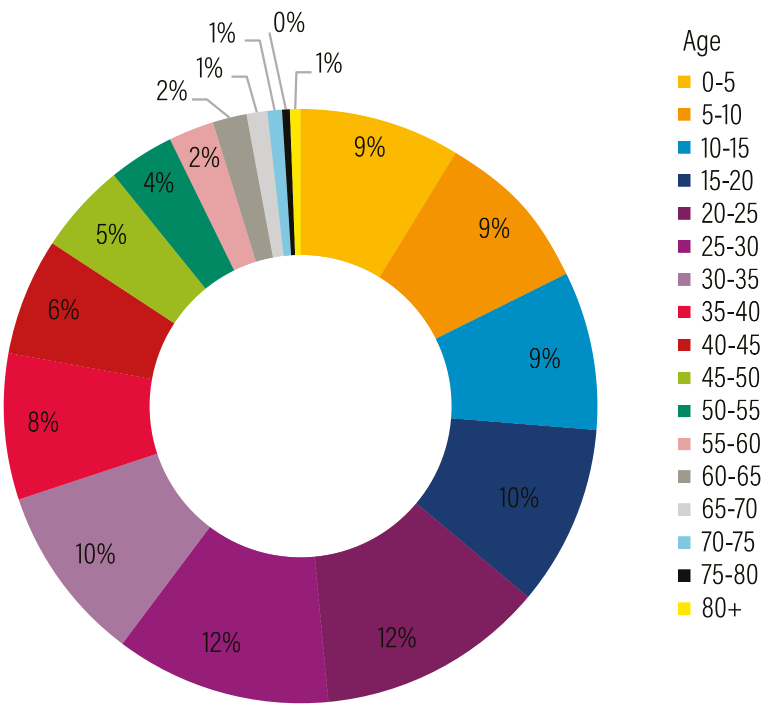
Data on observed $PM_{2.5}$ concentration (discussed in **Chapter 2**) were used to estimate the health risk in the SMC area. The health risk numbers were further distributed among different sectors according to monthly time-weighted contribution to the SMC area air pollution. Finally, the study's relative risk data were obtained[15] to check the connection between mortality and $PM_{2.5}$ emissions.

To estimate total health risk/premature mortality for the SMC area, we first obtained annual cause-specific (for adults: IHD, Stroke, COPD, LC, and for children: ALRI) mortality rate from WHO cause-specific data for different age groups and crude mortalities of urban areas of Gujarat state (Census of India, 2011) and then estimated the total premature mortality by using with age-wise population and PAF using the equation given below. The results are illustrated in **Figure 16.**

$$E = PAF \times B \times P$$

Where, E is Estimated Premature Mortality, B is baseline mortality per 100,000 population associated with different diseases (IHD, Stroke, COPD, LC, and for children: ARI), and P is exposed population.

Figure 16: Estimated share of the age-wise population in the SMC area in the year 2019



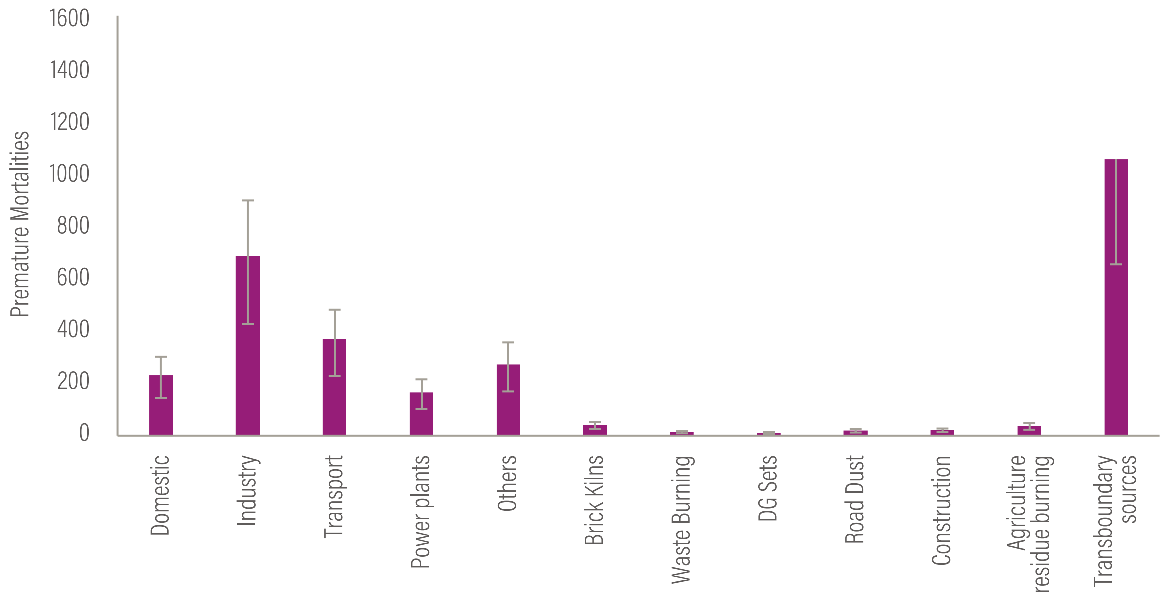
3.2.2. Result-Health Risk Assessment

Air pollution contributes to causing 2,914 (1806-3808) annual premature deaths in the SMC area (**Figure 17**). Considering the results of source apportionment (average of two sources), of all air pollution sources, transboundary air pollution is responsible for 36% of health risks, followed by industries (24%) and the transport sector (13%). Thus, industries, transport, and biomass burning are the most

[15] *Apte, J. S., Marshall, J. D., Cohen, A. J., & Brauer, M. (2015). Addressing Global Mortality from Ambient PM2.5. Environmental Science & Technology, 49(13), 8057–8066. https://doi.org/10.1021/acs.est.5b01236.*

significant contributors to premature mortality in the SMC area while considering SMC's in-boundary sources.

Figure 17: Air pollution health risk associated with different air pollution sources in the SMC area



3.3. CONCLUSION

The health risk analysis of air pollution reveals that in 2019, it was responsible for 2,914 premature deaths. Data from the source apportionment study was used to derive the sectoral contribution. It was found that transboundary air pollution is the major contributor to health risk, followed by road dust re-suspension, industries, and transport.

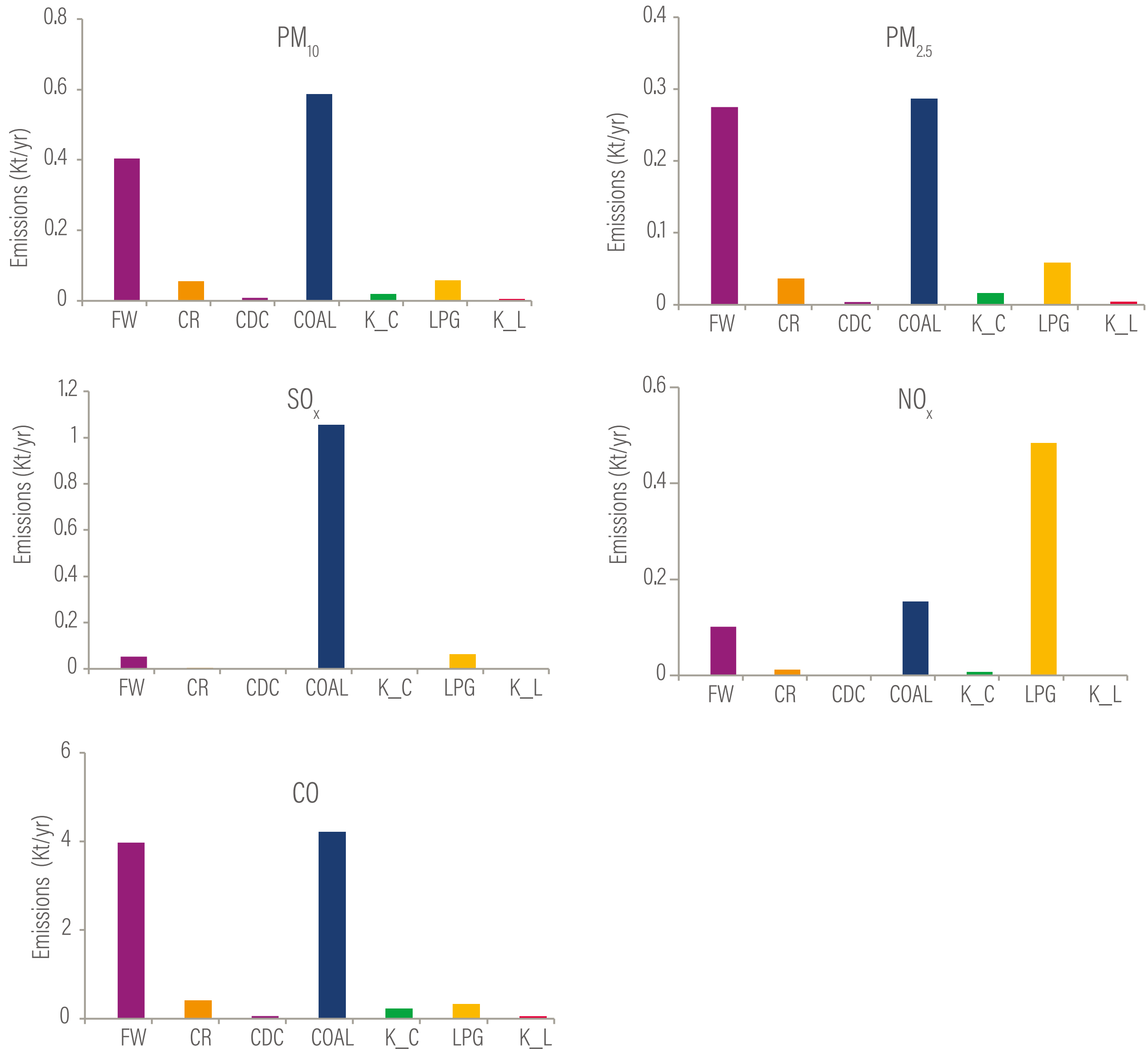
CHAPTER 04

>> HOUSEHOLD COOKING

4.1. EMISSION INVENTORY – HOUSEHOLD COOKING SECTOR

Emissions from cooking contribute to both indoor and outdoor air pollution. The use of polluting fuels, i.e., firewood, coal, crop residue, and cow dung, for household cooking and heating purpose is a significant source of air pollution in India and is responsible for adverse health outcomes[16]. Emissions of different pollutants (PM_{10}, $PM_{2.5}$, SOx, NOx, and CO) from the use of various fuels in the SMC area are presented in **Figure 18** for 2019. The polluting fuels in the SMC area contributed 1.14 kt and 0.680 kt of PM_{10}, and $PM_{2.5}$, respectively, in 2019. Coal burning is responsible for PM_{10}, $PM_{2.5}$, SOx, and CO emissions from household cooking fuel use, followed by firewood. Since the estimated households using LPG for cooking are higher, the higher NOx emissions could be attributed to the higher temperature combustion of LPG fuel (**Figure 18**).

Figure 18: Emissions of (a) PM_{10} (b) $PM_{2.5}$ (c) SOx (d) NOx (e) CO from different cooking fuels in the SMC area (Source: TERI ,2021)



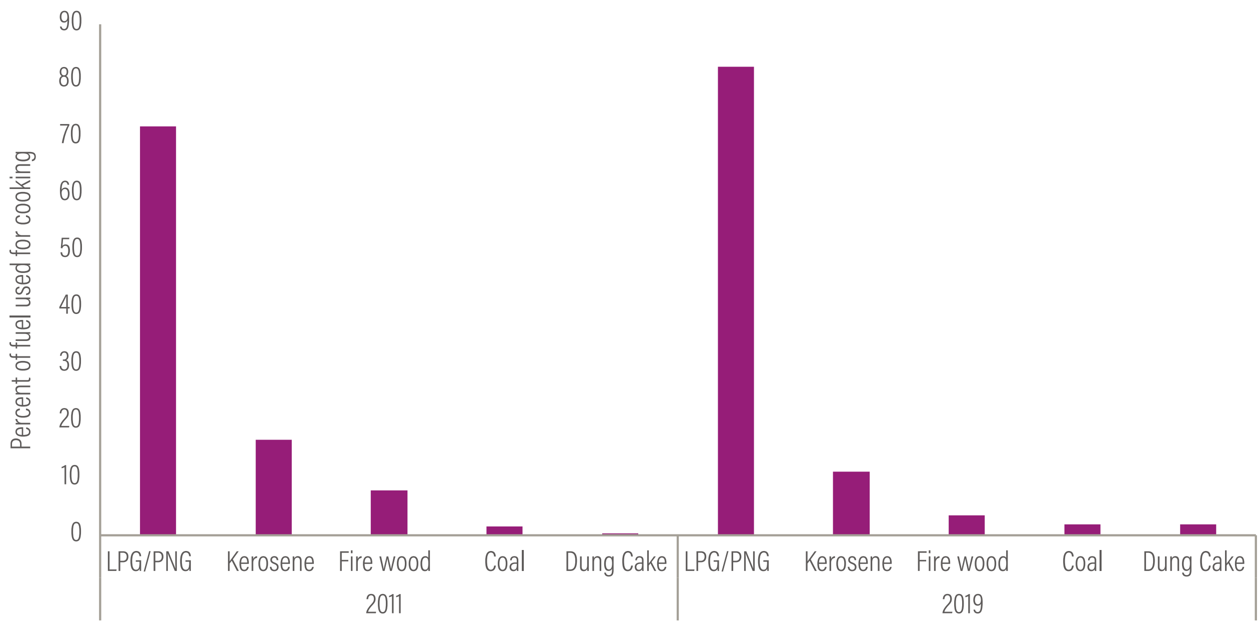
[16] *James, B. S., Shetty, R. S., Kamath, A., & Shetty, A. (2020). Household cooking fuel use and its health effects among rural women in southern India—A cross-sectional study. PLOS ONE, 15(4), e0231757. https://doi.org/10.1371/journal.pone.0231757.*

The source apportionment study, which applied receptor modeling and dispersion modeling, determined the $PM_{2.5}$ and PM_{10} contributions from the household sector in the summer and winter seasons. As per the dispersion model, the seasonal average household sector contribution to $PM_{2.5}$ concentrations was 2% in summers and 16% in winters, while it was 15% in summers and 12% in winters, according to the receptor model. The ambient $PM_{2.5}$ and PM_{10} concentrations are attributed to solid biomass fuel used for cooking in the SMC area and its surrounding areas.

4.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR

Due to the absence of recent data related to household cooking fuel use, the TERI estimated the percentage of households using fuels for 2019 using data from the Census of India 2001 and 2011. It was estimated that in 2019, 3.5% of the SMC area households used firewood, 1.9% coal, 11% kerosene, and 82% LPG/PNG as the primary source of cooking fuel. However, as per the Census of India, 2011, 71% of total households in the SMC area were using LPG as the primary fuel for cooking, followed by kerosene (20%), firewood (4%), and cow dung cake, coal, etc. (5%)
(**Figure 19**).

Figure 19: Different fuels used for cooking in the SMC area in the years 2011 and 2019 (Source: Census of India, 2011; and TERI Emission Inventory for 2019)

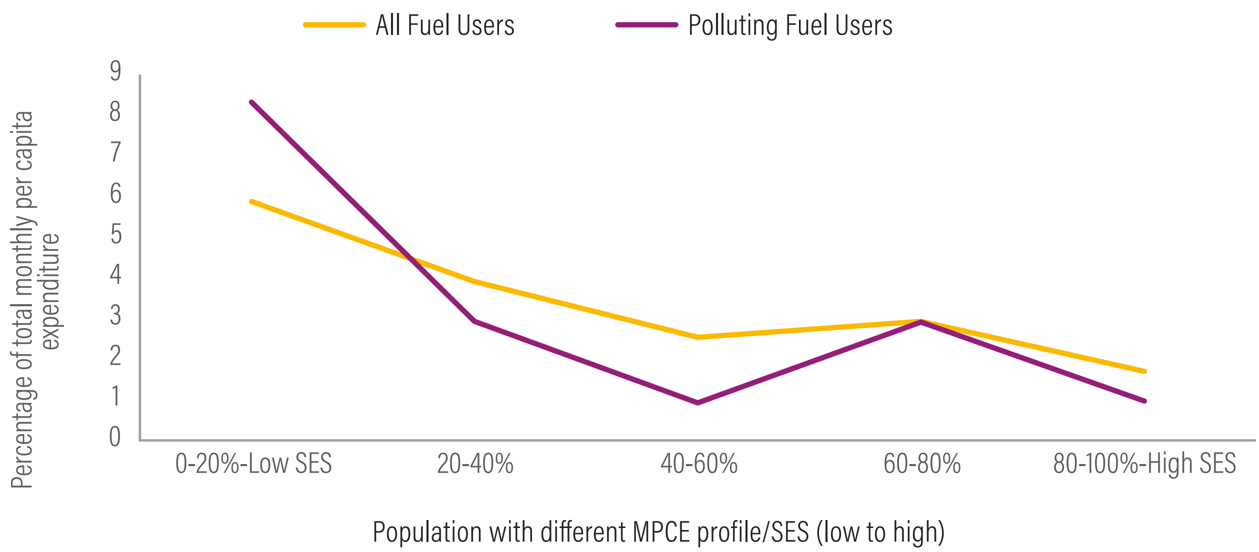


The fuel use pattern (i.e., single fuel or multiple fuels) for Surat district was assessed from the National Sample Survey (NSS) 68th round survey on Household Consumer Expenditure, published in 2011-12, including samples from both rural and urban areas. A detailed analysis of the data revealed that many LPG users are using multiple fuels for household cooking. In the urban areas of the Surat district, 41% of the total number of LPG consumers use LPG as the only fuel for household cooking, and the remaining 59% use other fuels, such as wood, cow dung cake, coal, and kerosene, along with LPG for cooking purposes. In 2017, a survey was carried out to evaluate susceptibilities, resilience capacities, and financial resources of vulnerable communities in the SMC area[17]. The primary survey of 513 households in three slum communities of the SMC area found that of the surveyed households, 434 (84%) used LPG, 65 (13%) used only kerosene, and the rest 3% used wood and coal. Of the 434 households using LPG, approximately 12 (3%) used other fuels along with LPG, and 422 (97%) were using only LPG.

4.3. MAJOR ISSUES RELEVANT TO THE SECTOR

The existing primary and secondary data analysis on fuel use patterns among households in the SMC area revealed that although LPG is a primary fuel in most households, some households continue to use traditional fuels for cooking. The use of other fuels along with LPG is identified as the critical challenge in the SMC area. Based on one-on-one interviews and group discussions with several stakeholders, several factors that encouraged households to use polluting fuels or other fuels along with LPG were identified. One of the significant constraints is affordability, as is evident from the analysis of household expenditure survey of Surat district urban area NSSO (2014) data. This analysis shows that low-income households spend 6-8% of their monthly per capita expenditure on purchasing cooking fuel (**Figure 20**), which is higher than that spent by high-income households (1- 2%).

Figure 20: Percentage of household monthly per capita expenditure (MPCE) on cooking fuels in the SMC area (Source: NSSO, 2014)

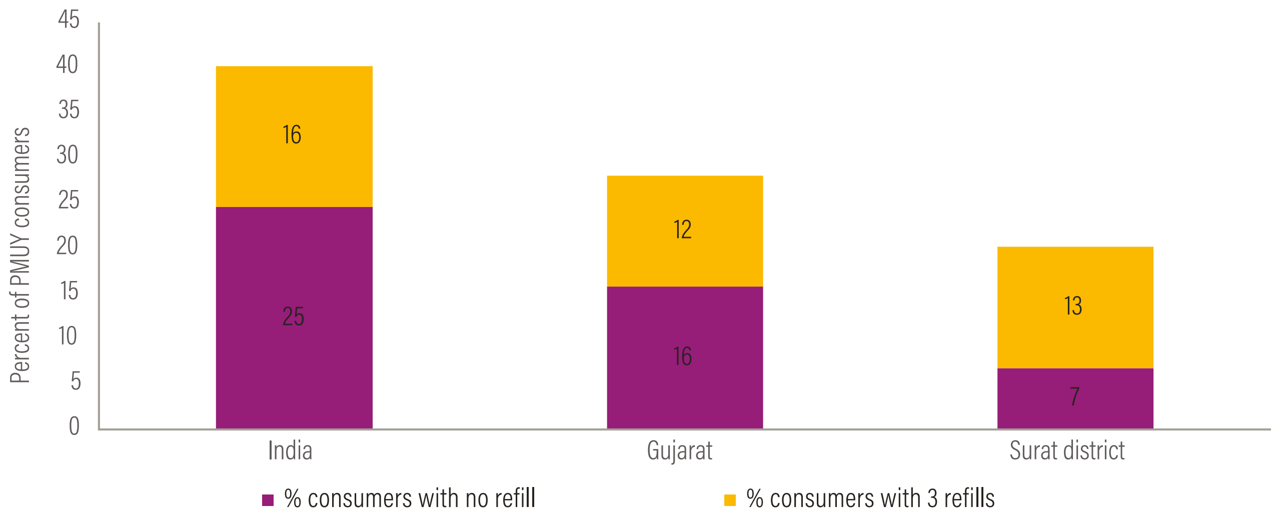


The analysis of Pradhan Mantri Ujjwala Yojana (PMUY) data also revealed a similar observation that although the number of LPG consumers are increasing under the scheme, 7% of the households in Surat district have not entirely shifted towards LPG, as depicted by the percentage of users who did not return for even a single refill (**Figure 21**). Of the total registered PMUY users in the Surat district, 13% of the consumers had their cylinders refilled less than three times in a year (average LPG refill

[17] *Rangwala, L., Burke, L., Wihanesta, R., Elias- Trostmann, K., & Chandra, M. (2018). Prepared Communities: Implementing the Urban Community Resilience Assessment in Vulnerable Neighborhoods of Three Cities. World Resources Institute. Cities Alliance.Rangwala, L., Burke, L., Wihanesta, R., Elias- Trostmann, K., & Chandra, M. (2018). Prepared Communities: Implementing the Urban Community Resilience Assessment in Vulnerable Neighborhoods of Three Cities. World Resources Institute. Cities Alliance.*

consumption), which is very low as compared with an average household LPG cylinder consumption of approximately six cylinders.

Figure 21: Consumers registered under PMUY during the period from May 2016 to 31 December 2018, and their refill summary (Source: https://pmuy.gov.in/Viewdata.html)



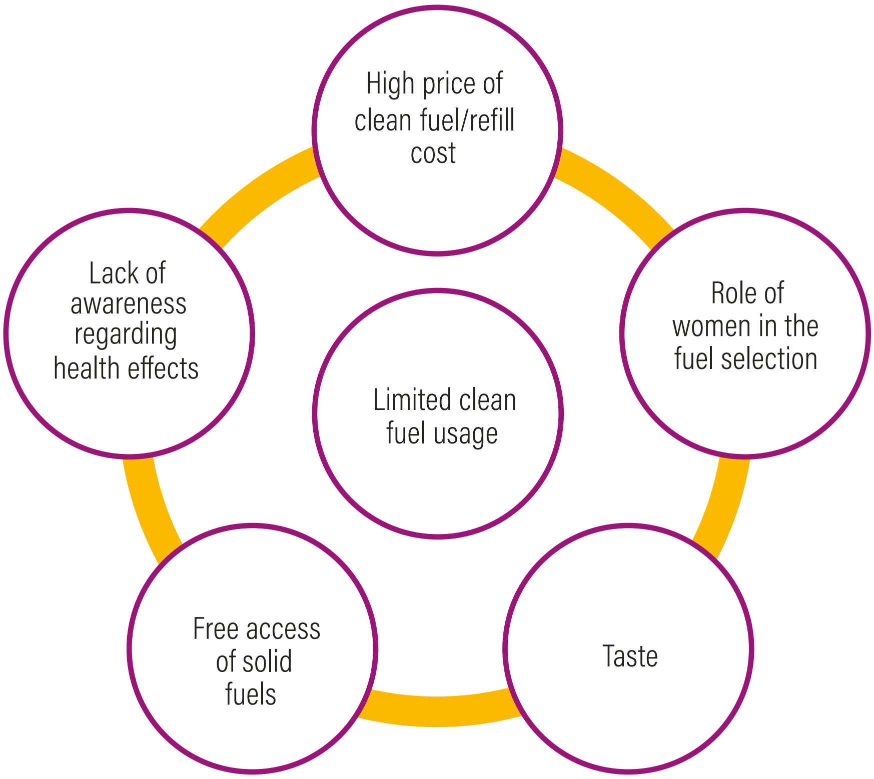
It can be concluded that although the number of registered LPG users is rising because of several government initiatives, many households continue to use LPG as the secondary fuel. Thus, unless these households use LPG as the only fuel, simply increasing the number of LPG connections will not achieve the scheme's objectives. Besides affordability, other factors (**Figure 22**) responsible for the use of polluting fuels and mixed fuels along with LPG include[18,19]:

- Decision-making Process: The cooking of food and fuel collection have historically been the woman's job, but she has a limited contribution in purchasing and selecting the cooking fuel.
- Taste perception: There is a strong perception that foods prepared on a traditional *chulha* (stove) with fuels such as wood, charcoal, and dung cake taste better.
- Lack of awareness: There is a lack of awareness among the community regarding the health effects of burning fuels for cooking and heating purpose.
- Free access to solid fuels: Solid fuels, such as firewood, crop residues, and waste, are cheap and readily available. Many households use these as cooking fuels to save money.

[18] Harish, S., & Smith. K. R. (2019). Ujjwala 2.0: From Access to Sustained Usage, Policy Brief, CCAPC/2019/03, Collaborative Clean Air Policy Centre.

[19] Petroleum Planning & Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India. (2016). Assessment report: Primary survey on household cooking fuel usage and willingness to convert to LPG. PPAC. http://ppac.org.in/WriteReadData/Reports/2017.

Figure 22: Factors responsible for limited clean fuel usage



4.4. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

After understanding the fuel use pattern and possible reasons for using polluting cooking fuel in the SMC area, information on central and state governments' existing policies and programs for reducing emissions, providing clean energy to all, and improving health were collated and compiled. These policies and programs were assessed to understand the prevailing gaps, challenges, and opportunities.

4.4.1. Pradhan Mantri Ujjwala Yojana (PMUY)

PMUY was rolled out by the Ministry of Petroleum and Natural Gas (MoPNG), Government of India, in May 2016 to boost women's empowerment by providing clean cooking fuel that would prevent health hazards associated with polluting fuel air pollution. The scheme has provided eight crores LPG connections to families below the poverty line (BPL), including financial support of INR 1,600 as an interest-free loan for a gas stove and refill cost under each LPG connection. By providing LPG, PMUY intends to protect the health of women and children by discontinuing solid fuels in smoky kitchens and ensuring their safety by eliminating the need to collect firewood from unsafe areas. In Gujarat, the total number of BPL households covered in October 2019 under PMUY was 29 lakhs[20].

[20] *PPAC. (2019). Ready Reckoner: Oil Industry Information at a Glance. Petroleum Planning and Analysis Cell. Ministry of Petroleum & Natural Gas, Government of India.*

4.4.2. Gujarat PNG/LPG Sahay Yojana

The Government of Gujarat launched LPG/PNG Sahay Yojana in May 2018 to provide subsidized PNG to BPL households in urban areas. The scheme offers a one-time subsidy of INR 1,600 per connection to each BPL household, along with a loan of INR 1,725 to new customers.

Challenges: As illustrated in **Figure 21**, approximately 7% of the PMUY beneficiaries in the Surat district did not return for LPG cylinder refills. This shows that merely providing new LPG connections is not enough to achieve the target under schemes such as PMUY; there is a need to motivate the households to use LPG exclusively.

4.4.3. Direct Benefit Transfer for LPG

The PAHAL Direct Benefit Transfer (DBTL) scheme was launched in 2013 by MoPNG, the Government of India. Under this scheme, domestic LPG cylinders are sold to LPG consumers at market-determined prices. In addition, oil companies transfer cash subsidies to consumers' bank account after the latter would book a refill request for the LPG cylinder. The subsidy on LPG refill is eligible on each cylinder, up to a maximum of nine cylinders per financial year per connection. Consumers can benefit from this scheme by linking their Aadhaar number (a 12-digit unique identity number) and bank account number with their LPG consumer ID.

Challenges: Lack of awareness about the working process of the scheme, and many potential consumers do not have access to banking services.

4.4.4. Subsidies on Cooking Fuels

Over the years, the Government of India has been offering subsidies on various fuels, such as LPG and kerosene. Kerosene was primarily available as a subsidized commodity for household use and was added to the Public Distribution System (PDS) commodities basket during the Second Five-Year Plan (1956-1961). However, LPG is not provided as part of PDS but is subsidized by the Central Government to promote the uptake of clean cooking. In September 2012, the Government made alterations in LPG subsidy policies, such as making changes to the volume of subsidized LPG accessible to each eligible household, modifying the eligibility criteria for accessing subsidized LPG and altering the unit value of the subsidy on a given volume of subsidized LPG.

Challenges:

- There are high levels of leakage in the distribution of subsidized kerosene.
- Subsidizing kerosene essentially fails to meet the objective of providing affordable cooking and lighting service to households.
- Though available at a subsidized rate, LPG for cooking is not economically viable to all sections of society.

4.4.5. Give It Up/Public Awareness Campaigns

This campaign was started to encourage well-earning households to voluntarily give up their LPG subsidy, which would be subsequently transferred to BPL households. As of March 2019, a total of 1.04 crore households had voluntarily given up their LPG subsidy[21]. As per MoPNG Office Memorandum (OM) no. P-20019/138/2014-LPG, dated Dec. 28, 2015, the benefit of LPG subsidy will not be admissible for LPG consumers if they or their spouse have a taxable income of INR 10 lakhs or more during the previous financial year as per the Income Tax Act, 1961.

Challenges:

- There is a lack of willingness among people who can afford LPG to give up their subsidy.
- More strategies are required to offer subsidies to deserving households only.

4.5. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

GPCB proposed the Air Pollution Control Action Plan for the SMC area under the Air Quality Improvement Program. As discussed in **Section 4.4**, various programs are being implemented by the government to promote the coverage of LPG/PNG for the household sector. The strategies proposed under SCAP for the household cooking sector are aimed to promote the maximum coverage of clean fuels for all.

Table 8: Outcomes and challenges of existing policies with respect to provision of clean fuel to households (Source: Surat –Air Pollution Control Action Plan, https://cpcb.nic.in/Actionplan/Surat.pdf)

Action Points for Household Cooking Sector	Implementation Status
Engage with concerned authorities continually for maximizing coverage of LPG/PNG for domestic and commercial cooking with the target of 100% coverage.	GoI has floated Ujjwala Scheme for facilitating the use of LPG as domestic fuel instead of burning wood, cow dung cakes, coal, etc.

4.6. CONTROL MEASURES IDENTIFIED DURING OPPORTUNITY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

Following the interaction with various stakeholders and one-on-one interviews and meetings conducted as part of the process of developing the SCAP, the following conclusions were formed:

- Various factors contribute to the usage of polluting fuels and mixed fuels along with LPG, as shown in **Figure 22**.
- Merely relying on LPG cannot be considered a sustainable solution, and other clean fuel alternatives, such as PNG and electricity, should also be promoted.

---

[21] *Tripathi, A., & Sagar, A. (2019). Ujjwala, V2.0. What should be done next? Policy Brief, CCAPC/2019/02. Collaborative Clean Air Policy Center.*

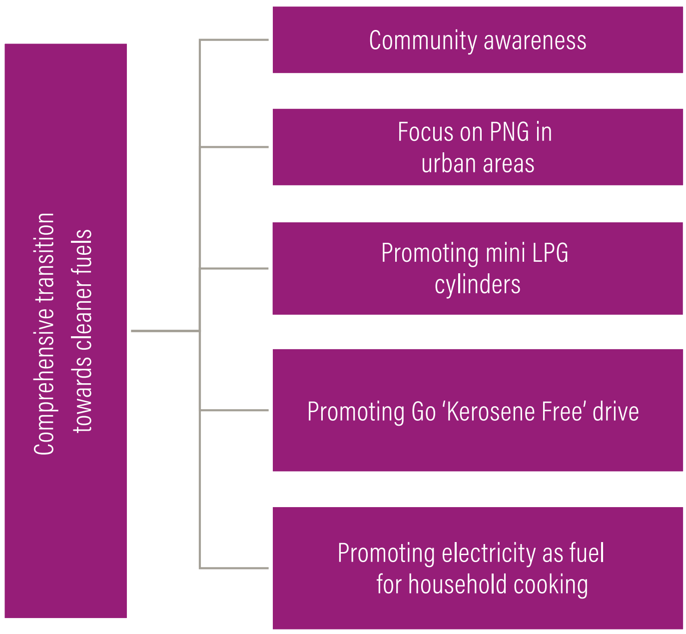
- Awareness must be created among households about the severe impacts of solid fuel usage on human health.

The recommendations listed above were considered while designing the strategies discussed in **Section 4.7.**

4.7. STRATEGIES TO MITIGATE AIR POLLUTION

After reviewing existing policies, action plans, and discussions with stakeholders, an attempt was made to propose a few interventions to mitigate emissions from household cooking in the SMC area. As discussed in the previous sections, many households continue to use polluting fuels for cooking for various reasons. Even households with access to clean cooking fuel stack other polluting fuels and use them as secondary fuel along with LPG/PNG. Several interventions are proposed to mitigate the air pollution emissions from polluting fuels, as illustrated in **Figure 23**.

Figure 23: Interventions focusing on increasing the use of cleaner fuel



4.7.1. Community Awareness

Based on literature review and an analysis of available data,[2,] it was concluded that both PMUY (presented in **Figure 21)** and non-PMUY LPG users (as per NSSO, 2014 survey) use other polluting fuels along with LPG. Thus, there is an urgent need to carry out an awareness program to encourage and educate people for a complete transition towards cleaner fuels, focusing on the immediate health benefits of using cleaner fuels from reduced air pollution exposure. The government has been using several mediums to conduct awareness to promote LPG. However, an unexplored medium that could be used is having a simple, colorful sticker with educational messages pasted on each LPG cylinder. These stickers can be pasted on both 5kg and 14kg cylinders. These messages should be printed in local languages so that it reaches the less educated LPG consumers. The stickers can display messages on the following benefits of using LPG over conventional fuels:

- Health risk benefits, especially for children and elders
- Reduced maintenance cost
- Easy to use, convenient, and reduced cooking time
- Improved opportunities for female child education by saving time spent on collecting wood
- Empowerment of women

4.7.2. Focus on Expanding the PNG Network to Other Sections in the SMC Area

A piped gas distribution network supplies PNG to various households in the SMC area. The PNG hardware includes a stove similar to an LPG stove, a meter, a directed system to the high-pressure pipeline network, and a pressure regulator[22]. Expanding the PNG network to the lower middle class and BPL households of the SMC area would free up LPG connections in urban areas, which can then be offered to rural, remote, and low-income families. In addition to being a one-time investment, PNG is 22.35% cheaper than LPG with respect to energy consumption for cooking[23]. Hence, it is essential to make the lower-income group aware of the benefits and subsidies provided by the government.

4.7.3. Promoting Go 'Kerosene-Free' Drive

Kerosene is considered a fuel used by poor urban households[23]. In the 'Go kerosene free' drive initiated in various parts of India, including Delhi, Chandigarh, and Gandhinagar in Gujarat, no subsidized kerosene is issued. In Delhi, the households (with Jhuggi ration card or JRC, BPL, *Antodaya Anna Yojana,* or AAY ration card) using kerosene for cooking were provided free LPG gas connection along with free cylinders, two-burner gas stoves, pipe, and regulator. A techno-economic analysis indicates that shifting from kerosene to cleaner fuels would be beneficial financially and health-wise for the government and households[24]. Replacing the kerosene supply with alternative fuels will motivate the people to convert to safe and clean energy, such as LPG, PNG, and electricity. Households shifting from kerosene can also be motivated to use a 5kg LPG cylinder as a cooking fuel (as discussed in **Section 4.7.4**).

4.7.4. Promoting Mini LPG Cylinders

To obtain a new LPG gas connection, the KYC process is mandatory to verify the address and identity documents, photographs, and bank account details. This caused several migrant individuals and families, students, etc., to remain excluded from the benefits of government schemes. To overcome this barrier, the Government of India, in 2015, launched mini-LPG cylinders weighing 5kg, explicitly targeting individuals and households that do not possess any documents to submit as residence

[22] *Jain, A., Choudhury, P., & Ganesan, K. (2015). Clean, Affordable, and Sustainable Cooking Energy for India. Possibilities and Realities beyond LPG. https://www.ceew.in/sites/default/files/CEEW-Clean-affordable-and-sustainable-cooking-energy-in-India-Feb2015.pdf.*

[23] *Palit, D., Shardul, M., Brahmachari., D. (2020). Clean Fuel for Cooking: Solution to Achieve Better Air Quality. Discussion Paper. The Energy and Resources Institute.*

[24] *Jain, A., & Ramji, A. (2016). Reforming Kerosene Subsidies in India: Towards better alternatives. The International Institute for Sustainable Development and Council on Energy, Environment, and Water.*

proof, including the economically weaker families, students, and migrant workers[25]. These cylinders are affordable for those sections of society and migrants who cannot bear the cost of the 14.2kg LPG cylinder. These cylinders' refill cost is also affordable for a low-income household (approximately INR 223 for a non-subsidized cylinder). A low-income household (approximately 4 persons per household) can afford a 5kg cylinder to spend their income as per their financial viability.

Therefore, awareness should be created among the urban poor households regarding the availability and usage of 5kg cylinders. The CAG Report (2019) also highlighted that only 34% of the surveyed PMUY beneficiaries were aware of the 5kg cylinders.

Clean fuel options to poor households, such as shifting to PNG because the state government is offering PNG connections at subsidized rates (being 22.35% cheaper than LPG), using LPG cylinders under the PMUY scheme weighing 5kg, or using electricity for cooking, can be considered.

4.7.5. Promoting Electricity as Fuel for Household Cooking

This intervention is essential for migrant workers residing in the SMC area and is suitable because the SMC area has a continuous and uninterrupted electricity supply (Consumer Expenditure Survey, 2014). An induction stove is an excellent option to achieve the objective of moving up the energy ladder in areas with adequate electricity supply and low tariff rates/subsidized electricity[27,28]. For instance, in Ecuador, the government is replacing every stove, even in rural areas, with induction. The program was started in 2014 and later extended to 2023, with a target of 3.5 million househod[29].

To understand the efficiency and affordability of induction stoves, an attempt was made in this study to compare two options, induction stoves versus LPG, as presented in **Table 9**. A new LPG connection costs INR 4,800, which includes the security deposit for the cylinder, the pressure regulator, and the gas stove, while an induction stove (1800W, Pigeon brand) costs a minimum of INR 1,300 if purchased online[7]. The additional cost with an induction stove would include buying induction stove-friendly steel utensils, as regular utensils cannot be used on induction stoves. We have estimated the cost of boiling 2 liters of water, based on data from[1] Chheti et al. (2017) and considering the electricity unit charges (up to 250 units with a monthly cost per unit of 425 paise/unit) and LPG cylinder price (the subsidized price of INR 595.5) for SMC area. Our estimations revealed that the cost of boiling 2 liters of water on an LPG stove and an induction stove is almost the same. Apart from being cost-effective, the use of induction stoves would help reduce indoor air pollution. As the migrant workers reside in cramped houses with limited ventilation, reduced air pollution would improve health.

---

[25] PIB, (2015, January 5). Launch of 5 Kg LPG cylinders for BPL families. https://pib.gov.in/newsite/PrintRelease.aspx?relid=114336.

[26] Banerjee, M., Prasad, R., Rehman, I. H., & Gill, B. (2016). Induction stoves as an option for clean cooking in rural India. Energy Policy, 88, 159–167. https://doi.org/10.1016/j.enpol.2015.10.021.

[27] Smith, K. R., & Sagar, A. (2014). Making the clean available: Escaping India's Chulha Trap. Energy Policy, 75, 410–414. https://doi.org/10.1016/j.enpol.2014.09.024.

[28] Gould, C. F., Schlesinger, S., Toasa, A. O., Thurber, M., Waters, W. F., Graham, J. P., & Jack, D. W. (2018). Government policy, clean fuel access, and persistent fuel stacking in Ecuador. Energy for Sustainable Development, 46, 111–122

[29] Chheti, R. C. (2017). Analysis on Integrated LPG Cook Stove and Induction Cooktop for Cooking Purposes in Bhutan. Faculty of Engineering and Information Sciences - Papers: Part B- 623.

Table 9: Cost comparison of LPG stoves to induction cook stoves

Sr. No.	Particulars	LPG Cookstove	Induction Stove	Source
1.	Thermal efficiency	57%	84%	Jain et al. (2015)
2.	Lifespan	15 years	10 years	Jain et al. (2015)
3.	Other costs	INR 350 (Towards hose replacement)	INR 2,000 (cost of induction compatible cookware) INR 300 (maintenance charge)	Jain et al. (2015) (Maintenance cost from the ground survey)
4.	Cost per new connec-tion	4,800	INR 1300- 1500 (pigeon induc-tion- 1800 w)	Pricing has been taken from online retail options catalogues (induction stoves) Jain et al. (2015) (LPG)
5.	Energy consumed in boiling 2 Litre Water	0.3942 kWh	0.303 kWh	Chheti et al. (2017)
6.	Cost of boiling 2 Litre water	INR 1.30	INR 1.29	Our estimations (assumed electricity unit charges and LPG cylinder price of SMC area)

These stoves can be an essential clean cooking fuel option for migrant workers in the SMC area. One induction stove can be provided to 2-3 workers living together, who are otherwise primarily dependent on kerosene for cooking. The government can coordinate with the industries (as a pilot project) in providing induction stoves and steel utensils to the migrant workers. This floating population does not possess the proper documents for obtaining LPG and PNG connections and works temporarily in various industries. Therefore, a pilot project to provide clean cooking fuel to migrant workers can be conducted in a few industries, where costs can be shared equally by the government and industries.

The government can also give emission reduction credits to industries for reducing air pollution. The direct cost of providing clean cooking fuel to a household includes INR 1,300 for an induction stove and INR 2,000 for appropriate utensils. Here, it is essential to mention that old aluminum utensils are not considered suitable for health in the long run[30] and must be replaced with steel utensils. Therefore, this intervention considers health impacts by providing clean fuel and suitable utensils. The introduction of electricity for cooking would mean that the in-boundary emissions of $PM_{2.5}$ and PM_{10} from cooking would be zero. The projects identified under SCAP for the household cooking sector are given in **Annexure 8.**

[30] *Gupta, Y.K., Meenu, M., & Peshin, S. S. (2019). Aluminium utensils: Is it a concern? The National Medical Journal of India, 32, 1, 38-40.*

Table 10: Suggested interventions for household cooking in the SMC area

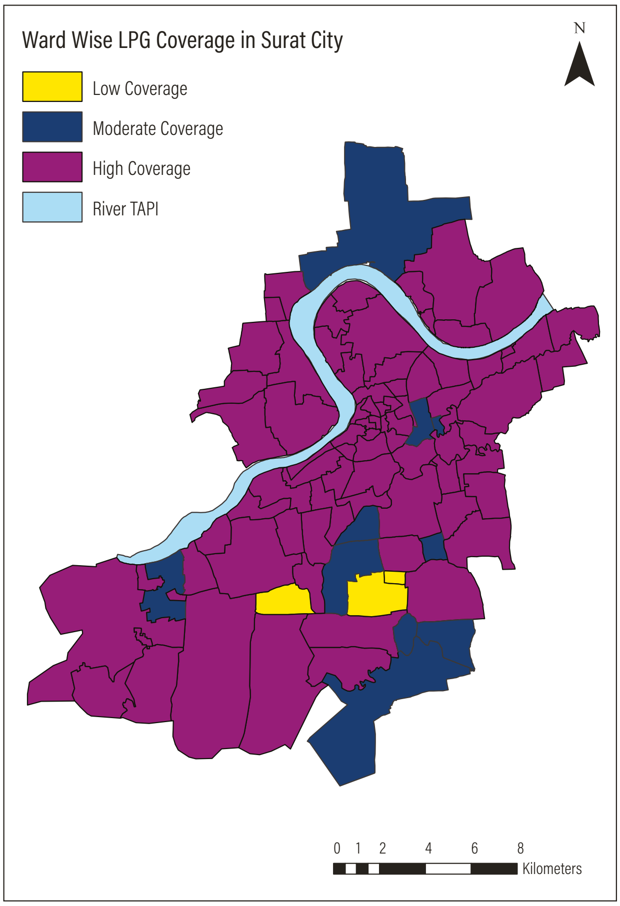
Sr. No.	Interventions	Technology/Methods	Implementing Agency
1.	Community awareness	Stickers on LPG cylinders Encourage LPG consumers to use it as their only fuel.	Oil/LPG companies
2.	Expanding PNG network	Increase PNG coverage from 14% (under state government PNG Sahay Yojana)	PNG company (Gujarat Gas)
3.	Promoting mini LPG cylinders	Use 5kg LPG cylinders in place of kerosene	Oil/LPG companies
4.	Go 'kerosene- free.'	Replace kerosene with 5/14 kg LPG cylinders/ induction stoves	Food and Civil Supplies Department
5.	Promoting induction stoves/electricity for cooking	A pilot program of providing induction stoves to laborers with 50-50 partnerships from the Government and industries	Industry CSR and Government

4.8. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

For the effective on-ground implementation of the interventions proposed for the household cooking sector, wards where the usage of clean fuels can be promoted, were identified. The available primary and secondary data were analyzed to understand the fuel use pattern at the ward level and prepare a micro-level plan. Wards where the dissemination of LPG is less, were identified and classified as low (less than 50%), moderate (50 to 70%), and high (more than 70%). The identified wards are Vadod, Vadod (part), and Sarsana, with an estimated LPG coverage of less than 50%. As recommended by GPCB's robust action plan and SCAP (**Table 10**), these wards (**Figure 24**) can be preferred primarily for increasing the clean fuel coverage through the following mitigation measures:

- Increasing the LPG connections in low-income strata
- Implementation of PMUY
- Shift to LPG from solid fuel and kerosene for domestic applications
- Community awareness
- Expanding PNG network
- Promoting mini LPG cylinders
- Go 'Kerosene-Free'
- Promoting induction stoves/electricity for cooking

Figure 24: Micro area planning map for the household sector of the SMC area



4.9. TECHNO-ECONOMIC ANALYSIS

For the Techno-Economic Analysis, the costing has been done for the three interventions suggested under SCAP, including shifting kerosene users towards LPG, creating awareness by fixing stickers on LPG cylinders, and Promoting induction stoves/ electricity for cooking **(Table 11).**

4.9.1. Implementation Cost for Proposed Policies and Programs

- **Community Awareness:** To promote LPG as an exclusive fuel and eliminate the stacking of polluting fuels and their associated emissions, it is proposed to paste stickers with educational messages on LPG cylinders until 2024. For a broad outreach, the messages on the stickers would be in regional languages. The cost of stickers for the years 2021- 2024 has been calculated. The incentives required for the years 2019-2024 to paste stickers on LPG cylinders are INR 0.83 crore, including the maintenance cost of managing the cylinders over these years.
- **Go Kerosene Free:** As per estimations, in the year 2019, 11% of households were using kerosene in the SMC area, which is used as a baseline year for calculating the costs of converting this kerosene using households to LPG. We assume that 11% of consumers belong to the BPL category. Hence, including them in the PMUY scheme and shifting these households towards LPG/ PNG would require approximately INR 26 crore (a subsidy of INR 1,600 subsidy per connection of either LPG or PNG). These consumers are expected to shift towards LPG in a period of four years, whereas approximately 40,693 consumers are shifted towards LPG under the PMUY scheme every year.

- **Promoting Induction Stoves/ Electricity for Cooking:** Induction stoves can be promoted as a cooking fuel option for poor households. For this, a pilot project can be initiated for around 1,450 households with access to electricity but continue to use traditional fuels. This project can be carried out for one year, where cookware costing INR 2,000 per household and induction cookstove costing INR 1,500 each can be provided to these select households. The estimated cost for this project is approximately INR 0.50 crore.

Table 11: Economic implications of proposed policies and programs

Sr. No.	Proposed Policy or Criteria	Implementation Time	Responsible Agency/Stakeholder	Total Cost (INR Crore)	Expected Outcome
1.	LPG Cylinder Stickers	2021- 2025	Oil/LPG companies	0.83 (Total Cost)	Reduced emission load and improved health, time efficient.
2.	Go Kerosene Free	2021- 2025	Food and Civil Supplies Department	26.04 (Total cost from 2021-2025) with 6.51 crores spent to convert 40693 consumers per year from 2021- 2025.	Target to eliminate the usage of kerosene and shift to cleaner fuel.
3.	Promoting Induction Stoves/ Electricity for Cooking	2021-2022	Industry CSR and Government	0.50 (Cost of the Pilot project of providing induction stoves with cookware for approx. 1450 households)	Clean fuel option for poor households. Helpful in achieving clean cooking fuel and electricity for all by 2022, as announced in the Union Budget in March 2019.

4.9.2. Health Risk Assessment

Air pollution health risk assessment (AP-HRA) was carried out to estimate the health risks of indoor and outdoor air pollution caused by household cooking. The interventions for the household cooking sector proposed in this study can help save around 230 lives from outdoor air pollution and 65 lives from indoor air pollution in the SMC area (**Chapter 3**). We assessed the number of lives saved from indoor air pollution using the indoor air concentration data of urban Gujarat[31]. The reason for this attribution is that the household sector is responsible not only for outdoor air pollution but also impacts the indoor environment. Assuming that an average person, especially women and children, spends 80% of their time indoors, the impacts of solid fuel-burning are more severe for such vulnerable groups. The following inferences have been made from the health risk assessment and related economic impacts:

- Although the current and previous governments have been promoting cleaner fuel options, a substantial number of households continue to use traditional fuel for cooking purposes.
- The above point does not direct to limited outreach of interventions related to LPG as the population in the low socio-economic category has access to LPG cylinders (included under PMUY); they prefer using coal and wood in partial quantity for cooking.
- Building awareness is of utmost importance in promoting cleaner fuels and its eventual replacement of traditional fuel for cooking.

4.10. SCENARIO GENERATION

For an enhanced understanding of the impacts of the proposed interventions, alternate scenarios in

[31] *Balakrishnan, K., Ghosh, S., Ganguli, B., Sambandam, S., Bruce, N., Barnes, D. F., & Smith, K. R. (2013). State and national household concentrations of PM2.5 from solid cookfuel use: Results from measurements and modeling in India for estimation of the global burden of disease. Environmental Health, 12(1).* https://doi.org/10.1186/1476-069x-12-77.

comparison to the BAU scenario were developed. The alternate scenario Clean Fuel Usage (CFU) is developed by considering the implications of the proposed interventions. The cost of implementing these interventions was also calculated.

The CFU scenario: The scenario is generated using the Census and NSSO data on households using fuels, the use of LPG along with other fuels, existing strategies by the government (such as PMUY), and assuming that the proposed interventions are implemented, it is estimated that by 2025, 94% of the households would be using only LPG, 1% electricity, and 4% firewood. In 2030, though the LPG penetration is estimated to be 100%, it is assumed that the number of households using LPG as their only fuel will be 97%, 1% of households will be using firewood along with LPG, and electricity would be used by 2%. In the CFU scenario, a reduction in emissions of all pollutants is visible compared with the BAU scenarios for 2025 and 2030, as we have considered the implementation of the interventions in these years. A reduction of 18% can be achieved in comparison with 2019 $PM_{2.5}$ emissions if the implications assumed in the CFU scenario are achieved by 2025. The emissions of $PM_{2.5}$ are estimated to reduce by 22% in 2025 in the CFU scenario compared with the BAU scenario, while a reduction of 67% is anticipated in 2030 compared with the BAU scenario. The emissions of $PM_{2.5}$, PM_{10}, SOx, and NOx are presented in **Figure 25**.

Figure 25: Emissions of various pollutants under business-as-usual (BAU) scenario and clean fuel usage scenario for the years 2025 and 2030

4.11. CONCLUSION

The household sector is the fourth and fifth-highest contributor in terms of $PM_{2.5}$ and PM_{10} emissions, respectively, in the SMC area in 2019. The analysis of primary and secondary data revealed that although the LPG penetration in the SMC area is satisfactory, the poor households use mixed fuels along with LPG. Hence, apart from providing clean fuel to all, community awareness is required to motivate the households to transition to clean fuels for cooking. Apart from LPG, other clean fuel options such as PNG expansion in low-income areas and electricity/induction stoves in areas where electricity is reliable should be explored. Considering the interventions (CFU scenario) proposed for the household cooking sector, it is assumed that a reduction of 22% in $PM_{2.5}$ can be achieved in 2025 (CFU scenario) in comparison with the BAU scenario. The reduction of emissions from the household sector will improve outdoor and indoor air quality, resulting in reduced premature mortality and improvement in the living conditions of the people.

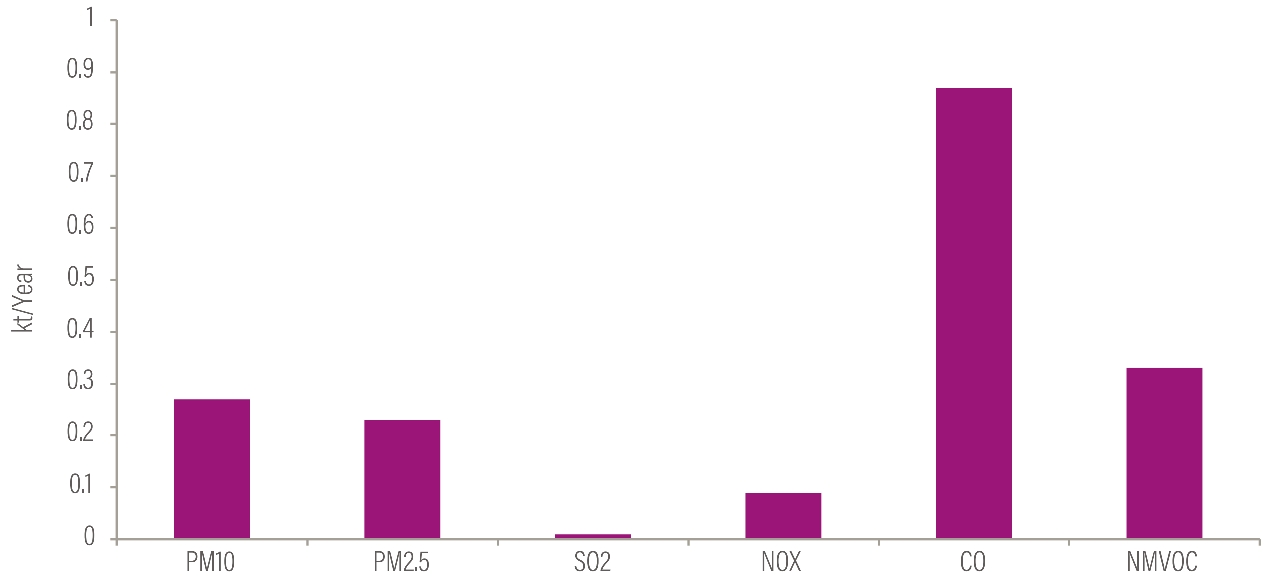
CHAPTER 05

>> OPEN BURNING OF MUNICIPAL SOLID WASTE

5.1. EMISSION INVENTORY – OPEN BURNING OF MUNICIPAL SOLID WASTE SECTOR

The illegal burning of municipal solid waste (MSW) is one of the significant sources of air pollution in cities of developing countries[32,33]. However, emissions from MSW burning are not considered in the current emission analysis conducted in several urban areas due to the unavailability of primary data on MSW burning. The available emissions estimations of MSW burning are purely based on the rule of thumb method (assumption, no primary data from the field), which at times gives uncertain results and is responsible for fallacious policy recommendations[34,35]. WRI India collected primary data on MSW burning by conducting field surveys in the SMC area to address this gap. Air pollution emissions from open burning of MSW in the SMC area were then calculated by multiplying the estimated quantity of MSW burned based on a field survey of different areas with emission factors (Refer to **Chapter 2** for details). According to the estimation, open burning of MSW contributes about 0.23 kt, 0.27 kt, 0.01 kt, 0.09 kt, 0.87 kt, and 0.33 kt of $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, and NMVOC emissions, respectively, in the SMC area in the year 2019 (**Figure 26**).

Figure 26: Estimated emissions of $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, and NMVOC from open municipal solid waste (MSW) burning in the SMC area in the year 2019 (Source: TERI, 2021)



[32] *Nagpure, A. S., Ramaswami, A., & Russell, A. (2015). Characterizing the Spatial and Temporal Patterns of Open Burning of Municipal Solid Waste (MSW) in Indian Cities. Environmental Science & Technology, 49(21), 12904–12912. https://doi.org/10.1021/acs.est.5b03243.*

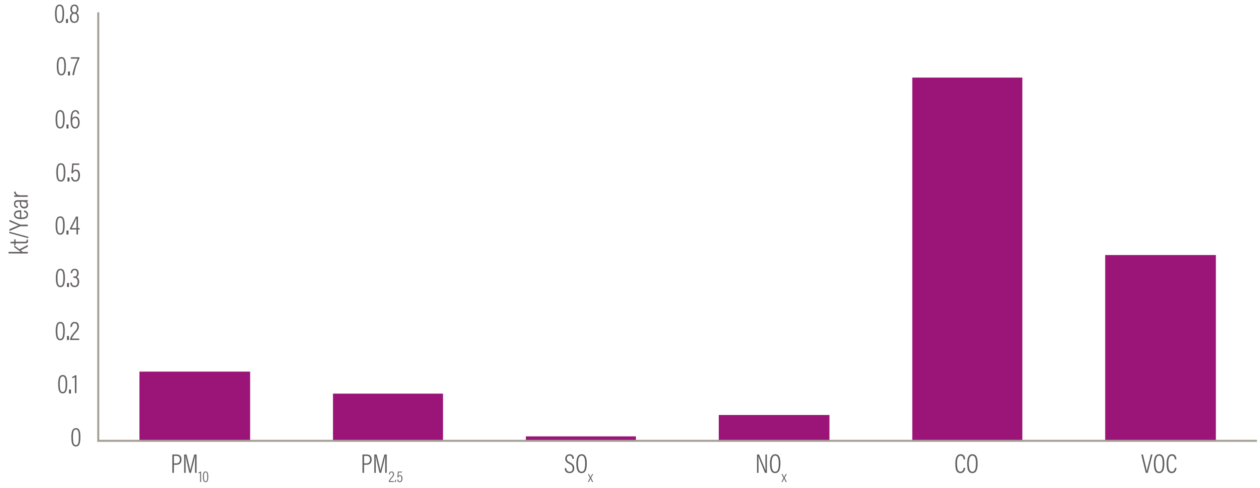
[33] *Wiedinmyer, C., Yokelson, R. J., & Gullett, B. K. (2014). Global Emissions of Trace Gases, Particulate Matter, and Hazardous Air Pollutants from Open Burning of Domestic Waste. Environmental Science & Technology, 48(16), 9523–9530. https://doi.org/10.1021/es502250z.*

[34] *Nagpure, A. S., Ramaswami, A., & Russell, A. (2015). Characterizing the Spatial and Temporal Patterns of Open Burning of Municipal Solid Waste (MSW) in Indian Cities. Environmental Science & Technology, 49(21), 12904–12912. https://doi.org/10.1021/acs.est.5b03243.*

[35] *CPCB. (2010). Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Indian Cities. Central Pollution Control Board, Government of India.*

As part of the SCAP emission inventory, there is no data currently available for MSW burning at the landfill site of SMC. To estimate the MSW burning at the landfill site, it is assumed that 2% of the total MSW dumped is burned every day in landfills located in the SMC area. Based on these assumptions, the estimated emissions for different pollutants are given in **Figure 27**.

Figure 27: Estimated emissions of $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, and VOC from MSW burning at the landfill in the SMC area in the year 2019 (Source: TERI, 2021)



The source apportionment study using the receptor model indicates that in winters, MSW burning is responsible for 2% of the total $PM_{2.5}$ concentration in the SMC area, whereas, in the dispersion model, it was found to be 0.3% in summer and 1% in winter.

5.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR IN THE SMC AREA

SMC has addressed the challenges in MSW management and made efforts to improve it; as a result, SMC has been recognized nationally with various awards and appreciation. Recently, SMC has been ranked the second cleanest city of India in Swachh Survekshan 2020[36]. According to SMC solid waste management statistics, the SMC area generates about 1,800- 2,200 metric tons (MT) of MSW every day[37]. About 52% of this includes compostable waste, 19% plastic, 7% paper, 7% textile, 7% inert, 5% mixed waste, and 3% others[38] (**Figure 28**). SMC is responsible for managing MSW within SMC limits, including collection, transportation, processing, and disposal of MSW.

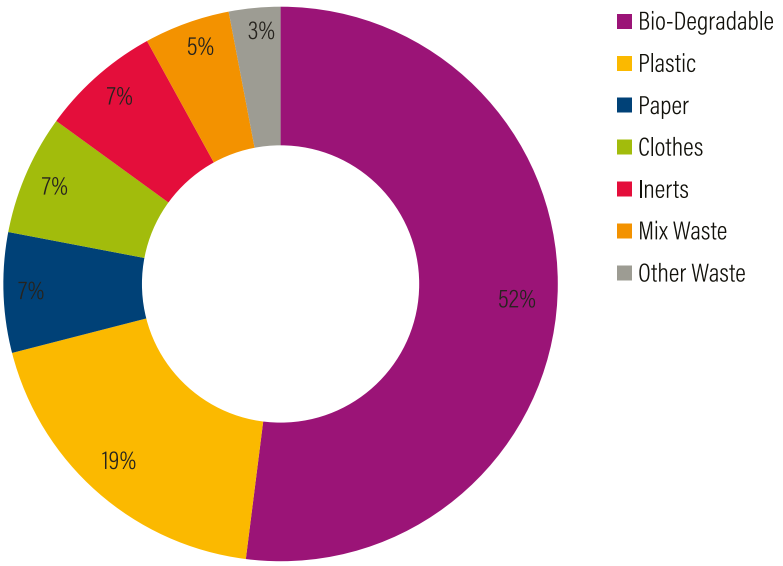
---

[36] *Awards and Appreciations. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Home/AwardsAndAppreciations.*

[37] *Solid Waste Management Statistics (2021, March 10). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementStatistics.*

[38] *Swachh Bharat Mission Proposal DPR for Surat city. (November 2016). Surat Municipal Corporation. Facile Maven pvt. ltd.*

Figure 28: Composition of daily generated MSW in the SMC area (Source: Swachh Bharat Mission proposal for the SMC area 2016)



5.3. MAJOR ISSUES RELEVANT TO THE SECTOR

Neither the literature survey nor the stakeholder consultation was able to bring forth data related to MSW burning quantity, location, and emissions for the SMC area. Only one study has estimated the contribution of MSW burning in air pollution emissions based on a few assumptions. In this study, Guttikunda and Jawahar (2012)[39] have assumed 10-25% of MSW generated per day is burned in the SMC area, but no field-based data has been referred to. Presently, neither city-level nor intracity-level primary data on MSW burning are available for the SMC area, an issue that is critical for developing a clean air action plan. The interactions with the residents of various localities in the SMC area reveal that people are not aware of the environmental and health impact of MSW burning. People are burning MSW due to various reasons (waste reduction, heating, infrequent/less collection of waste, behavioral attitude towards waste burning), which need to be considered in management policies related to MSW burning.

5.4. PRIMARY SURVEY OF MSW BURNING IN THE SMC AREA

Looking at the current issues of the unavailability of primary data on MSW burning, we first conducted a detailed intracity scale study of MSW burning to understand the different contexts of MSW burning in the SMC area, essential for developing a clean air action plan to mitigate air pollution. The details of the survey are discussed in this section. The study's final results were shared with TERI to develop emissions inventory and conduct air quality modeling and source apportionment analysis.

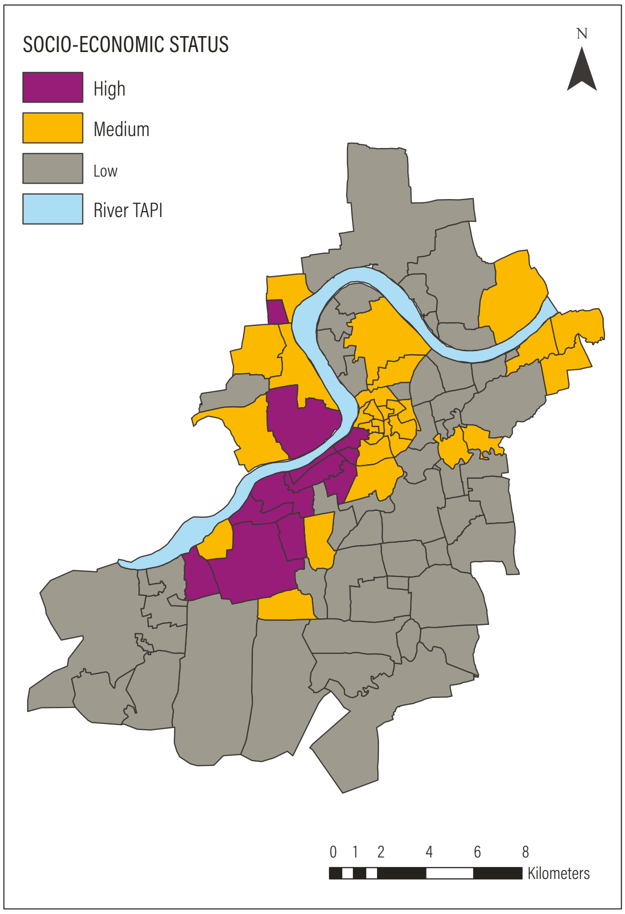
[39] *Guttikunda, S. K., & Jawahar, P. (2012). Application of SIM-air modeling tools to assess air quality in Indian cities. Atmospheric Environment, 62, 551–561. https://doi.org/10.1016/j.atmosenv.2012.08.074.*

5.4.1. Methodology

Primary data on MSW burning was collected using the transect method developed by Nagpure et al. (2015). Open-burning of municipal solid waste (MSW. In this method, SMC areas (101 municipal wards) were classified into different zones as per their socio-economic status (SES) and land use pattern (**Figure 29 and Annexure 4)**. Then, the transect routes were laid out into different streets and roads of each zone (covering 54 wards of the SMC), representing the survey area's SES and land-use characteristics (**Figure 30**).

All transect routes in the sample wards were covered either on foot or by a vehicle in the morning and evening hours for three consecutive days during the winter (January 2020) and summer (June 2019) seasons. As part of each day's transect sampling, the number of MSW burning incidences was recorded, including latitude and longitude waypoints of each MSW burning incident, rough mass, and composition. By considering the number of MSW burning incidences, transect length, and width (includes street width and building length of each side of the street), MSW burning frequencies/km^2 for each zone of SMC for both winter and summer time was estimated. MSW burning incidences and mass (per capita) were calculated for each zone and then applied to the population of the rest of the similar zones in SMC to scale up the results. More details of the transect method are available in Nagpure et al. (2015). Open-burning of municipal solid waste (MSW.

Figure 29: Socio-economic status (SES) and dominant land-use patterns in the SMC area



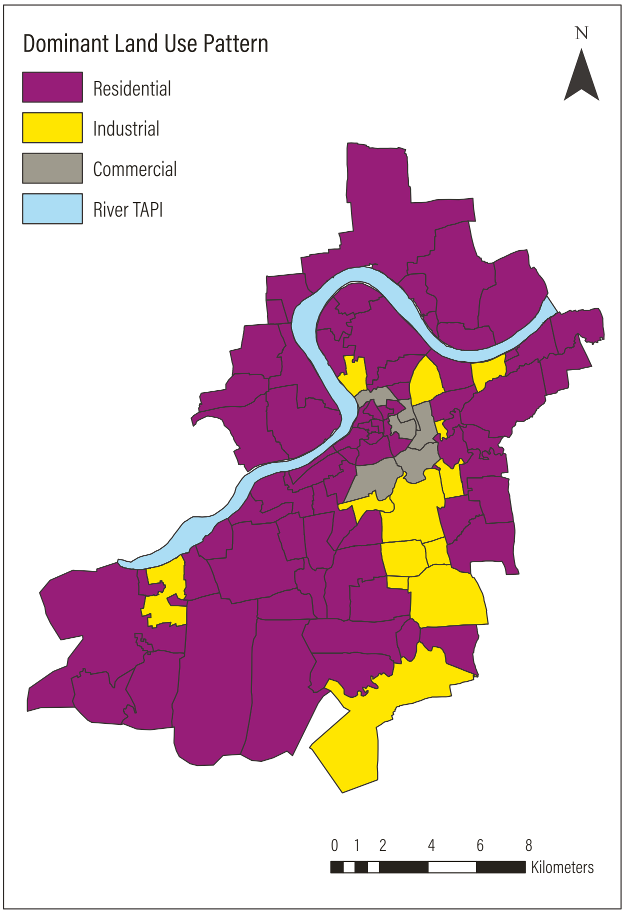
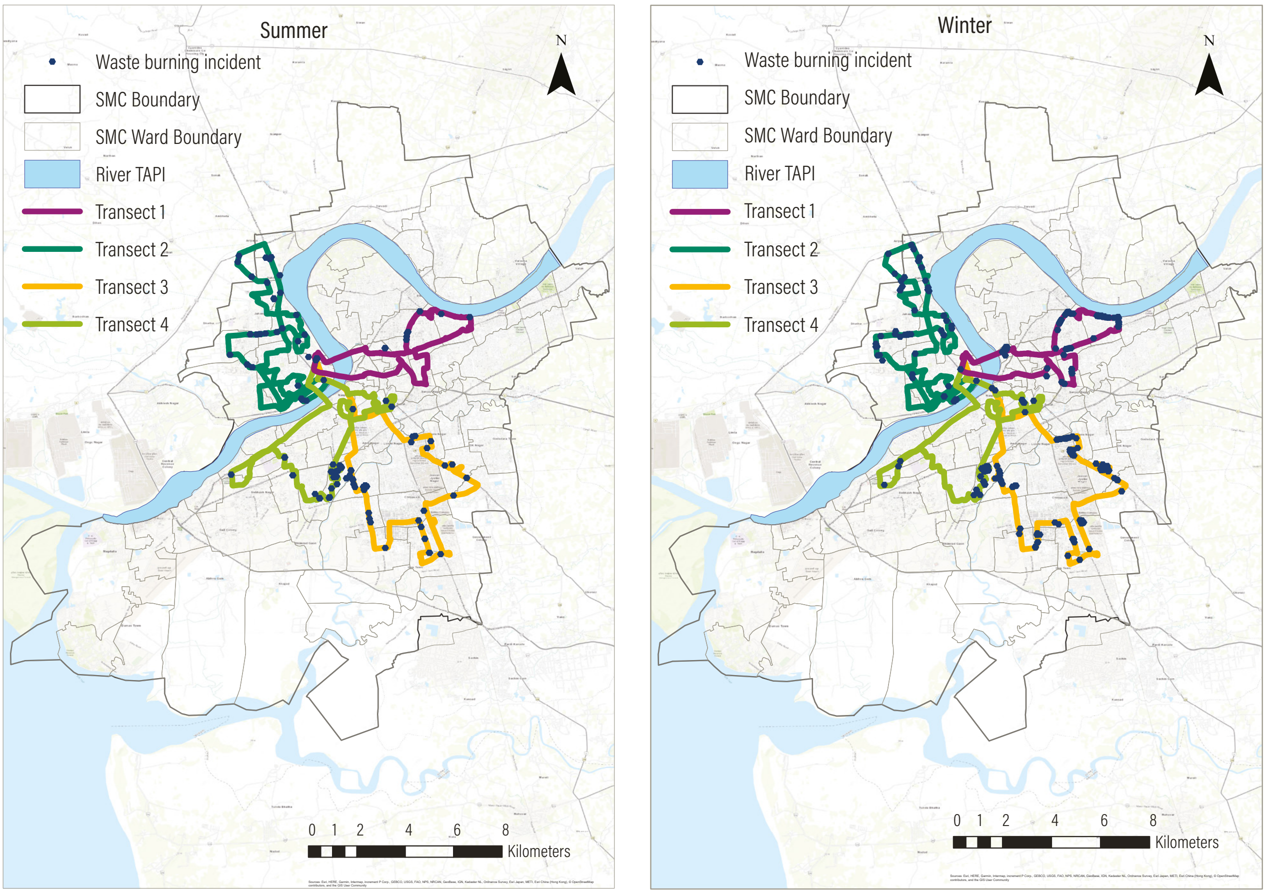


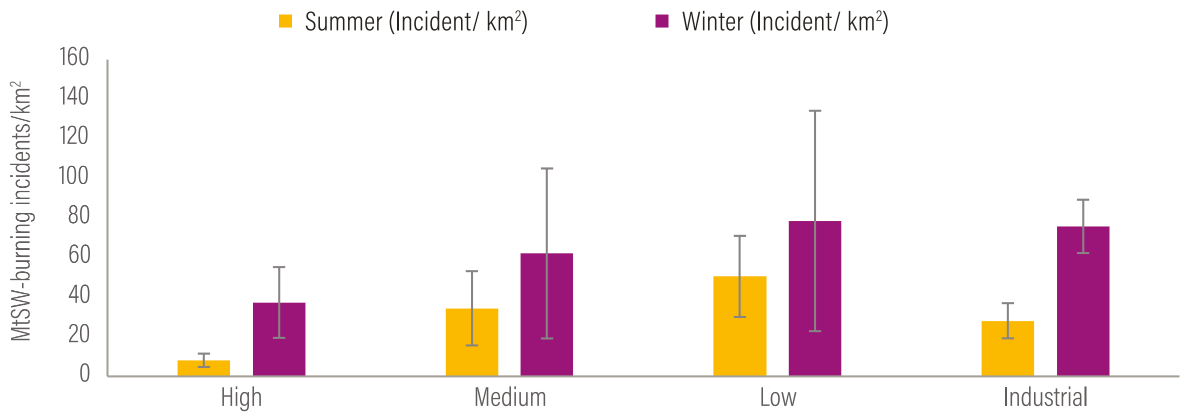
Figure 30: MSW burning survey transect routes during summers (left) and winters (right) in the SMC area



5.4.2. Findings from the Survey on MSW Burning

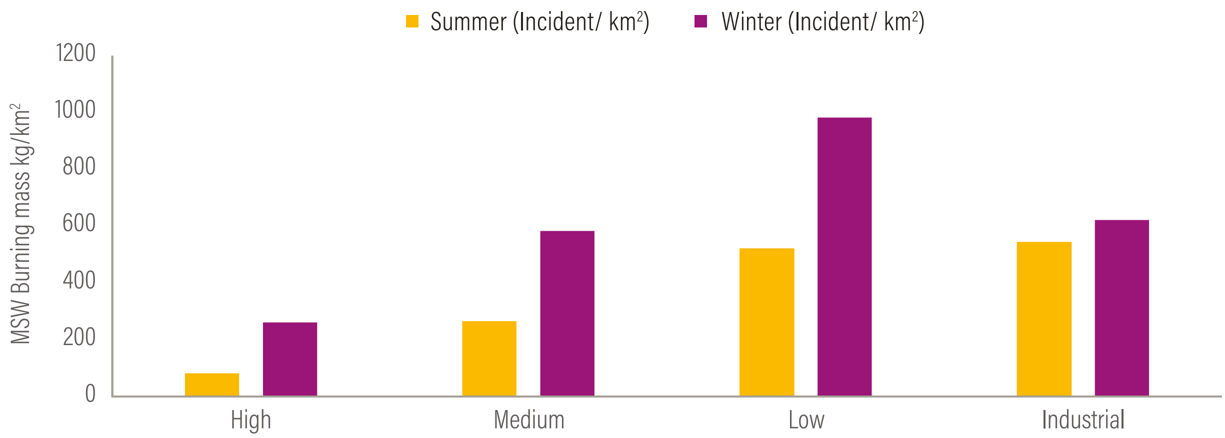
The survey results indicate that MSW burning incidents in the SMC area were more prevalent in the morning hours in both summer and winter months. With respect to the seasons, the highest number of incidents was observed in all areas in the winter, ranging from 37 incidents/km^2 in high SES to 79 incidents/km^2 in low SES areas. Considering both winter and summer, low-SES areas had a maximum number of MSW burning incidents (51-79 incidents/km^2), followed by industrial areas (28-76 incidents/km^2), medium-SES areas (34-62 incidents/km^2), and high SES areas (8-37 incidents/km^2). **Figure 31** illustrates these estimates.

Figure 31: Daily MSW burning incidents per km² in four areas (high-SES, medium-SES, low-SES, and industrial) of the SMC area during winter and summer seasons



Similarly, the highest MSW burning mass (kg/km²) was observed in low-SES and industrial areas in the winter and summer seasons (**Figure 32**). In low SES areas, MSW burning mass ranges between 521-982 kg/km² per day in summer and winter, followed by 545-621 kg/km² per day in industrial, 265-584 kg/km² per day in medium SES, and 82-262 kg/km² per day in high SES.

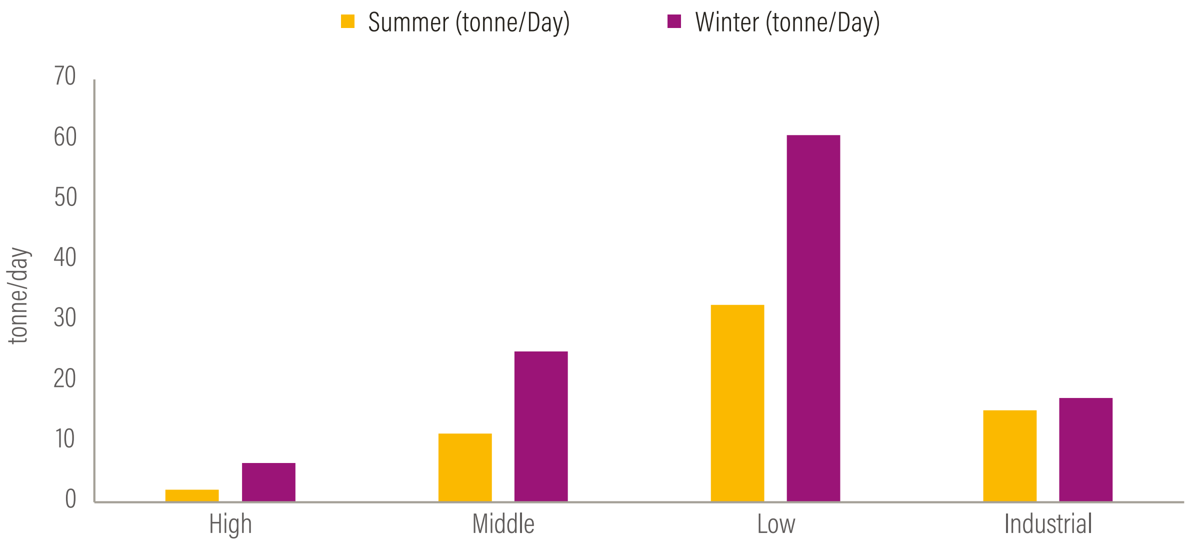
Figure 32: Daily incidents of MSW burning mass/km² in four areas (high-SES, medium-SES, low-SES- and industrial) of the SMC area during winter and summer seasons



The scaled-up estimation of MSW burning for the SMC area indicates that about 61 and 109 tons of MSW gets burned in the SMC area every day in summer and winter months, respectively, which is 2-4% of the total MSW generated day in the SMC area. The highest MSW burning was observed in low SES and industrial areas **(Figure 33).** Therefore, of the total generated waste in the SMC area, the estimated proportion of the quantity of MSW burned is relatively less than the range (10- 25% of generated MSW per day) specified in the 2012 study by Guttikunda and Jawahar[40].

[40] *Guttikunda, S. K., Nishadh, K., & Jawahar, P. (2019). Air pollution knowledge assessments (APnA) for 20 Indian cities. Urban Climate, 27, 124–141. https://doi.org/10.1016/j.uclim.2018.11.005.*

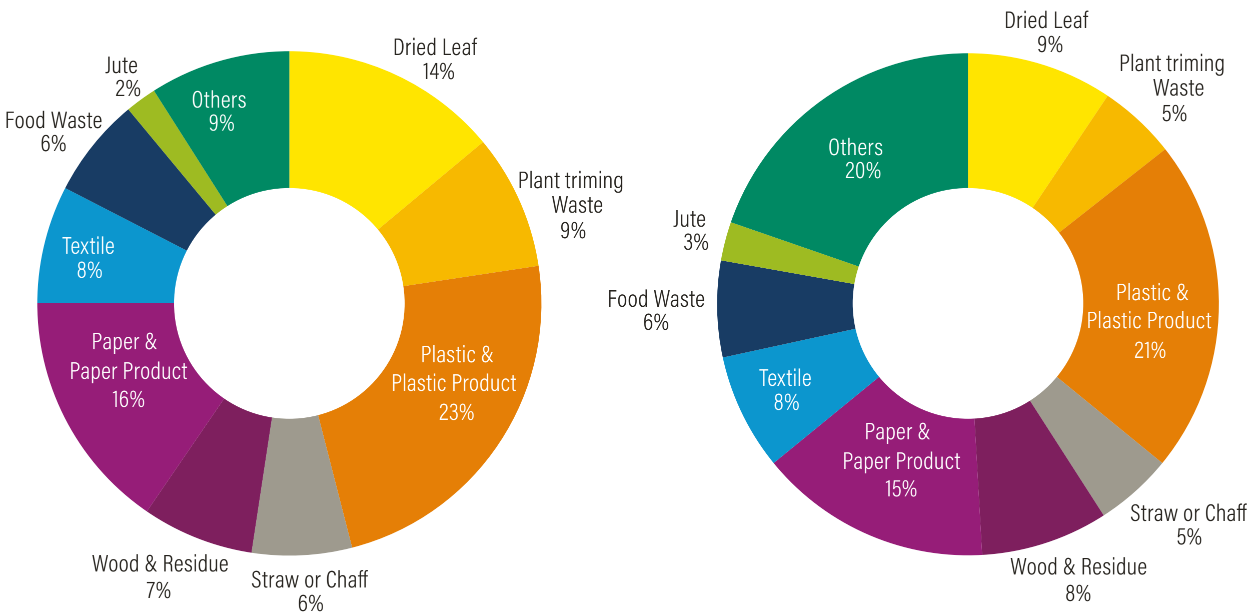
Figure 33: Daily incidents of MSW burning in four areas (high-SES, medium-SES, low-SES- and industrial) within the SMC area during winter and summer seasons



5.4.3. Composition of MSW Burned

The composition of MSW burned varies across SMC areas. For example, the highest amount of compostable MSW burned was observed in low-SES areas, whereas high SES areas showed more recyclable MSW. Estimations of the composition of MSW burned for the SMC area in both winter and summer seasons are illustrated in **Figure 34.**

Figure 34: Composition of estimated MSW burned in summer (left) and winter (right) seasons in the SMC area



5.4.4. MSW Burning at Old Dumping Site Bhatar

At present, MSW collected from the SMC area is disposed into the Khajod landfill. Previously, it used to be dumped in an open space in the Bhatar area of SMC. During the primary survey, continuous burning of MSW was observed in the previously used dumping ground of Bhatar, which can also be seen in the visual captured in Google Maps on 08/07/2019 (**Figure 35**). However, due to the vast quantity of dispersed waste, our method could not collect and estimate the MSW burning at this site.

Emissions from the landfill MSW burning were estimated in the source apportionment study and are discussed in **Chapter 2**.

Figure 35: MSW burning in Bhatar area, an old MSW dumping site (Smoke observed in Google Maps (picture captured on July 8, 2019))

5.5. INFORMAL PUBLIC SURVEY TO UNDERSTAND DIFFERENT REASONS FOR BURNING MSW

Informal open-ended interviews were conducted with randomly selected households, shopkeepers, and workers from different areas in SMC to understand their perceptions of MSW burning in their area during the primary transect survey. Some of the reasons presented by respondent households for burning MSW were that it was an easy way to get rid of waste, it was a daily routine to avoid waste accumulation in the vicinity (behavior), the waste collection bin was located far from the house, they missed the waste collection truck in the morning, it helped prevent the breeding of mosquitoes, and that there was an infrequent waste collection in the industrial area, among others.

5.6. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

A thorough review of policies and programs being implemented at various governance levels was conducted to better evaluate the possible strategies for the mitigation of air pollution from MSW burning.

5.6.1. Swachh Bharat Mission

The Swachh Bharat Mission (SBM) is a national initiative by the Government of India to clean cities. It covers 4,041 statutory cities and towns. The mission aims to make India clean by providing sanitation facilities for all households, including toilets, solid and liquid waste disposal systems, and a secure and sufficient drinking water supply. This policy targets waste collection and disposal, which directly impacts the MSW burning. The Government of Gujarat also launched the Mahatma Gandhi Swachhata Mission (MGSM), a vision similar to SBM to make towns and villages open defecation-free and zero-waste.

Challenges: SBM phase 1, which ended in 2019, aimed at the 100% scientific disposal of MSW, which is yet to be achieved. Creating awareness among the residents and engaging the stakeholder to achieve this target is time-consuming and requires more rigorous effort[41].

Opportunities: The main target of SBM is to improve the general quality of life in rural and urban areas, accelerate sanitation coverage, and provide solid waste management. SBM reviews the hygiene, sanitation, and solid waste management of villages, cities, and towns across the country under Swachh Survekshan

5.6.2. Solid Waste Management Rules, 2016

The Solid Waste Management Rules[42], 2016, replaced the Municipal Solid Waste Management Rules, 2000. The salient features of the Solid Waste Management Rules, 2016, are the following:

---

[41] Swachh Bharat Mission: We may be ODF, but not garbage free. (2021). Down to Earth. https://www.downtoearth.org.in/blog/waste/swachh-bharat-mission-we-may-be-odf-but-not-garbage-free-67101.

[42] Waste Management Rules and Action Plans. (2021, March 18). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Home/WasteMgtRulesAndActionPlans.

- The segregation of waste at the source is compulsory.
- Infrastructure must be provided for the collection of solid waste from all households with a door-to-door collection system.
- MSW should not be openly dumped, burned, or buried on the streets, open areas, public spaces, drains, and water bodies.
- Informal waste pickers and ragpickers must follow proper waste management practices endorsed by municipalities and urban local authorities.
- Urban local authorities can charge a user fee for bulk generators to collect and process their waste.
- Non-recyclable waste with a calorific value of 1,500 kcal or more must not be disposed of into landfills and must be used solely to generate energy through either refuse-derived fuel from waste or for distribution as feedstock.

Challenges: The main challenges that persist are waste segregation not taking place at the source, insufficient community awareness about MSW management, MSW burning at the old dumping site, and open burning of MSW in the SMC area[43].

Opportunities: SMC has implemented various interventions as per Solid Waste Management Rules, 2016, such as preparation of an MSW management plan, setting up a door-to-door collection of MSW, setting up eight refuse transfer stations, a centralized waste processing treatment plant at Khajod, and a 20-tons-per-day (TPD) plant for plastic waste management, installing an organic waste treatment plant at vegetable markets and slaughterhouses, and a construction and demolition waste processing plant[44].

5.6.3. Plastic Waste Management Rules, 2016

The Government of India has notified the Plastic Waste Management Rules[45], 2016, according to which every local body is responsible for setting up infrastructure for segregation, collection, processing, and plastic waste disposal. As part of these rules, the concept of Extended Producer Responsibility (EPR) was introduced. EPR is a policy in which the product manufacturers are responsible for collecting and processing their products till the end of the product's life cycle.

Challenges: Some of the challenges associated with plastic waste management are setting up material recovery facilities at a decentralized level, collecting and segregating plastic at the household level, and handling the toxic effects of plastic due to recycling.

[43] Swachh Bharat Mission Proposal DPR for Surat city. (November 2016). Surat Municipal Corporation. Facile Maven pvt. ltd.

[44] Solid Waste Management Approaches. (2021). SMC. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementApproaches.

[45] Ministry of Environment, Forest and Climate Change, Government of India. (2016). Plastic Waste Management Rules, 2016. https://cpcb.nic.in/rules-4/

Opportunities: Single-use plastic was banned in SMC under the Plastic Waste Management Rules, 2016[46], which led to a reduction in environmental pollution. As a replacement for single-use plastic, cups, tumblers, and bowls made of coconut shells were promoted, and so were cloth bags to carry groceries, vegetables, fruits, and other items as part of the Swachh Survekshan campaign.

5.6.4. ANUDAN Scheme

SMC launched the ANUDAN scheme[47] based on a public-private partnership (PPP) model to involve residential societies in maintaining cleanliness in their neighborhoods and personal health and hygiene. All registered and non-registered residential societies are eligible to participate in this initiative. At present, more than 862 societies have benefited from this scheme and are participating in different areas of the city.

As part of the scheme, SMC pays residential and non-residential societies for maintaining cleanliness in areas at the rate of 80 paise and 65 paise per sq. m. per month, respectively. However, if the monthly amount does not add up to INR 1,600, a minimum amount of INR 1,600 is paid to the society.

Challenges: It is difficult to monitor the scheme at the unit level and manage several resident welfare associations (RWAs) as they increase over time.

Opportunities: The scheme allows the SMC to collaborate with RWAs in waste management directly, promotes ownership and unit-level waste management among residents through the RWAs, and helps reduce the financial burden on SMC with respect to waste management.

5.6.5. Public Health By-Law

Public health by-laws (PHBL)[48] are drafted by the SMC with a sole objective to protect people from health threats, prevent disease, and strive for healthy populations. PHBL covers the segregation, storage, delivery and collection, processing, and disposal of solid waste. Enforcement of provisions, schedules of fines, and a list of offenses are also part of the by-laws.

Opportunities: PHBL provides obligatory duties and responsibilities to the SMC to implement solid and liquid waste management in the SMC area. The by-laws list down the duties of waste generators for segregation and storage and prohibition of various activities for waste generators.

[46] *Solid Waste Management Approaches. (2021). SMC. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementApproaches.*

[47] *Public Health Bye Laws For SMC. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Documents/WMRAndAP/PublicHealthByelawsForSMC.pdf.*

[48] *Public Health Bye Laws For SMC. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Documents/WMRAndAP/PublicHealthByelawsForSMC.pdf.*

5.7. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

Under the air quality improvement program for the SMC area prepared by the GPCB, an air pollution control action plan was proposed to control emissions from the burning of biomass, garbage, crop residue, and municipal solid waste (**Table 12**).

Table 12: GPCB's Air Action Plan – Open MSW burning related actions (Source: Surat –Air Pollution Control Action Plan, https://cpcb.nic.in/Actionplan/Surat.pdf)

Action Points	Implementation Status
Regularly check and control open burning of biomass, plastics, garbage, leaves, etc.	MSW is collected and transported through a primary collection system (collection from the house, shops, and other areas) and a secondary collection system (transfer of MSW from primary dumping site to disposal site) in SMC. This system covers 95% of the SMC area.
Regular collection and control of municipal solid wastes	The primary collection system comprises the door-to-door collection system from about 12 lakh households; this system also includes a container-lifting truck and other modes such as night scraping-brushing, hotel kitchen waste collection, etc.
Proper collection of horticulture waste (biomass) and its disposal following composting and gardening approach.	All the primary collecting vehicles reach the transfer station from where secondary vehicles are loaded to transfer the collected waste to the disposal site. There are six RTSs located in the different zones of the city. (Currently, eight RTS are functional.) 600 TPD composting plant has been installed and made operational phase-wise by an agency contracted by SMC. It has also initiated the process for establishing the RDF plant.

5.8. CONTROL MEASURES IDENTIFIED DURING OPPORTUNTIY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

WRI India conducted the SCAP Target Approach - MSW workshop on February 25, 2020, with various stakeholders, including the Municipal Commissioner SMC, the Hon. Mayor SMC, officials from SMC (Public Health Management, Hospital Management, and Environment Cells of the SMC), Regional Officer GPCB, representatives from textile industries' association, an academic from Center for Social Studies, local NGOs engaged with informal sector waste pickers, consulting agencies working on waste minimization projects, and others who are directly or indirectly engaged in MSW management. Stakeholders highlighted the following points for improving MSW management:

- Municipal solid waste, which is not collected and treated effectively, persists as a significant environmental problem for public health in SMC. There is an urgent need for introducing behavior change among more people.
- It is important to focus on waste segregation and involve informal waste pickers since these informal workers (ragpickers and scrap dealers) play a critical role in MSW management and waste recovery.

- It is important to increase the participation of the citizens, the informal sector, and other stakeholders in MSW management.
- Promoting MSW segregation at source through awareness building measures is important as it is a critical process in recycling.

5.9. STRATEGIES TO MITIGATE AIR POLLUTION

After analyzing the data on MSW burning collected from different neighborhoods (categorized by SES and land-use pattern), a public survey, a review of policies being implemented currently, inputs from the opportunity framing workshop, GPCB action points, stakeholder interviews, and best practices, we identified the following mitigation strategies to reduce MSW burning in SMC:

5.9.1. Awareness Program Targeting Citizens of the SMC Area on the Impact of Open Burning of MSW

As is evident from the data collected in the primary survey on MSW burning, the SMC area residents burn MSW despite the available infrastructure. The reasons for MSW burning vary. Those residents who continue with this practice say that they find burning a convenient way to reduce MSW accumulation, find the MSW collection bin far from their home, feel that it helps prevent mosquito breeding, miss the MSW collection truck, and find the frequency of MSW collection to be less (reasoning based on an informal survey conducted during a transect walk and having a small sample). One of the critical factors that emerged from analyzing responses was citizens' behavior for MSW burning in the SMC area. Citizens do not seem to be aware of the consequences of toxic pollution from MSW burning and its health impacts. Therefore, instead of waiting for the next MSW collection truck, walking some yards, or informing responsible authorities, they prefer burning MSW. The analysis by SES, education and land-use patterns in the SMC area reveals a strategic need for intracity level awareness. Merely holding lectures, workshops, group meetings, and panel discussions would not be adequate to educate everyone. It is essential to cover the entire population for which awareness programs can be planned.

Table 16 describes the various components of awareness interventions that can be implemented in the SMC area. Awareness is a tool to bring about a change in the behavior of people. In addition, other interventions are required to curb the practice of MSW burning.

5.9.2. Recyclable Utilization Facilities

The composition of burned MSW includes organic waste (dried leaves, plant trimming waste, food waste, straw, or chaff), recyclable waste (paper, plastic, jute, pieces of rubber, and leather), and textile or thread waste. Almost 50% of MSW (found to be burnt in open) is recyclable, especially plastic, plastic products, paper, paper products, and other recyclable materials (leather, rubber, thermocol or polystyrene, jute, wood). To mitigate the burning of recyclable waste, proper segregation and availability of Material Recovery Facilities (MRF) are recommended under the Solid Waste Management Rules, 2016. The Rules define MRF as a facility where non-compostable solid waste can be temporarily stored by local bodies or agencies authorized to facilitate segregation, sorting, and recovery of recyclables by the informal sector before waste is delivered or taken up for processing. SMC started MRF centers at all Secondary Refusal Transfer Stations (SRTSs) with an average daily waste of 360

MT[49]. In addition, under Swachh Bharath Mission DPR, the SMC proposed MRF construction with a capacity of 600 TPD, two new RTSs alongside eight old functioning RTSs, and 100 TPD plants for recycling and storage[50]. It is recommended that MRF plant units be installed at a more decentralized scale (if possible, at ward level) to enhance maximum material recovery. As MSW characteristics and composition vary across different land use and SES, MRF with specific targets in different areas can be implemented. For example, recyclable waste composition in low SES areas is different from higher SES areas.

Industrial, residential, and commercial waste characteristics are different from each other. Therefore, RWAs, community-based organizations (CBOs), NGOs, self-help groups (SHGs), and the private sector could be involved to improve segregation and material recovery efficiency. **Table 17** describes significant action points associated with this intervention.

5.9.3. Prevention of Textile or Thread Burning

During the primary survey, the burning of textile waste was observed in most low SES and industrial areas. As per the estimation, about 9% of the total MSW burned per day is textile. This textile waste can be converted into heat and electricity through a gasification technique. The use of gasification technology has advantages such as reduced auxiliary fuel consumption and fewer emissions than incineration. Incorporating a gasification system into textile waste processing reduces energy and investment costs helps meet clean energy production and environmental regulations (**Table 18**).

5.9.4. Organic Waste Conversion

According to our estimation, of the total waste burnt per day, 28% is organic waste, which includes dried leaves, plant trimming (garden waste), food waste, and straw or chaff. To minimize the accumulation and burning of organic waste, organic waste conversion (OWC) units can be installed in the city at a decentralized scale based on the MSW characteristics of the area. OWC units produce manure or compost, which generates revenue. With the collaborative support of SHGs, NGOs, RWAs, informal waste handlers, and the private sector, SMC can initiate decentralized OWC in different areas. In addition, SMC can encourage cow sheds, dairy farms, and cattle farms to install OWCs to convert the waste generated to manure. Furthermore, OWC can be installed in high and medium-SES neighborhoods for better results, as these neighborhoods are more aware of the system and manure generated from OWC has a high chance of utilization. SMC has already proposed a decentralized organic waste processing plant at four locations with a capacity of 10 TPD and at 100 locations with a capacity of 1 TPD (**Table 19**).

5.9.5. Monitoring and Penalizing Open Burning of MSW

Monitoring is required to understand the operational status and for effective compliance and implementation of policies and programs. Therefore, SMC and GPCB must improve monitoring capacity by enhancing the workforce, collaborating with local groups, and using different applications. For

---

[49] *Centre material recovery facility. (2021, April 21). Surat Municipal Corporation. https://www.suratmunicipal.gov.in: https://www.suratmunicipal.gov.in/CleanSurat/Home/PastEventsAndInitiatives.*

[50] *Swachh Bharat Mission Proposal DPR for Surat city. (November 2016). Surat Municipal Corporation. Facile Maven Pvt. Ltd.*

example, an online user-friendly grievance redressal portal or application should be provided to citizens for registering complaints against MSW burning.

During the primary survey in this study, it was observed that MSW burning is a behavioral issue. To minimize waste burning, there is a strong need to implement penalties. The penalties can be different for different zones and MSW characteristics of the SMC area. For example, those who practice open burning in sensitive areas, such as hospitals, schools, play areas, parks, and exercise zones, must be penalized more. The burning of hazardous waste must have more penalties as compared with that of regular garbage. This process can be extended gradually into different areas of the city. One of the measures proposed is to increase the fine levied for open burning of MSW from INR 100 to INR.500 in the SMC area.[51,52] (**Table 20)**.

5.9.6. Prevention of Landfill Fires

During the primary survey in this study, incidences of accidental waste burning were observed in Bhatar (an old dumping ground). The closure of the Bhatar dumping site would be necessary as per Solid Waste Management Rules, 2016, in addition to shifting the accumulated waste to the proposed landfill site and the subsequent rehabilitation of the Bhatar dumping site. The Bhatar dumping area is about 0.23 km^2 in size, and the waste accumulated is estimated to be 35,45,040 MT[53]. Moreover, in the Khajod landfill site, no accidental fire incidents observed, but under preventive measures, the site's scientific closure is also required (**Table 21**).

Under SCAP, potential projects to mitigate open MSW burning in the SMC area have been identified (**Annexure 8**). In addition to the above-mentioned mitigation measures, SMC is installing waste to Refuse Derived Fuel (RDF) to an energy plant with a capacity of 1200 TPD and a centralized waste processing plant with a capacity of 2000 TPD (EPC Basis)[54], which will help manage MSW management and burning.

5.10. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

The primary survey data was analyzed before designing strategies at the micro-level (intra-city scale) in the SMC area for reducing the burning of MSW. However, a few wards were identified during the field survey where a higher number of burning incidents of MSW was observed (**Figure 36**). Therefore, the wards with the highest number of burning incidents (highlighted in dark blue colour in **Figure 36)** should be considered the primary and preferable locations for implementing the proposed mitigation strategies. These wards include TPS – 4 Ashvanikumar Navagam, TPS – 8 Umarwada, Fulpada, Kapodra, Dindoli (52), Bhestan, Pandesara, Udhana, Bamroli, Dindoli part (81), Bamroli (Part) and

---

[51] SCAP target approach workshop - Construction Sector. (2019, November 25). Surat, Gujarat.

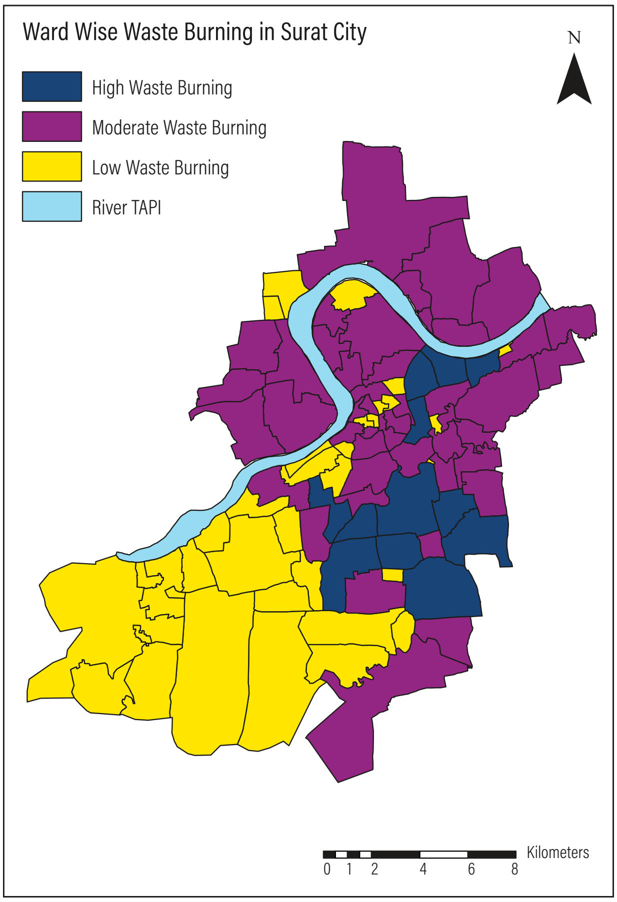
[52] Public Health Bye Laws For SMC. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Documents/WMRAndAP/PublicHealthByelawsForSMC.pdf.

[53] Kulkarni, T. (n.d.). GHG Accounting and Planning approach to Solid Waste Management from the landfills in Surat City, Gujarat. https://www.researchgate.net/publication/282642291_GHG_Accounting_and_Planning_approach_to_Solid_Waste_Management_from_the_landfills_in_Surat_City_Gujarat.

[54] Solid Waste Management Approaches. (2021). SMC. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementApproaches.

Bhattar. The focus should be placed on the industrial areas and their surrounding wards, such as Bhestan, Bhattar, Udhana, and Ashvanikumar Navagam, since the highest burning incidents (more than five per day) were observed in these areas. With interventions suggested by GPCB and proposed recommendations under SCAP (**Section 5.9**), these wards (**Figure 36**) can be preferred primarily to implement mitigation measures.

Figure 36: Micro area planning of open MSW burning in the SMC area



Mitigation Measures:

- The burning of MSW in the open must be checked and controlled on a regular basis, and fines must be imposed on the defaulters.
- In the identified locations (**Figure 36**), a complete ban/prohibition on the open burning of garbage/ MSW must be immediately enforced.
- Authorities must conduct surveys on MSW burning every year in these areas to assess the efficacy of mitigation measures.
- Awareness campaigns should be carried out in areas with high numbers of waste burning incidents (**Figure 36**) to discourage the community from burning MSW.
- Prioritize these areas to implement OWC and set up MRF at the decentralized system for better MSW management.

- Involve the informal waste sector for maximum recovery of recyclable material.
- Ensure 100% door-to-door collection system coverage along with improved MSW composting and recycling efficiencies.
- Bhestan, Udhana, Ashvanikumar Navagam, Pandesara, and Bhatar, where industrial units (textile and weaving) are located, require gasification plants for the scientific disposal of textile waste.
- In Bhatar, the old dumping site requires scientific closure to prevent landfill fires.

5.11. TECHNO-ECONOMIC ANALYSIS

Air pollution associated with MSW burning was responsible for about 14 premature deaths (as indicated in **Chapter 3**) in the SMC area in the year 2019. The SMC's interventions for MSW management and those proposed in this report will lead to a reduction in air pollution from the MSW burning and in the associated health risks. This section analyzes the rough cost of the interventions proposed to mitigate the MSW burning and improve MSW management.

An attempt has been made to carry out techno-economic analysis for the following interventions:

- Awareness programs
- Organic waste conversion (OWC and decentralized waste to compost plant)
- Recovery facility
- Monitoring of waste burning
- Prevention of textile or thread burning
- Prevention of landfill fires (Closure of old dumping site at Bhatar)

In the case of the SMC area, it was observed that the burning of waste is primarily a behavioral aspect. Therefore, carrying out awareness programs among the people of SMC will help reduce the practice of burning waste in the city. Awareness in the SMC area can be built through various channels, such as mass media (advertisements in newspapers, TV, and radio, and street plays), social media (Facebook, Twitter, Instagram, etc.), awareness programs (one-day programs encouraging citizen engagement) once a year, public meetings, and spreading the message through various community leaders. As per this study, 28% of MSW burned contained compostable materials; hence, composting plants, such as waste to compost plant (decentralized) and OWC for bigger societies/colonies, would help reduce waste burning. The required capacity of these mitigation measures has reference to the Swachh Bharat Mission proposal for Surat city, 2016 (**Table 13)**.

Table 13: Key parameter includes capacity and method considered and unit cost – Organic waste conversion

Key Parameter	Decentralized Waste to Compost	OWC
Capacity installed up to 2025	40 TPD	100 TPD
More capacity is required up to 2030	40 TPD	55 TPD
Segregation required	Yes	Yes
Capital Cost (INR, per tons in crore)	0.25*	0.12β
Operational Cost (INR, per tons in crore)	0.3Ψ	0.8β

** Based on Swachh Bharat Mission Proposal for Surat city -DPR*

Ψ *Estimated based on Advisory on On-Site and Decentralized Composting of Municipal Organic Waste under Swachh Bharath mission – urban*

β *Based on Excel industries ltd. Quotation*

The recyclable materials, such as plastic, paper, jute, thermocol, leather, and rubber, share 50% of the total burnt material, as per the primary survey. Of this, 22% and 15 % are plastic and paper products, respectively. Hence a recovery facility for recyclable materials must be set up at a decentralized level. Presently, there is an MRF of 360 MT capacity in the SMC area. Thus, an additional capacity of 240 MT is required to create the proposed capacity of 600 MT. **Table 14** represents the unit costing of the recovery facility.

Table 14: Key parameter include a timeline, and unit cost of the recovery facility

Recovery Facility	
Capital cost (INR per tons in crore)	0.9#
Operational cost (INR per tons in crore)	0.2#
Implementation time	Up to 2025

 # Based on Advisory of Material recovery facility for Municipal solid waste under Swachh Bharath mission – urban

Monitoring the burning of MSW in the open is required to understand the effect of compliance with mitigation measures; hence, a yearly survey on MSW burning is required to monitor the status. The transect walk approach should be followed to estimate the annual status of open MSW burning (**Table 15)**. A gasification plant for heat generation is being proposed as a mitigation measure to prevent textile or thread burning. A capacity of 150 TPD should be considered for up to 2025, increasing to 200 TPD after 2025. The plant should be operated on a PPP mode basis. Its required capacity and running parameters have been referred from the Swachh Bharat Mission proposal for Surat city 2016. The costing of the closure of the old dumping site at Bhatar has been done after referring to the case study of the *Pirana* dumpsite biomining project in Ahmedabad, Gujarat. The project's cost is estimated to be INR 108/ton (approx.)[55], and the waste placed at the dumping site is approximately 3,545,040 MT[56]. Hence, the approximate total cost of the closure of the dumping site at Bhatar is INR 38 crore.

[55] *MOHUA, Advisory on Landfill reclamation. (2020). MOHUA; Government of India.*

[56] *Kulkarni, T. (n.d.). GHG Accounting and Planning approach to Solid Waste Management from the landfills in Surat City, Gujarat. https://www.researchgate.net/publication/282642291_GHG_Accounting_and_Planning_approach_to_Solid_Waste_Management_from_the_landfills_in_Surat_City_Gujarat.*

Table 15: Economic implications of proposed policies and programs

Sr. No.	Proposed Policy or Criteria	Implementation Time	Responsible Agency/ Stakeholder	Capital cost (INR crore)		Operational cost (INR crore)		Expected Outcomes
				2021-25	2026-30	2021-25	2026-30	
1.	OWC for bigger societies, colonies, etc.	2021-2030	SMC (with support from NGOs, SHGs, RWAs, ragpickers)	12	7	31	22	Reduction in MSW burning incidents
2.	Decentralized waste to compost plant	2021-2030	SMC (with support from NGOs, SHGs, RWAs, ragpickers)	10	10.5	5.6	7.4	Reduction in emissions along with prevention of mortality
3.	Recovery facility	2021-2025	SMC (with the help of NGOs, SHGs, RWAs, rag pickers, and the Private Sector)	22		19		
4.	Awareness program	2021-2023	SMC (with the help of NGOs and SHGs)	Total Cost (INR crore) 4				
5.	Monitoring of open MSW burning	2021 -2030	SMC	0.11				
6.	Prevention of textile or thread burning (gasification plant)	2021-2030	Industries Association, GPCB, GIDC, SMC	PPP mode				
7	Closure of old dumping site Bhatar	2021-2025	SMC, GPCB	38				

The cost of implementing OWC, waste to compost, and recovery facility was estimated using the capital cost (construction and equipment cost). The operational cost (honorarium/salary and regular repair, maintenance cost, etc.) and total cost of awareness activities, and monitoring of open MSW burning, and the closure of the old dumping site were estimated. It is assumed that SMC will arrange the land required to set up the plants. Proper waste collection and segregation at the household level are required for achieving the desired results from organic and recyclable waste management[57] and burning. Studies also suggest that open waste burning incidents can be reduced by the implementation of an efficient solid waste program[58]. Hence, the benefits expected from the mitigation measures are reduction in MSW burning incidents and emissions and prevention of mortality, and other benefits,

[57] *Bhushan, C., Sambyal, S. S., & Walani, N. (2018). Model Framework for Segregation: Guidelines for managing municipal solid waste through segregation, reuse and recycling. Centre for Science and Environment.*

[58] *Guttikunda, S. K., Goel, R., & Pant, P. (2014). Nature of air pollution, emission sources, and management in the Indian cities. Atmospheric Environment, 95, 501–510.* https://doi.org/10.1016/j.atmosenv.2014.07.006.

including revenue generation from selling fertilizers/manure and reusable/recyclable materials and their products.

5.11.1. Health Risk Assessment

The total cost of decreasing air pollution from open MSW burning as per the proposed mitigation measures is INR 104 crore (excluding operational cost), which will be spent over a time span of 10 years. In addition, an air pollution health risk assessment (AP-HRA) was carried out to assess the health risks of air pollution caused by open MSW burning. The proposed mitigation measures, if implemented, can help save approximately 14 lives every year.

5.12. SCENARIO GENERATION

The SMC area falls under the Smart City Mission of the Ministry of Housing and Urban Affairs (MoHUA). Assuming that the SMC will be executing projects related to this Mission, including MRF, RDF, OWC, and extension of schemes such as ANUDAN in the next five years, it is estimated that incidents of burning MSW in the open will no longer take place. Additionally, intense efforts will be made to bring about behavior change among citizens while working on the proposed mitigation measures for the sector, which is currently performing well with respect to waste segregation and ensuring collection efficiency across the SMC area. Thus, in the future, incidents of open MSW burning are projected to be zero for 2025 and for 2030 as well.

5.13. CONCLUSION

The MSW burning sector contributed approximately 2% and 1% emissions of $PM_{2.5}$ and PM_{10}, respectively, in the SMC area in 2019. SMC is working towards creating an efficient MSW management system and has been recognized as the second cleanest city in India by Swachh Sarvekshan 2020. However, incidents of burning MSW were recorded during the primary survey, which could be related to behavioral aspects and infrastructure efficiency. The proposed mitigation measures, i.e., awareness programs, recyclable utilization facilities, organic waste conversion, and monitoring, can help in the reduction of these incidents in the SMC area. These approaches will result in zero incidents of burning MSW in the open incidences, as indicated for scenario generation and reduced emissions, thus averting premature mortality within the SMC area.

Table 16: Mitigation measures for awareness program for citizens of the SMC area

Issues	Level of Intervention	Goal	Proposed Actions	Implementation Period	Implementing Agency	Integration with Swachh Bharat Mission Proposal for Surat city – DPR
Lack of awareness among citizens regarding the adverse impact (health and environment) of MSW burning	Neighborhood-centric awareness program as per SES, infrastructure, land use, characteristics	Spread message among the entire population to stop MSW burning	Education program to create awareness among citizens through various mass media tools, such as local newspapers, local news channels on TV or radio, street plays, social media platforms, citizen engagement events, recording announcements through waste collection vehicle, organizing awareness seminars at the community level	Mid-term (But repeat after every 2-3 years)	SMC (with the help of NGOs and SHGs)	Initiatives such as drawing competitions at schools, cleaning drives at various locations, Swachhata pledge taking events for public awareness through information, education, and communication (IEC) campaigns for MSW management
		Build awareness through the involvement of different community leaders	Involvement of RWAs, schools, religious leaders, medical practitioners, local women's association, voluntary organizations, and local NGOs in spreading the message among different sections of society to either compost and recycle their waste or adequately dispose of through the SMC collection system	Mid-term		
		Spreading the message among the industrial units	Awareness campaigns, meetings, and seminars among industries to stop MSW burning and dispose of industrial and solid waste separately	Mid-term	Industries Association and GIDC	

Table 17: Mitigation measures for recyclable utilization facilities

Issues	Level of Intervention	Goal	Proposed Actions	Implementation Period	Implementing Agency	Integration with Swachh Bharat Mission Proposal for Surat city – DPR
Burning of paper, plastic, wood, pieces of leather, rubber, thermocol, jute	City level	Adopting the 5R concept-reduce, reuse, recycle, recover and remove to reduce MSW burning	Waste reduction through recycling, reuse, reduce, and recover	Long term	SMC (with the help of NGOs, SHGs, RWAs, ragpickers, and private sector)	SMC has set up a common plastic waste management facility, as per Plastic Waste (Management and Handling) Rules, 2016, on a PPP basis.
		Maximum recovery and storage of recyclable waste	100% collection of recyclable waste and transfer to a recovery facility Setting up of MRF facilities in a more decentralized manner for maximum segregation, recycling, and recovering of waste fraction	Mid-term	SMC	SMC has planned to set up a material recovery facility at Vanakaneda near Kadodara. A material recovery facility of 600 MT per day for Surat is proposed. SMC started an MRF center at all SRTSs with an average daily waste of 360 MT
		Involve informal waste pickers in waste management and provide easy access to recyclable waste	Involvement of informal sector (waste pickers) for maximum recovery of recyclable material	Short term	SMC	Informal (ragpickers, scrap dealer) systems, SHGs, and local NGOs play an essential role in MSW management and valuable waste recovery Scrap dealers and waste pickers help to reduce environmental impacts by improving resource recovery and reducing waste quantities for disposal

Table 18: Mitigation measures for prevention from textile or thread burning

Issues	Level of Intervention	Goal	Proposed Actions	Implementation Period	Implementing Agency	Integration with Swachh Bharat Mission Proposal for Surat city - DPR
Textile waste and thread burning	Industrial and residential - low SES wards	Shifting of industries from the present incinerator to alternate non-emitting gasification technology, to stop textile waste burning	Gasification plant for heat generation for shredded textile, thread, and their packaging material	Mid-term	Industries Association, GPCB, and GIDC	Proposal for 150 TPD gasification plant to convert non-hazardous industrial waste, such as textile shredding, packaging material, cardboard, and paper, etc. With the increase in waste generation capacity, the plant capacity would increase, up to 200 TPD, in PPP mode.

Table 19: Mitigation measures for organic waste conversion

Issues	Level of Intervention	Goal	Proposed Actions	Implementation Period	Implementing Agency	Integration with Swachh Bharat Mission Proposal for Surat city - DPR
Garden MSW burning	Residential areas	Organic waste conversion to prevent burning of organic waste	Home/garden/roof composting in residential areas	Long term	SMC (with the help of RWAs, NGOs, and SHGs)	OWCs for bigger societies and colonies (pilot project) (100 locations – OWC of 1 TPD each up to 2025) and increase to 55 TPD by 2030 Decentralized waste to compost plant of 40 TPD (10 TPD at 4 locations) till 2025 and increase to 40 TPD by 2030
Food waste and straw or chaff burning	City level		Decentralized compost/ manure production at residential or community level (RWAs) with the help of NGOs or local entrepreneurs for all types of SES neighborhood	Long term	SMC (with support from NGOs, SHGs, RWAs, ragpickers)	
			100% door-to-door collection of waste where composting is not possible	Mid-term	SMC	

Table 20: Mitigation measures for monitoring and penalizing of MSW burning

Level of Intervention	Goals	Proposed Actions	Implementation Period	Implementing Agency
City level	Monitoring of MSW burning	Formation of committee or task force by the SMC to monitor MSW burning in the SMC area.	Short-term	GPCB and SMC
		Regular checking of open MSW burning by the committee or task force, preferably wards identified as high waste burning wards in Micro Plan **(Section 5.10)**, gradually extends to the entire city. Defaulters should be penalized. Conduct a survey on MSW burning every year for monitoring through the transect walk method.	Long-term	
		To register complaints against MSW burning in SMC, citizens should be able to connect through a mobile app, and a more focused approach should be followed.	Short-term	
	Penalizing the burning of MSW	To restrict MSW burning, specific guidelines should be developed for taking action against those found burning MSW: Strict penalties in the form of fines and cancellation of the license of industries and commercial establishments. A fine slab for the residential area (INR 200-500) can be considered.	Long-term	

Table 21: Mitigation measures for prevention of landfill fires

Issues	Level of Intervention	Goal	Proposed Actions	Implementation Period	Implementing Agency	Integration with Swachh Bharat Mission Proposal for Surat city – DPR
MSW burning at old dumping site at Bhattar	City level	Prevent landfill fires (in present-day and in the near future)	Closure of old dumping site at Bhatar Scientific closure of landfill site in the near future to prevent landfill fires	Long term	SMC	Mentioned about the scientific closure of old landfill site at Khajod

CHAPTER 06

>> INDUSTRIES

6.1. EMISSION INVENTORY – INDUSTRIES SECTOR

The SMC area is the hub of many industries, predominated by textiles, diamond processing, chemical, and petrochemical industries. As per TERI's emissions inventory data, industries are one of the major contributors to SO_2, CO, $PM_{2.5}$, PM_{10}, and NO_2 pollution in the SMC area. Industries located in the SMC area share about 69% of in-boundary total SO_2 emissions, followed by 29% of CO, 27% of $PM_{2.5}$, 23% of PM_{10}, and 12% of NO_2 emissions (**Figure 37**). The source apportionment analysis shows that industries are among the largest sources of $PM_{2.5}$ pollution in the SMC area. The averaged source contribution to $PM_{2.5}$ concentrations in summer and winter seasons in the SMC area is 17% and 27%, respectively.

Figure 37: Annual emissions of different pollutants from industries located in the SMC area (Source: TERI, 2021)

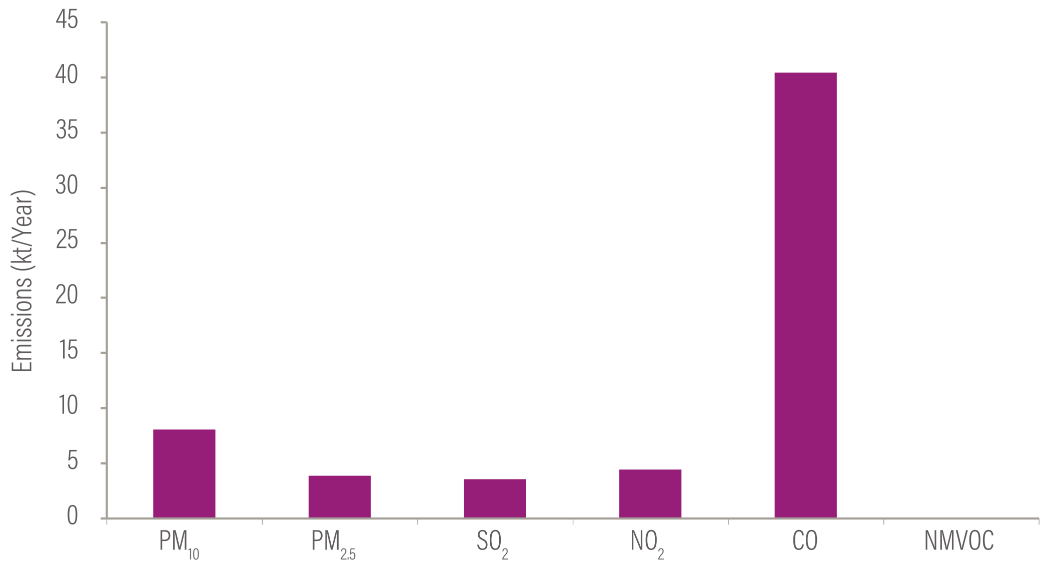
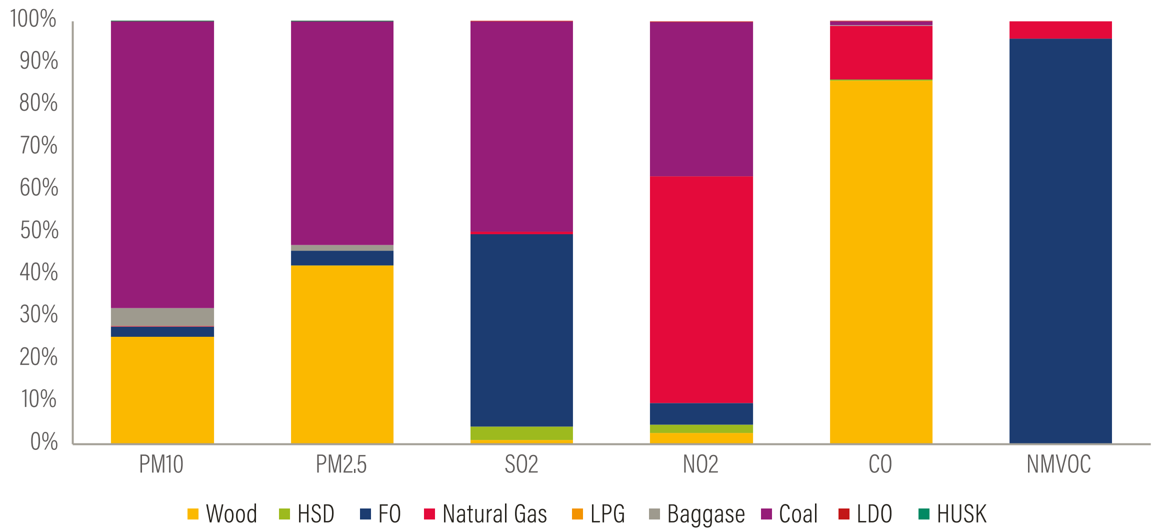


Figure 38: Estimated emissions from the use of different fuels in industries located in the SMC area



A further breakup of industrial emissions into large, medium and small industries shows large industries are responsible for the majority of SO_2 emissions, medium industries generate a majority of CO emissions, and small industries generate most of the PM_{10} emissions. The source apportionment study using receptor modeling and dispersion modeling determined the $PM_{2.5}$ and PM_{10} contributions from the industries sector in the summer and winter seasons. As per the dispersion model, the sector contribution to $PM_{2.5}$ concentrations was 17% in summers and 27% in winters, while according to the receptor model, it was 31% in summers and 27% in winters. The receptor model combines the industrial emissions with those of power plants in the SMC area.

6.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR IN THE SMC AREA

The industrial development in the SMC area and Surat district is attributed to a large number of textiles, diamond processing, chemical, and petrochemical industries. The chemical, petrochemical, and natural gas industries at Hazira are large-scale industries, whereas textile and diamond processing are medium to small in nature. The following is a brief description of the industries located in the SMC area:

- **Textiles**: The textile industry in the SMC area mainly engages in yarn production, weaving, processing, and embroidery. The SMC area is well known for the production and trading of synthetic textile products. Nearly 30 million meters of raw fabric and 25 million meters of processed fabric are daily produced in the SMC area[59]. Almost 5,00,000 power looms, and 450 dyeing and printing units are located in the clusters Pandesara, Sachin, Kadodara, and Palsana in and around the SMC area. There are about 150 wholesale markets in SMC and its surrounding areas.
- **Diamond Processing**: The diamond cutting and polishing industry was introduced in the SMC area at the turn of the 20th century. The diamond industry is one of the most labor-intensive industries in India. There are about 6,500 diamond polishing units in Gujarat, employing about 70 lakh people[60]. The SMC area alone has 38% of these units and 57% of this workforce. More than 10,000 enterprises are in the distribution business associated with the diamond polishing industry in SMC and its surrounding areas. Over 1.5 million people are directly or indirectly dependent on the diamond cutting and polishing industry here.
- **Corporate Industrial Production Units**: The Hazira industrial area and port are located on the Tapi river's northern banks adjacent to the SMC area. It is home to several major processing facilities/manufacturing centers of Reliance Petrochemicals, Essar Steel, Larsen & Toubro, KRIBHCO, ONGC, Shell, ABG Shipyard, and Torrent Power.
- **Industrial Cluster**: Presently, there are nine major industrial estates in the Surat district, namely, Khatodara, Bardoli, Olpad, Katargam, Ichhapore, Bhatpor, Pandesara, Hazira (Mora), and Sachin (**Table 22**). The Ichchapore industrial estate, established by Gujarat Industrial Development Corporation (GIDC), is the largest, followed by the Sachin industrial estate.

[59] *FOSTTA, Annual Report (2019). Federation of Surat Textile Traders Association (FOSTTA).*

[60] *IBEF presentation. (2019). 'Gujarat the Growth Engine of India.'*

Table 22: Industrial cluster in Surat district (Source: MSME Department, 'Brief Industrial Profile of Surat', 2019)

Sr. No.	Name of Industrial Cluster	Developed Area (ha)	No. of Plots	No. of Allotted Plots	No. of Vacant Plots	No. of Units in Production
1.	Sachin – SMC area	749.35	1557	1553	4	2075
2.	Pandesara – SMC area	218.27	547	545	2	782
3.	Surat Apparel Park – SMC area	54.96	126	124	2	50
4.	Bardoli – Surat District	4.71	45	45	0	67
5.	Ichhapore-Bhatpore Kawas – Surat District	919.84	323	298	25	337
6.	Hazira-Mora – Surat District	428.04	4	4	0	4
7.	Khatodara – SMC area	3.08	43	43	0	142
8.	Olpad – Surat District	31.59	70	70	0	68
9.	Katargam – SMC area	38.33	54	54	0	8

There are 171,918 establishments in the Surat district[61]. Out of the 171,918 registered enterprises, about 93% are micro-enterprises, 6% are small enterprises, and large and medium enterprises are less than 1%. Out of the total enterprises in the Surat district, about 96% are located in the SMC area. The city's distribution pattern also resembles the district, where 99% of enterprises are macro and less than 1% are small, large, and medium enterprises. As per the Surat Urban Development Authority (SUDA) Development Plan 2035, the total manufacturing enterprises established in the SUDA area are 50,180, out of which 49,437 are within SMC limits and the rest 743 in the SUDA ex-SMC area. These details are given in **Table 23.**

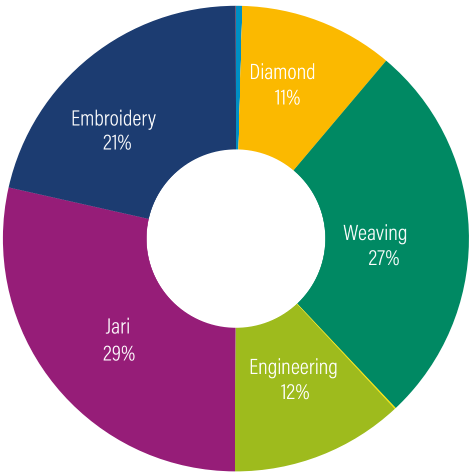
Table 23: Number of enterprises and characteristics for Surat district (Source: MSME Department, 'Brief Industrial Profile of Surat', 2019)

Sr. No.	Particular	Textile Processing	Diamond	Chemicals
1.	No. of Units	40100	10,000	80
2.	No. of People Employee	1165000	400000	30000
3.	Current Investment (INR crore)	1345000	25000	500
4.	Current Annual Turnover (INR crore)	68000	200000	6000
5.	Current Area (in Lac2 meter)	68	45	9

Figure 39 illustrates the distribution of industries in the SMC area by type. It depicts that 77% of the SMC area's total units are textile-based industries, including weaving, jari, embroidery, and processing. In addition, 11% of the industry is engaged in diamond processing, and the remaining 12% are engineering and other industries.

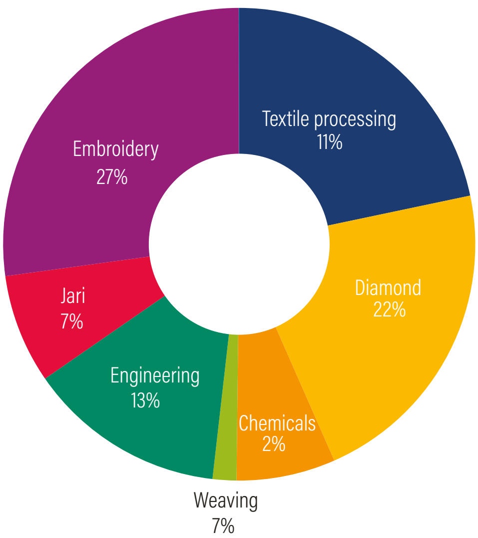
[61] *MSME Profile of Surat District. (2018). https://surat.nic.in/district-industries-centre/.*

Figure 39: Composition of industries as per their main output product in the SMC



As illustrated in **Figure 40,** out of the 1065,193 workers engaged in 165,355 enterprises, about 77% are engaged in micro-enterprises,16% in small-scale enterprises, 5% in large-scale, and only 2% in medium enterprises. It becomes evident that 63% of the total workers are engaged in textile units, including weaving, jari, embroidery, and processing work, 26% workers in the diamond processing industry, 13% in engineering, and the remaining 1% in other types of industries.

Figure 40: Workforce distribution as per the type of industry in the SMC area



6.2.1. Growth Pattern of Industrial Clusters' Operations

The growth of industries in the SMC area showed a steep increase from 1978 to 1995, after which it has been progressing steadily. Industrial land use is almost seven times that of commercial land use in the city. The land use under industrial sectors was increased to 3023.4 hectares in 2004, from 2784 hectares in 1995[61]. Major and medium industrial activities are in the northern and southern parts of the

[62] *Development Plan 2035 SUDA. (2017).*

SMC area, mainly along both sides of the trunk railway line linking the SMC area with Mumbai and Ahmedabad.

GIDC has established ten industrial estates in the Surat district, three big industrial estates, and one each in the north (Katargam), south-west (Katodara), and extreme south (Pandesara), as well as mini-industrial estates for diamond cutting and polishing in the eastern corridor (Nana-Varaccha Road). These are the major industrial establishments in the SMC area, outside the walled city area. The industrial zone in the SMC area is 15 km^2, which is only 5% of the total area of the SMC area. This zone is crammed with several micro, medium, and small enterprises, primarily in textile and diamond processing. However, the zone-wise distribution of industrial land shows that 57% of the industrial land use of SMC is in the south zone of Udhana, followed by 17% in the north zone of Katargam, 14% in the east zone of Varachha, and 10% in the south-west zone of Athawa. The central zone has no industrial land.

6.2.2. Location of Industrial Clusters

Figure 41 shows the industrial areas in the SMC area and the nearby locations. **Figure 42** depicts the ward-wise industry map for the SMC area. As per the land use pattern at the ward level, 26 wards of the SMC area show industrial land use is predominant over other forms.

Figure 41: Industrial clusters distribution – SMC area and SUDA boundary

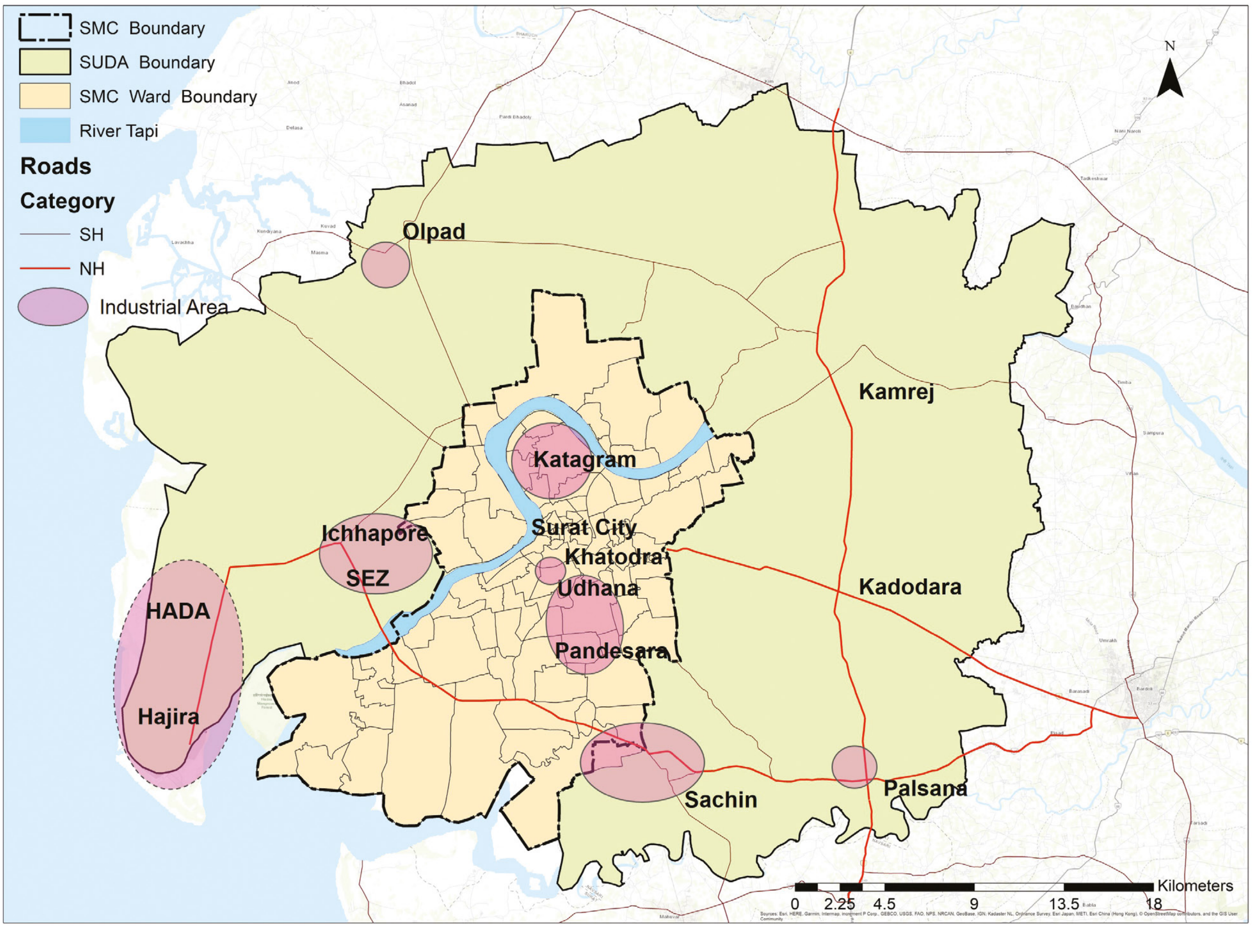
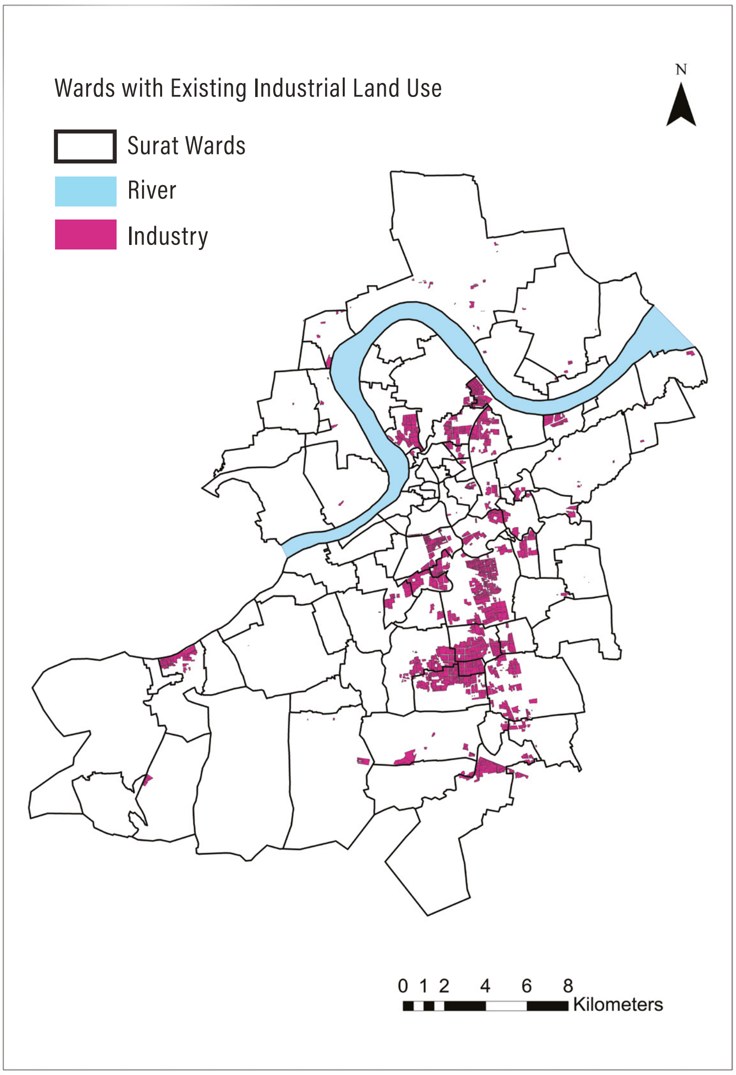


Figure 42: Distribution of industrial units in the SMC area wards



6.3. MAJOR ISSUES RELEVANT TO THE SECTOR

As mentioned in the previous sections, the following significant issues were identified in the primary assessment of the sector:

- The SMC area industries belong to micro, small, and medium enterprises (MSMEs). Most of these are engaged in textile value chain production, textile dyes, and intermediate dye manufacturing, which are required to treat and polish textile products. With such small units agglomerated within the limit and proximity of the SMC area, it becomes difficult to provide solutions involving major retrofitting or relocating plans.
- The Pollution Control Board's existing monitoring mechanism does not address the Air Pollution Control Device (APCD) quality and efficiency to curb pollution, especially for small units.
- Coal and lignite are the primary sources of energy in the industrial units of the SMC area. In addition, the smaller unit boilers in MSMEs are employing wood and bagasse for production. Such solid fuels add to the sector's emissions; thus, it becomes essential that policies and programs that control such emissions must first focus on small and micro-enterprises.

6.4. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

6.4.1. Assessment of Programs and Policies Pertaining to Industrial Operations in the SMC Area's Industrial Cluster

At the national, state, regional, and district levels, several agencies have implemented different programs and policies to mitigate air pollution, improving MSMEs' energy efficiency and market competitiveness by providing financial and technical assistance. **Table 24** provides a selective list of the significant programs implemented in this sector.

Table 24: Details of existing program about industries in the SMC area

Sr. No.	Program	Objectives
1.	GPCB and Abdul Latif Jameel Poverty Action Lab (J-PAL) - Emissions Trading Scheme (ETS)	An ETS, or 'cap-and-trade system, caps the amount of pollution allowed to be emitted from regulated industries and allots permits to plants. The plants that can inexpensively reduce pollution can then earn by selling their permits to other factories. In this way, the system uses the power and flexibility of markets to deliver the win-win of simultaneously: Reducing the total cost of regulation Increasing profits Protecting citizens from air pollution The Surat ETS is projected to: Reduce particulate emissions by 29%, from current levels Lower the costs of reducing particulate emissions Increase average industry profits relative to status quo regulations Increase every industry's gain relative to status quo regulations.
2.	Bureau of Energy Efficiency (BEE) - Small Medium Enterprises (SMEs) program	To improve the energy intensity of the Indian economy by improving the energy efficiency (EE) of the SME sector To accelerate the adoption of EE technologies and practices in 25 SME clusters through knowledge sharing, capacity building, and innovative financing mechanisms. The project was implemented in the Surat textiles cluster as well.
3.	Bureau of Energy Efficiency - World Bank - Small Industries Development Bank of India-Global Environment Facility' Financing Energy Efficiency in MSMEs' project (Phase III)	The Financing Energy Efficiency in MSMEs project aims to increase energy efficiency investments in targeted MSME clusters in India. It builds their capacity to access commercial finance. There are four components in the project: Building of capacity and awareness for energy efficiency Activities to increase investment in energy efficiency Knowledge management Project management support

Sr. No.	Program	Objectives
4.	The United Nations Industrial Development Organization (UNIDO) -Energy Efficiency Services Limited (EESL) - Promoting Market Transformation for Energy Efficiency in Micro, Small and Medium Enterprises	The project aims to promote the implementation of energy efficiency in the MSME sector by: Creating and sustaining a revolving fund mechanism to ensure the replication of energy efficiency measures in the sector and Addressing the barriers identified for scaling up energy efficiency measures and promoting a cleaner and more competitive MSME industry in India. The Surat textiles cluster is a part of the project.

6.4.2. Challenges

- While many industries from the SMC area express enthusiasm for the projects mentioned earlier (or similar projects), their interest fades as these interventions fail to deliver their targets. In addition, these industries have to incur the costs of retrofitting the technologies needed to implement the interventions. It becomes challenging to convince the industries association that these interventions have long-term benefits and eventually produce monetary gains.
- Most of the industrial clusters fall within the double jurisdiction of Gujarat Industrial Development Corporation (GIDC) and SMC, and their resource allocations and monitoring lie with the GIDC. GPCB is the agency responsible for pollution control monitoring. The separate operation mandate of controlling agencies prevents the industries association from opting for any non-conventional fuel-based intervention.
- APCDs are crucial for all industrial units in the SMC area to limit their emissions. However, the assessment of 447 industrial units (representative sample obtained from GPCB, Regional Office, Surat) revealed that despite having APCDs installed in their units, most of the MSMEs fail to calibrate the devices at regular intervals and do not get quality checks done owing to the lack of human resources and technical capacity. This causes a major gap in controlling industrial unit emissions at the source.

6.4.3. Opportunities

WRI India conducted two major workshops as part of the SCAP project, which focused on industrial sector emissions and their related interventions. Following was some of the positive aspects wherein more work can be progressed,

- Despite policies and programs focusing on the energy efficiency of textile processing units, as mentioned in **Table 24**, interventions have failed to locate a common operational ground through which energy efficiency and pollution control objectives can be achieved. Having an upgraded database that will be linked with the online portals owned by GPCB (Xgen) and ETS (JPAL+GPCB) for providing information on the quality of APCD devices along with their regular calibration and monitoring checks will help in framing short or medium-term interventions when industrial pollution becomes a challenge for the city.
- Agencies such as Gujarat Energy Development Agency (GEDA), in collaboration with GIDC and industries' associations, can better monitor non-conventional fuel for industrial production. Even

for standby consumption, energy production options such as rooftop solar can be considered as this would significantly reduce the load on conventional fuel supply.

- Apart from the day-to-day operations, the industrial unit owners have inadequate information on replacing fuel, non-conventional fuel options, energy efficiency measures, and other pollution control aspects. This is a major reason for not opting for such interventions, apart from the longevity of projects and monetary benefits. A significant amount of research is required to prepare IEC campaigns targeting industrial unit owners. These campaigns can run regularly for long periods with support from GEDA, GIDC, and industries' associations.

6.5. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

Under the air quality improvement program, the GPCB has recommended various policies and programs to mitigate industrial emissions from the SMC area's industrial clusters. These policies and programs are listed in **Table 25**.

Table 25: GPCB suggested measures – As per Air Quality Improvement Plan (Source: Surat – Air Pollution Control Action Plan, https://cpcb.nic.in/Actionplan/Surat.pdf)

Sr. No.	Action Points	Implementation Status
1.	Identification of brick kilns and their regular monitoring in brick kilns, including use of designated fuel and closure of unauthorized units	As per the air quality improvement plan, currently, there are no functional brick kilns in the SMC area. These are operating in the rural periphery of the SUDA boundary regularly monitored by GPCB.
2.	Conversion of natural draft brick kilns to induced draft	As indicated in the previous point, no brick kilns are functioning in the SMC area. Monitoring is being conducted for fuel consumption and authorization by GPCB in the outer rural periphery of the SUDA boundary.
3.	Ensuring installation and operation of air control devices in the polluting industries	For this short-term activity, the following actions are indicated in the air quality improvement plan of GPCB: Textile industries, after taking consent from GPCB, have installed APCD devices in their processing units. For these installed APCDs, monitoring is being done as per the prescribed format, and the frequency of checks/inspections is as per the regular activity calendar. As referred to in **Table 24**, the ETS has been initiated in a phased manner. The primary requirement is to have a Continuous Emission Monitoring System (CEMS) through which information on generated emissions is collected in centralized servers. The textile processing units have installed the Auto Fuel Firing System, especially in Pandesara, Katargaam, and Sachin areas. This system would reduce emissions since no manual solid fuel-driven firing is required. There will also be lesser chances of personal exposure. In 2020, GPCB ordered the closure of 21 industries under the Air (Prevention and Control of Pollution) Act, 1981.

6.6. CONTROL MEASURES IDENTIFIED DURING OPPORTUNTIY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

WRI India conducted a target approach workshop on November 5, 2020, wherein a virtual platform was used to reach out to industry experts. The major stakeholders included Pandesara Industries Association, Palsana Industries Association, Sachin Industries Associations, South Gujarat Textile Processors Association, and SteamHouse Pvt. Ltd, who expressed their views on the efficacy of the proposed strategies. The participants also included GEDA, Gandhinagar, GERMI, Gandhinagar, the SMC, GPCB regional, and head offices. During the workshop, the emission mitigation policies formed based on primary data collected from various stakeholders and an assessment for source apportionment were presented. The stakeholders identified the following control measures:

- The quality of APCDs poses a major challenge that the industrial units in the SMC area need to improve. Despite many industries having installed APCDs in their units, there is no mechanism by which the emission capture can be prolonged through periodic reinstallations and retrofitting.
- The industries' associations in the SMC area expressed an interest in integrating concepts such as the circular economy and waste to energy for powering their industrial units; however, only a few of such cases exist because of which the authorities are not taking any action to provide alternate sources of energy to the MSME sector, specifically those that can drastically reduce emissions from the sector.
- There is a lack of coordination between implementing the policy that focuses on energy efficiency in the MSME sector and the pollution control projects. Efforts need to be made to improve this niche area if stakeholders are to be brought on a single platform to regulate sectoral emissions.

6.7. STRATEGIES TO MITIGATE AIR POLLUTION

As indicated in the air pollution emissions inventory and source apportionment analysis, industries are one of the major contributors to air pollution in the SMC area. We identified interventions and proposed strategies for short, medium, and long-term actions to mitigate air pollution from the industrial cluster of the SMC area.

6.7.1. Ensuring Installation and Operation of Air Pollution Control Devices and Retrofitting of APCDs

APCDs are the technologies and systems used to regulate and eliminate air pollution, including particulate matter and gas emissions from various industrial activities. Air pollution control technologies and systems include scrubbers, air filters, electrostatic precipitators, cyclones, mist collectors, incinerators, catalytic reactors, biofilters, etc. The majority of industries located in the SMC area use APCD. However, many of the APCDs may be malfunctioning or performing inefficiently. APCDs require regular maintenance and inspection for safeguarding their efficiency and life span. For this, skilled professionals are required. Stringent norms must be in place in all industries to hire a professional for the maintenance of APCDs. Industries must send their APCD performance report to the GPCB with geographically coordinated enabled pictures or videos regularly. GPCB or other regulatory authorities must regularly cross-check the data performance of APCD to ensure these are functioning properly.

To ensure the installation and operation of APCDs, there should be a provision for obtaining sample measurements, such as having sample and velocity ports and pressure taps built into the equipment. For example, a regular check of pressure drop across the control unit, system pressure, and liquid and gas flow rates are minimal necessities for ensuring proper control equipment operation. During the APCD installation and startup, it is important that all the baseline data on the APCD are recorded. The startup data can compare the regular pressure drops and current draws to help troubleshoot the industries and GPCB.

As per the interactions with the GPCB, many APCDs installed in industries are either outdated and require regular maintenance. Retrofitting certain APCDs according to their characteristics can improve their efficiency. Norms should be in place for retrofitting certain APCDs after checking their efficiency as per the prescribed method. Each APCD must be tested as per the prescribed International Organization for Standardization (ISO) method at a recognized laboratory by CPCB and equipped with suitable retrofitting technologies. GPCB should identify and develop a list of industrial sources, APCDs, and retrofitting technologies to implement pollution reduction programs in different phases. For example, in 2020, under the NCAP, many state pollution control boards issued notices to retrofit the APCDs of all operational DG sets with 125 kVA and higher capacity. A similar strategy can be applied to other industrial air pollution sources in the SMC area after identifying retrofitting possibilities in APCD. To better understand the current APCD coverage, efficiency, maintenance status, and retrofitting possibilities, there is a need for regulatory agencies such as GPCB and CPCB to conduct a detailed study.

Time duration anticipated: Research and assessment can be initiated in 2021; implementation can be undertaken in 2022. The targeted coverage for retrofitting the existing APCDs in the SMC area's industrial clusters would be 2022-23.

Responsible agencies: GPCB, CPCB, Industrial Association of Surat, any technical education or research institute in the region, retrofitting manufacturing agencies, APCD manufacturing agencies.

6.7.2. Improvement and Monitoring of Energy Efficiency

Several industries in the SMC area are exclusively using conventional fuel and excessive energy, resulting from economic and technical capacity constraints. This is responsible for air pollution and other associated problems. There is a need to develop and promote an ecosystem for industries located in the SMC area to enhance energy and resource efficiency. The energy-intensive industries (both large and MSME clusters) must be the first target of this action. For each industrial unit, there should be norms for resource and energy audits every year. This audit will allow authorities to understand the current energy use, the possibilities of energy-efficient interventions, and the requirement of capacity enhancement in industries for maintaining efficient energy use. The audit study should report the efficiency improvement and monitor the adoption of new technologies and equipment, energy-saving, and emission reduction. The implementation of energy and resource conservation evaluation should be followed strictly. Currently, there are no policy or inspection programs that monitor the loss of energy-efficient resources. Having an authorized check on the industrial clusters' energy-efficient resources will enhance the performance of various industrial units.

Time duration anticipated: An energy efficiency improvement and monitoring program can be introduced in the next phase of production in 2021 as many industries are generating low output due to the

COVID-19 pandemic. The program can be implemented initially for five years. At the end of each year, an analysis of program performance should occur, based on which strategies should be developed for the following year. An independent agency can provide supporting research to the regulatory agency.

Responsible agencies: GPCB Industrial Association of Surat, GEDA, Bureau of Energy Efficiency

Handholding to be provided by: GPCB Regional Office and GEDA can develop the database for industries, energy use, efficiency, opportunities, and challenges. In addition, for the small and medium units, the local and regional institutes can develop capacity-building programs for improving energy efficiency and the technical capacity of industries.

6.7.3. Accelerate Technology Transformation for Automation/Digitization in MSMEs

Energy accounts for a significant share of the total input costs for energy-intensive industries such as textiles, chemicals, and dyes. The MSMEs largely operate with inefficient equipment, old technology, and an unskilled workforce, leading to wastage of energy, higher production costs, low productivity, and higher emissions of pollutants. The decision-makers in MSME have always been reluctant to adopt energy efficiency initiatives as they would have to make high initial investments. Awareness of the life cycle cost analysis of new technologies and their associated benefits in energy and productivity improvement needs to be built. The industries need to be strengthened through international exchange of knowledge, cooperation on advanced air pollution control technologies, and productivity improvement experiences. GPCB, GIDC, the Department of Industries, and the SMC should organize international conferences, seminars/webinars, and roadmap clusters for technology infusion, best practices, and capacity building.

Large industries have sophisticated equipment for monitoring and analyzing energy and resource consumption; SMEs also need to become more agile and bolder in monitoring their consumption and production. The myths around automation need to be busted to advocate ***Industry 4.0*** - a fourth industrial revolution and promote the digital transformation of manufacturing/production and value creation processes. The industries can begin with simple automation that can revolutionize current practices and improve productivity by automating processes and consumption.

Time duration anticipated: On a roll-out basis, background implementation can be initiated as early as 2022, including research and capacity building module implementation for the MSMEs. Existing schemes indicating energy efficiency module internalization for the textile units can be explored for extensions that would address air pollution control from the specific lot. Similar extensions and stricter monitoring protocols can be implemented through sectoral chemical, engineering, and MSME schemes.

Responsible agencies: Industries Associations of Surat and Gujarat, GPCB, GEDA, Gandhinagar, BEE, Ministry of MSME, Ministry of Textiles can be approached to internalize stricter monitoring extension programs. In addition, the State Government of Gujarat's regulations can be applied through their Skill Development Programme and Livelihood Promotion amalgamations which are already existing.

Handholding to be provided by: GPCB Regional Office and GEDA, Gandhinagar, can provide scope for developing pilot projects wherein an energy efficiency research database can be created.

In addition, more spaces for effective strategic collaborations can be explored with the Government of Gujarat-owned companies such as Gujarat Livelihood Promotion Company.

6.7.4. Revisiting the Norms for New Installations

Authorities can initiate strict norms for new high energy consuming and high polluting industries in the SMC area. The requirements of high energy-consuming, high-polluting, and resource-intensive industries should clearly define the energy and resource-saving and pollution emission indicators and encourage clean and renewable energy sources for production. Regulators could make industry entrance requirements stricter by standardizing the Consent to Operate (CTO) format to include important information (i.e., industries' production capacity, fuels consumed, combustion equipment installed and its capacity, and APCDs installed) in a structured manner. Industries should be encouraged to receive the Environment Management System certification. With tough competition and export-oriented businesses, sustainable practices would be an advantage for the MSME to market their products abroad.

Time duration anticipated: The new installations shall be covered in five years, starting from 2021. By the time more industries enroll, new rules and regulations can be amended in Gujarat state's existing energy efficiency rules through GEDA and GERMI. GIDC can be responsible for issuing new listings based on the current energy efficiency and pollution control norms. The entire process is expected to be completed in 7- 10 years.

Responsible agencies: GPCB along with GEDA and Industries Associations of Surat.

Handholding to be provided by: State Government of Gujarat will be allowing timely revisions in their MSME and GIDC policies.

6.7.5. Promoting Co-Generation through Monitoring of Small Boilers

There are high fractions of baby/small boilers (with capacity < 2 TPH) installed in the SMC area's industrial cluster, and many baby boilers were used in small-sized textile industries. The air pollution emission conditions for such boilers (1200 mg/nm^3) are quite relaxed compared to the norms for big boilers installed in the organized sector, thereby providing a considerable margin for such industries to pollute the environment. Moreover, installing a Continuous Emissions Monitoring System (CEMS) on such small boilers is not economical for the industries. Therefore, it is necessary to explore other monitoring options which are economically feasible to the medium and small industries where these boilers are installed. Proper guidelines should be available to monitor the emissions from these boilers.

The anticipated primary solution for the ease of operations with the least air pollution and improved energy efficiency loss has a community co-generation system through which heat (in the form of steam) can be supplied to member industries. This option, which is already in implementation, would benefit the whole monitoring process. Introducing sustainable fuel options for heat generation would suffice to have less pollution and achieve a circular economy of heat generation for small boilers owning industrial units in Surat industrial cluster.

Time duration anticipated: Implementation or research-based monitoring module preparation can be initiated as early as 2021 and completed by 2024 end of the year.

Responsible agency: With no hierarchy, GPCB along with Directorate of Boilers (Labor and Employment Department) and Industries Associations of Surat.

Handholding to be provided by: State Government of Gujarat for allowing speedy adjustments in boiler inspection, energy efficiency, and subjective retrofitting norms for a particular category of boilers. In addition, GPCB can coordinate the implementation of projects wherein baby boilers can be studied and a specific monitoring mechanism can be developed.

6.7.6. Carrying Capacity Assessment

To effectively utilize the city boundary's natural resources, a research study could be carried out to understand the city's carrying capacity to understand the threshold number of industrial units within the SMC area with respect to their contribution to the city's air pollution. Such an assessment would also help build an understanding of how the city can accommodate different industries. The reason being an operational limit can expand industrial clusters within the city or urban development limits, which can be addressed through the assessment study. The energy efficiency, circular economy, and reduction of air pollution principles will be the core pillars for this assessment conducted every five years in the purview of environmental impact assessment norms.

Time duration anticipated: The impact assessment, which will be a part of a five-year project, can be conducted in three phases – baseline, midterm, and end line, with action research and updates in monitoring mechanisms by the SMC and GPCB. The final assessment for 2021-2025 will include suggestions on updating the policies and programs affecting the growth of industries within the city limits. In addition, the Gujarat Forest Department's district office can be involved in developing green patches in newly developed areas and suggesting cost-effective adaptation measures.

Responsible agencies: SMC and GPCB will be primarily responsible, while SUDA will be responsible for the growth pattern monitoring in expanding city limits.

Handholding to be provided by: Industries' Associations and the State Government of Gujarat will be involved in the proposed policies and program-level changes. These updates will be suggested following the carrying capacity assessment study.

6.7.7. Capacity Building Modules

There is a need to improve the capacity of industries for potential energy and cost-saving through technologies, management, and skill-building. The training module will target issues such as optimizing boilers efficiencies, inspection and maintenance of pollution control technologies, energy efficiency opportunities, and retrofitting/upgrading APCDs. The MSME sector lacks awareness in identifying, selecting, and installing suitable APCDs and optimizing their use to ensure maximum efficiency and productivity. Relevant training would enable MSMEs to choose suitable and cost-effective APCDs and install and use these correctly, thus producing the desired results. The training program focusing on the operation and maintenance of furnaces and boilers should include a broad overview of boilers, thermo-pack, and boilers. It should also include a module on the boiler combustion process and overall boiler/furnace efficiency. The program should focus on an intelligent mix of measures to reduce energy consumption, lower air pollution control costs, and lower PM and other emissions.

Time duration anticipated: This action should be implemented for three years, starting from 2021, and the process to select industries should be continuous.

Responsible agencies: GPCB, Industries' Associations of Surat, and GEDA (Gandhinagar)

6.7.8. Shifting towards Alternative Fuel – Long Term Action[63]

The analysis of fuel usage patterns in the industrial clusters of the SMC area indicates that coal, lignite, wood, and furnace oil are the primary fuels used by industries, which contribute to the high SO_2, CO, $PM_{10,}$ and $PM_{2.5}$ emissions. Cheaper costs and availability of these fuels are responsible for using these fuels in the SMC area. High cost and inadequate supply of clean fuel such as natural gas are reasons for the non-usage of clean fuels. Responsible agencies and industry associations need to support an ecosystem for cleaner fuels. Once the ecosystem for alternate fuels is ready, a phase-out of polluting fuels should be carried out.

The industrial areas in the SMC area have access to natural gas due to the existing supply infrastructure. However, owing to the cost of shifting from conventional fuel to natural gas, industries are unwilling to switch to natural gas. As per the cost dynamics of different fuels vis-à-vis the steam generation, coal is cost-effective compared with natural gas, LDO, and HSD.

Market research is also needed for alternate fuels, such as bagasse and briquettes from biomass. This could pilot in a few industries, with support from the government and industry associations, and the impact could be studied following 12-25 years of continuous use of these fuels.

Time duration anticipated: 12 to 25 years

Responsible agencies: Industries' associations, GPCB, GEDA, Ministry of MSME, and Ministry of Textiles can be approached to internalize stricter monitoring extension programs. In addition, the state government's Skill Development Program and Livelihood Promotion can help industries develop their technical capacities.

6.7.9. Increase Efforts in Comprehensive Control of Small Size Boilers – LTA

Currently, most of the small industries have individual low-capacity boilers installed for steam generation. The coal-fired, firewood and other polluting fuel-based boilers have a size less than 20 tons per hour (TPH) and should be phased out from the SMC area. The aggregated steam needs of smaller industries can be replaced with a centralized system using cleaner fuels, such as natural gas and electricity.

[63] *Long Term Actions– Projects and Propositions which would take a cohort of time for retrofitting or updating, would be tagged as LTA and Responsible Agency or Handholding Support Agency won't be displayed as project implementation cannot be predicted along with multiple stakeholders' involvement. In addition to this, a significant physical and policy level infrastructure will be mobilized, thus making these interventions more coercive to predict actual involvements.*

The opportunity to install a centralized steam generation system should involve private and public sector organizations. This will help improve the efficiency of the system and indirectly reduce fuel consumption in industrial areas. It would also make monitoring a few centralized steam generation units much easier than many baby boilers in small industries.

Time duration anticipated: 10 to 20 years

Responsible agency: Industries' associations, GPCB, GEDA, Ministry of MSME

6.7.10. Provide Financial and Technical Support to Reduce Emissions – LTA

The main barrier in introducing new safe and clean technologies is financial constraints, as the management is hesitant to invest capital. As most MSMEs have a modest annual turnover, significant financial constraints discourage firms from adopting clean technologies. In addition, there is a lack of awareness regarding credit schemes for the MSME sector, and most units rely on self-finance. Thus, there is a need to connect MSMEs to state and union governments' credit schemes.

Time duration anticipated: 10 to 20 years

Responsible agency: Industries Associations, GPCB, GEDA, Ministry of MSME

6.7.11. Target to Reduce and Control Emission from Industry – LTA

The pollution emitted by industries should be treated at the source. This would be in accordance with the environmental regulation requirements, strengthen internal management, increase capital investment, utilize advanced production and management technologies, and ensure that emissions remain within limits. The industries shall conscientiously fulfill their social responsibility of environmental protection and accept supervision from society.

Time duration anticipated: 10 to 15 years

Responsible agency: Industries Associations, GPCB, GEDA, Ministry of MSME

6.7.12. Relocating Air Polluting Industries – LTA

In many industrial areas, such as Pandesara and Katargam, residential areas are in close vicinity of the industries, making the residents there prone to various health risks resulting from air pollution. These residential colonies are home to the labor force of industries and cost the residents their health. This study recommends that all the red category polluting industries be moved out of the SMC area. The development agencies and urban planning departments should properly coordinate to demarcate industrial and residential areas and develop remedial measures or buffer zones to protect the residential population from industrial air pollution. Proper land-use planning should be done for upcoming industrial areas and the expansion of the existing ones.

Time duration anticipated: 12 to 25 years

Responsible agency: Industries' associations, GPCB, GEDA, Ministry of MSME, and Ministry of Textiles can be approached to internalize stricter monitoring extension programs. In addition, the State Government's Skill Development Program and Livelihood Promotion can help industries develop their technical capacities.

6.8. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

The micro-level plans are area-specific mitigation measures that have been populated based on primary and secondary assessments of the industries sector. As many industries are cluster-specific, it is essential to compartmentalize existing and proposed mechanisms for emissions reductions per the influence areas across the SMC area to channel efforts in an improved manner.

6.8.1. Current Micro-Level Plan by GPCB

- To intensify the monitoring of industries for reducing emissions, GPCB has been taking action against non-complying industrial units. These actions often include shifting the usage to cleaner fuels, banning the usage of the fuels causing pollution, regulation, and monitoring through random auditing for APCDs, and an online reporting system in the industries. Two examples are CEPI Index, which used the data collected through the XGN portal, and ETS, which is implemented in partnership with industry associations. Information is collected on the CEMS portal.
- GPCB has been ensuring the installation of APCDs in all industrial units and has been able to take steps such as conversion to side-hood suction in furnaces, promoting cleaner production practices, fugitive emission control, and action/closure against defaulting/unauthorized industrial units. In 2020-21 non-complying industrial units in the SMC area were advised closure based on the applicable criteria.
- The ETS project has allowed GPCB to provide a plant-wise inventory of vents and ensured that it is routed to a vapor recovery system followed by a flare system, wherever applicable. In addition, in a recent notification to the industrial units situated in Pandesara, Udhana, and Sachin, GPCB suggested the implementation/adoption of Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).
- The GPCB advocates for a special training module on 'fugitive emissions and their health impacts on individuals and surrounding communities for its staff, operating personnel, and drivers to spread awareness of the risks/hazards associated with spills and leaks of various chemicals.
- The GPCB will prepare and implement the local area action plan for pollution hot spots and strictly enforce air pollution control measures in all industries, including those located in unauthorized areas. In addition, for non-complying industrial units, either the owner will prepare a unit/plant-wise action plan for time-bound compliance, or these will be shut down.
- The GPCB has collaborated with third-party think tanks and expert agencies to carry out pollution load estimation from the industrial sector to set targets for emission. South Gujarat Textile Processors' Association has effectively piloted such a database through their industrial units.
- The GPCB has ensured that the maximum number of industries are placed in a category wherein it is mandatory to use clean fuel. The GPCB has issued notices to those units found using wood, coal, furnace oil, and pet-coke kind of fuels in their regular checks.

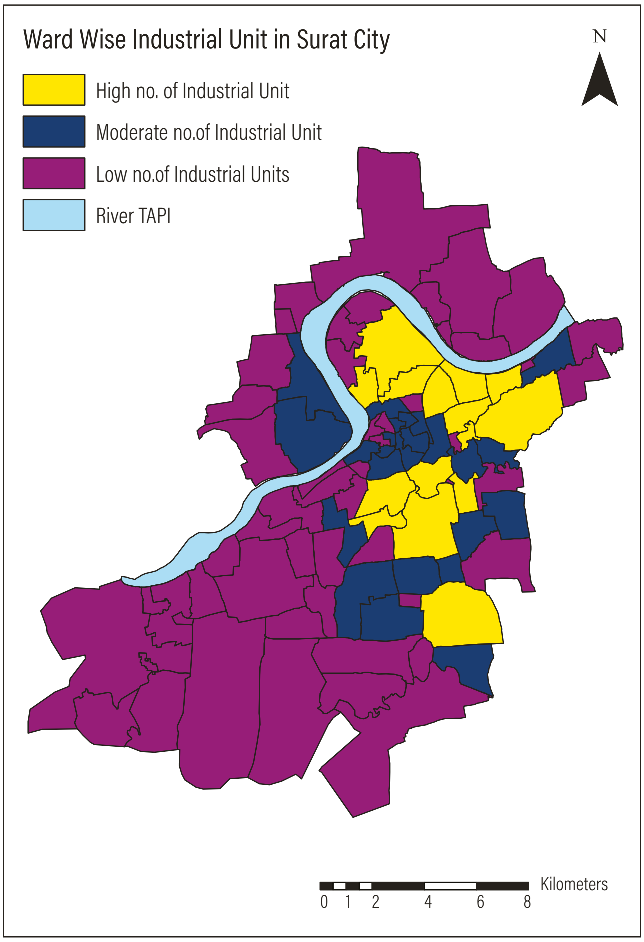
- The GPCB has ensured control of fugitive emissions in industries (especially steel, power plants, and engineering units) wherein the authority has been able to direct industrial units in Hazira, Pandesara, Sachin, and Udhana for installing covering hoods of inert material for processes such as charging, loading, unloading, and conveyor transfer. This has resulted in a reduction in indoor air pollution and personal exposure reductions in the microenvironment. In addition, many such units have also been directed to develop buffer zones, and industry associations have been advised to procure fogging machines to capture pollution during peak hours of production.
- In their effort to collaborate on adaptation-based options, the GPCB has been able to target excessive DG sets in industrial units by ensuring a continuous electricity supply. Rooftop solar programs have been leveraged in industrial units for clean energy. For this, industry associations such as Sachin, Palsana, and Pandesara have been engaged wherein GEDA is providing expertise. GPCB is also working out the waste-to-energy option in collaboration with NTPC and SMC at the Hazira industrial estate. A detailed outreach program by GPCB has been launched to promote renewable energy options in industries in the SMC area.

6.8.2. Micro-Level Plan Recommendation

After examining GPCB's recommendations in the industrial pollution control micro plans, we analyzed various datasets and designed the following micro-level air pollution mitigation plan (**Figure 43**):

- The clean air action plans and micro-plans of GPCB and WRI India should target municipal wards, such as Udhana, Pandesara, Ved Road, Bhestan, Sachin, and Katargaam, which have a heavy aggregation of medium and small industries and use coal and wood for firing up their processing vessels.
- Udhana, Pandesara, Ved Road, Bhestan, Sachin, and Katargaam municipal wards are located on major routes. The national highway is close to Sachin, making residents more vulnerable to higher industrial and transportation air pollution exposure. Therefore, targeting these wards will lead to multiple benefits.
- The fuel alteration scenario will help wards that are yet to accommodate more units since wards such as Unn, Adajan, Bhimrad, Sarsana, and Amroli-Utran have better road access, lesser population density, and lesser industrial unit density. This is important for developing non-conventional fuel infrastructure since interventions such as community boilers and processing vessels monitoring equipment installations would need an amalgamation of space–finance–behavior aspects. Thus, it would be better to implement a pilot project that focuses on fuel alterations in the newly developing sites.
- In addition to the above points, increasing the green cover in the areas surrounding the influence areas mentioned earlier will be essential, especially in the wards where more space is available. As indicated in the assessment, wood continues to be a major industrial fuel. In recent years, there has been a reduction in the green cover in the surrounding areas due to the illegal felling of trees for industrial and commercial burning. Increasing the green cover would lead to sequestration in the hot spots.

Figure 43: Micro level plan – Industries sector



6.9. TECHNO-ECONOMIC ANALYSIS

Techno-economic assessment (TEA) is a framework used to analyse the economic and technical performance of a process, service, or product. A technical feasibility assessment analyzes the effectiveness of a particular technology. In contrast, an economic feasibility assessment analyzes the cost incurred (capital, operational, maintenance, salvage value, etc.) and the benefits achieved in the form of lives saved by better air quality[64]. The attributed costs are for the longer time duration mitigation actions to curb the industrial emissions in each cluster situated within the SMC area.

6.9.1. Implementation Cost for Proposed Policies and Programs

The costs mentioned in **Table 26** are for the direct and indirect financial allocations proposed to implement the short – medium – long term strategies. Mostly these costs are for the types of technical retrofitting, installations, capacity building, and advocacy activities associated with each mitigation step. The cost assessment is applicable for the SMC area, and the costs could be higher if the industries situated in the SUDA boundary are included.

[64] *CSTEP. (2018). Comprehensive clean air action for the city of Patna. https://www.cstep.in/publications-details.php?id=861.*

Table 26: Economic implications of proposed policies and programs

<table>
<tr><th>Sr. No.</th><th>Proposed Policy or Criteria</th><th>Implementation Time</th><th>Responsible Agency/Stakeholder</th><th>DC – (INR crore)</th><th>IDC (INR crore)</th></tr>
<tr><td>1.</td><td>Ensuring installations, operations, and retrofitting of APCDs</td><td>2021-2023</td><td>Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC</td><td>1</td><td>0.5</td></tr>
<tr><td colspan="6">Remark: APCD installations will require thorough advocacy with the industry associations. The retrofitting tasks, too, will have to be approved by the state government. The direct cost would include primary research, advocacy tasks, stakeholders' consultations, and 25% coverage to address non-attaining industrial units in the first year, i.e., 2021-2022. The second-year will include more capacity-building tasks. The indirect costs would be borne as a part of the maintenance of the newly installed APCDs.</td></tr>
<tr><td>2.</td><td>Energy efficiency improvement and monitoring</td><td>2021-2024</td><td>Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC</td><td>1.75</td><td>0.75</td></tr>
<tr><td colspan="6">Remark: This mitigation action will depend on the energy efficiency measure promoted as an alternative to the conventional fuel system, which has already been embedded in the SMC area industrial clusters. As per the micro-area planning and existing policies mentioned in Tables 24 and 25, the audit will take up a considerable chunk of financial provisions to understand the shift and other requirements in the first three years. In addition, the physical installations, research, and impact assessment (interim at 2.5 years if five years have been taken as the project period) will be added to the direct cost. The physical installations (meters, motors, and engineering control devices) will incur maintenance costs, which will be added to indirect costing.</td></tr>
<tr><td>3.</td><td>Accelerate technology transformation for automation/ digitization in MSMEs</td><td>2021-2024</td><td>Industries' Associations, GIDC, GPCB, GEDA, GERMI</td><td>2.35</td><td>1.1</td></tr>
<tr><td colspan="6">Remark: This mitigation action will involve stakeholders' networking and advocacy to promote failsafe automation in the industry as an option to reduce pollution by involving the least human interventions. The direct costing will involve industrial unit level advocacy tasks and training and capacity building tasks needed at the ULB and ministry levels, wherein internalization with the existing schemes will be considered. The indirect cost will involve any physical installation or retrofitting (structure or engineering controls) and maintenance.</td></tr>
<tr><td>4.</td><td>Revisiting the norms for new installations</td><td>2021-2030</td><td>Industries' Associations, GIDC, GPCB, GEDA, SMC</td><td>3.10 (for 1st 4 years)

5.85 (for 2nd 4 years)</td><td>1.25 (for 1st 4 years)

2.37 (for 2nd 4 years)</td></tr>
<tr><td colspan="6">Remark: This mitigation action will involve strict advocacy, stakeholders' networking, and implementation work at the ULB and state levels. As per the technology transfer principles discussed in the previous point, new installations in the industrial units will be monitored strictly. The direct costing will involve industrial unit level advocacy tasks and training and capacity building tasks needed at the ULB and state levels. These are important to bring in the actualization of air pollution mitigation principles in action by monitoring the new installations (processing equipment, APCDs, and other technical criteria required with the processes responsible for the air pollution) wherein internalization with the existing schemes will be taken into account as well. The indirect cost will involve any physical installation or retrofitting (structure or engineering controls) and maintenance.</td></tr>
<tr><td>5.</td><td>Promoting co-generation through monitoring of small boilers</td><td>2021-2025</td><td>Industries' Associations, GIDC, GPCB, GEDA, District Administration, Directorate of Boilers</td><td>40</td><td>5</td></tr>
<tr><td colspan="6">Remark: There are various industries in SMC area clusters that are dependent upon small capacity boilers. As explained in Section 6.7, many of these small energy generation units are not accounted for, especially with respect to the fuel they are using. A new co-generation unit will ensure that all small boilers are profiled thoroughly and then considered for establishing a standard steam generation unit. The direct cost indicated here is for establishing and initial operation of the co-generation unit in a single SMC area industrial cluster. The additional indirect cost will be spent on the associated capacity building and advocacy tasks and maintenance of the anticipated co-generation unit for the mentioned period of five years.</td></tr>
<tr><td>6.</td><td>Carrying capacity assessment</td><td>2021-2024</td><td>Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC</td><td>1.25</td><td>0.75</td></tr>
<tr><td colspan="6">Remark: The SMC area city limits harbor many MSMEs due to their involvement in diamond and textile processing and enterprising. This leads to additional pressure on the 'city's resources,' including clean air. A carrying capacity assessment as an action research study will evaluate the SMC area's limitations in harboring additional industrial units. The direct cost of this five-year study will include stringent capacity building, monitoring, and advocacy work, wherein the indirect cost will include installation, retrofitting, and maintenance of any engineering control or monitoring chain for the validation of qualitative data.</td></tr>
</table>

<table>
<tr><th>Sr. No.</th><th>Proposed Policy or Criteria</th><th>Implementation Time</th><th>Responsible Agency/Stakeholder</th><th>DC - (INR crore)</th><th>IDC (INR crore)</th></tr>
<tr><td>7.</td><td>Implementing capacity building module</td><td>2021-2023</td><td>Industries' Associations, GIDC, GPCB, GEDA, GERMI, SMC</td><td>3</td><td>1.15</td></tr>
<tr><td colspan="6">Remark: Capacity building for the various components, as explained in Section 6.7, would cover all the industrial clusters situated in the SMC area. The direct cost will cover all the logistics, advocacy, and networking tasks, wherein the indirect costs will cover the maintenance of physical installations such as APCDs and energy efficiency monitoring tools.</td></tr>
<tr><td>8.</td><td>Shifting towards alternative fuel</td><td>2022-2030</td><td>Industries' Associations, GIDC, GPCB, GEDA, District Administration</td><td>5.75 (for 1st six years)

2.28 (for 2nd three years)</td><td>2.38 (for 1st six years)

0.75 (for 2nd three years)</td></tr>
<tr><td colspan="6">Remark: The long-term actions (mentioned in Section 6.7) are longer time duration mitigation actions that will work after the results achieved through the seven actions listed earlier in this table. Non-conventional energy efficiency measures would need time to come into effect. To popularize the same for any industrial unit will be arduous for the authorities and technical handholding agencies. Beginning 2022, for the next nine years, activities including action research, extension implementation studies, policy internalization, expansion of implementation projects, pilot modules/projects, and capacity building events (IEC included) will take place for which the direct cost will be spent. The indirect cost will cover the tasks of the physical maintenance (installation, retrofitting, relocation, and rebuilding).</td></tr>
<tr><td>9.</td><td>Increase efforts in comprehensive control of small-size boilers.</td><td>2022-2028</td><td>Industries Associations, GIDC, GPCB, GEDA, District Administration, Directorate of Boilers</td><td>2</td><td>1.35</td></tr>
<tr><td colspan="6">Remarks: Considering the success of the common steam generation pilot facility in the SMC area's industrial cluster, as explained in Section 6.7, all other industrial clusters will be explored to install common steam generation facilities. The direct cost mentioned above will be spent on capacity building and advocacy tasks. At least three other industrial clusters will have common steam generation facilities, nullifying small boilers responsible for the heavier air emissions from MSMEs.</td></tr>
<tr><td>10.</td><td>Provide financial and technical support to reduce emissions</td><td>2022-2030</td><td>Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, Transport Department and SSCDL</td><td>37 (for 1st five years)

29 (for 2nd five years)</td><td>13 (for 1st five years)

8 (for 2nd five years)</td></tr>
<tr><td colspan="6">Remarks: This particular mitigation action will solely depend upon the advocacy and stakeholder' networking wherein the MSMEs will be connected with the Central and state governments' financial subsidy schemes. The cost will be spent connecting each industry willing to establish itself, from scratch, as an energy-efficient unit or retrofitting its plant operations to shift from conventional to non-conventional fuel for production. Since MSMEs have a massive chunk in the SMC area's industrial clusters, the financial provision for the mitigation actions listed in Section 6.7 would be higher.</td></tr>
<tr><td>11.</td><td>Target to reduce and control emissions from industry</td><td>2022-2030</td><td>Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, Transport Department and SSCDL</td><td>22 (for 1st five years)

22 (for 2nd five years)</td><td>6 (for 1st five years)

6 (for 2nd-five years)</td></tr>
<tr><td colspan="6">Remarks: The APCDs are one type of engineering control wherein the processing vessel is provided with an adequate emission mitigation unit. However, several other point sources would add up to the final stack emissions/ambient air emissions. Considering this, every unit will have to have an EHS policy, with a clear distinction of administrative and engineering controls listed. These measures would target reducing air emissions and improving operations, occupational health scenarios, and CSR aspects of participating industries. Each industrial unit will be treated as a point source through which mitigation actions can be implemented. In nine years or more, the government will have to provide financial support for effectively implementing the unit level or cluster level monitoring mechanisms to curb pollution.</td></tr>
</table>

Sr. No.	Proposed Policy or Criteria	Implementation Time	Responsible Agency/Stakeholder	DC - (INR crore)	IDC (INR crore)
12.	Relocating air polluting industries	2022-2030+	Industries' Associations, GPCB, GEDA, District Administration, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, GIDC, SUDA, Transport Department and SSCDL	NA	NA

1. '*' – Implementation Time – Implementation time slots are two-phased implementation processes that have been decided as per the release of Surat CAP in the year 2021. If completed within five years, suggested policies and programs on or before 2025 have been kept in the first IT Slot, whereas those proposed measures concluding till 2030 or more have been kept in the second slot of 2030. The cost has been given for their actual implementation period, which has been shown as Years: From-To in the above table.
2. DC – Direct Cost - Expenses directly attributable to project outcomes for the mentioned time or addition of that.
3. IDC – Indirect Cost - Expenses associated with parallel associations and the proposed programs/business/segment operationalization.
4. Note 1: All the costs have been referred to base on similar literature available in the secondary database and are pertaining to Gujarat state. However, these are just rough estimates, and the actualization of these policies may vary from shown figures if being decided to work upon.
5. Note 2: Some policies have been divided into two-time slots for the 2030 IT Slot. And two separate set of costing has been given.

A total of **INR 225 crore** will have to be spent as a part of the emissions regulations from the industries of the SMC area. The cost will cover a period of more than ten years of policy implementation. A longer duration is anticipated for enacting the proposed measures because of the different stakeholders that need to be brought on the same platform. While most of this cost will be through the coordinated efforts of the stakeholders, industry associations will play a significant role in coordinating and regulating these measures at the industrial unit level. Specific projects will have to be identified to evaluate these measures as a single pilot wherein the crux of operations can be determined. This project has been briefly explained in **Annexure 8.**

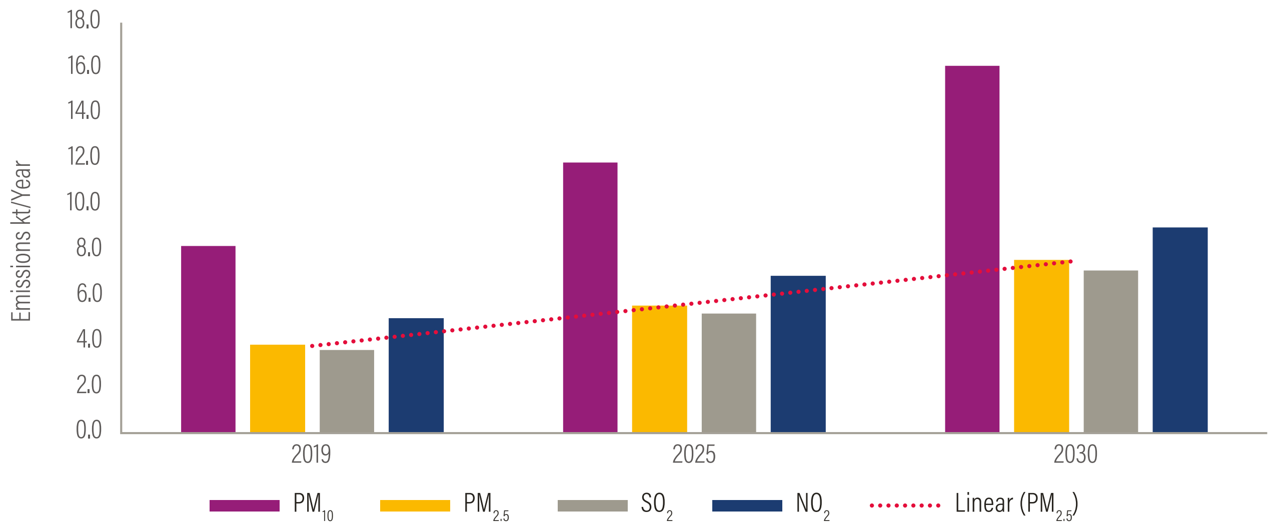
6.9.2. Health Risk Assessment

Mortality caused by $PM_{2.5}$ emissions from the industries sector has been discussed in detail in **Chapter 3**. With the average annual $PM_{2.5}$ contribution of 27%, industries as a sector cause 686 premature deaths in the SMC area, considering the current situation wherein no added mitigation measures exist. Reducing exposure to industry emissions can be achieved through the proposed mitigation mechanisms to avert these premature deaths.

6.10. SCENARIO GENERATION

It is evident from the above assessment that emissions of SO_2, CO, and $PM_{10/2.5,}$ are arising from fuels such as wood, furnace oil, high-speed diesel, and coal. The highest emitted pollutants for the highest attributing fuel options were derived for the highest consuming (type) industries. Thus, it can be concluded that those small industries are responsible for the highest share of emissions (70%), followed by medium-sized industrial units (25%) and large industries contributing the least (5%). Of the emissions from small industries, SO_2, CO, and PM_{10} emissions amount to 60%, 7%, and 5%, respectively.

Figure 44: BAU projections for SMC area



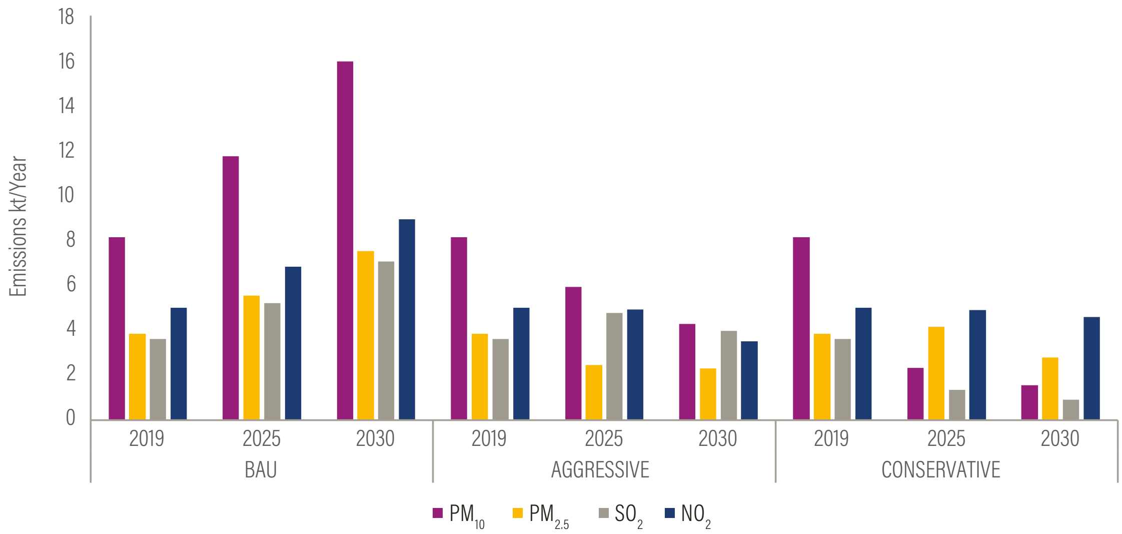
Similarly, for the medium-sized industries, SO_2 and CO contribute the highest, with 13% and 6%, respectively, of the total emissions of 19%. In the large-scale industries category, PM_{10} (2%), $PM_{2.5}$ (1%), and CO (1%) are the three highest contributing pollutants. Considering the fuel usage patterns in different types of industries, the following scenarios were designed for the reductions of emissions from the industries in the SMC area:

Business As Usual (BAU): No or negligible change in fuel consumption pattern will be observed in this scenario. Thus, emissions from different industries would be similar and expand with the numbers of industries in clusters and city areas (textile processing and enterprise units). Since there are no adoptions considered here and energy consumption for running industrial units is expected to increase by 5.9% annually, a reduction in fuel consumption will not be observed for the fifth (2025) or tenth (2030) change year. **Figure 44** shows the increase in BAU scenario in the absence of any mitigation options in the industrial clusters of the SMC area.

Aggressive Policy Implementation Scenario (APIS): This scenario will aggressively adopt policies and program-level findings from previous projects **(Table 24)** and proposed mitigation measures **(Table 25)**. Specific considerations would be given to energy efficiency, pollutant capture at source, stringent monitoring, and control of emissions by expanding authorities of GPCB and altering conventional fuels by introducing innovations in industrial policy at the industrial cluster and city levels and in program implementation. In this scenario, the gradual implementation of policies such as technology retrofitting, APCD installations, and non-conventional fuel usage implementation for the industries will change fuel consumption patterns. Thus, emissions from different industries are expected to be a downward trend, especially in the industrial clusters nearer to the SMC area's core. Such industrially populated wards will be targeted for the physical changes that the programs and policies will produce. With this scenario implementation, the anticipated outcome for 2025 would be a 35% reduction in emissions from the BAU scenario. Co-factoring the fuel consumption from the BAU scenario and pertaining emissions, and by 2030, the anticipated reduction would be 60%.

Conservative Policy Adoption Scenario (CPIS): In this scenario, learnings from the policies and programs mentioned in **Table 24** would be conservatively adopted through the mitigation measures proposed in **Table 26.** The focus would be more on conserving resources by imparting knowledge and filling in the gaps in the micro-implementation of the policies and programs. The industrial units can levy time to adopt the measures, especially those units that have to retrofit the energy and other infrastructures. Capacity-building programs by the state departments and incentivization policies will be gradually adopted. However, with considerably slower adoption in this scenario, it is anticipated that such gradual change will be long-lasting and taken up by the industrial units' owners. In this scenario, technical interventions focusing on the circular economy will be adopted after the 'carrying capacity assessment.' AFR will replace conventional fuel through strict action and with coordination of authorities and industrial associations. Some portion of conventional fuel will be used for the initial conversion of AFR. At a later stage, a complete transition will be achieved. This change will be clubbed with interventions such as 'common community boilers' and 'regulating baby boilers' in the SMC area industrial clusters. With this adoption, the anticipated outcome for 2025 would be a 50% reduction in emissions from conventional fuel consumption, which will be enhanced by another 22%, making it a 30% reduction in fuel consumption by 2031. Comparative reductions for both of these scenarios have been given in **Figure 45.**

Figure 45: Scenario building – Emissions reductions in the industrial clusters of the SMC area



6.11. CONCLUSION

The industries' sector contributes 27% $PM_{2.5}$ of the SMC area's total pollution load, one of the highest shares among all sectors. This is significant because many industrial units in the SMC area continue to use conventional fuel for their processing vessels. Coal, lignite, wood, furnace oil, and even bagasse is used in industrial units near the city. This significantly adds to the city's total emission load, and immediate attention is required on switching to cleaner fuel options for MSMEs, particularly for large industrial units dependent on natural gas as their primary processing fuel. Interventions such as community boilers and technology retrofitting of APCDs can prove beneficial in monitoring the sectoral emissions in the SMC area. Industrial clusters, such as Pandesara, Palsana, Sachin, Udhana, Katargam, and Kadodara, can be targeted with the proposed programs. For the more sophisticated mitigation policies, such as LTAs mentioned in the proposed mitigation actions, focus can be placed on large industrial units harboring industrial clusters, such as Hazira and Ichhapore belt. It is anticipated that large industries can take the lead in the proposed pilot projects and policy interventions. For example, industries such as NTPC, ONGC, L&T, ESSAR Steel, and Reliance Industries can set technical and CSR support benchmarks to the smaller units registered under the MSME Act 2006 through the development and expansion of MSMEs in the best possible way. It is also expected that textile processing associations and chemical industries associations will have to take the lead in implementing air pollution mitigation, considering their collation of similar types of industries and quality of coordination. In any eventuality, the city's expansion will have to undertake after conducting a carrying capacity assessment, as the SMC area will have to be assessed further to include pollution-causing industries. Thus, it is advisable to curb industrial pollution at the source by working on each industrial unit as an emission-causing entity.

CHAPTER 07

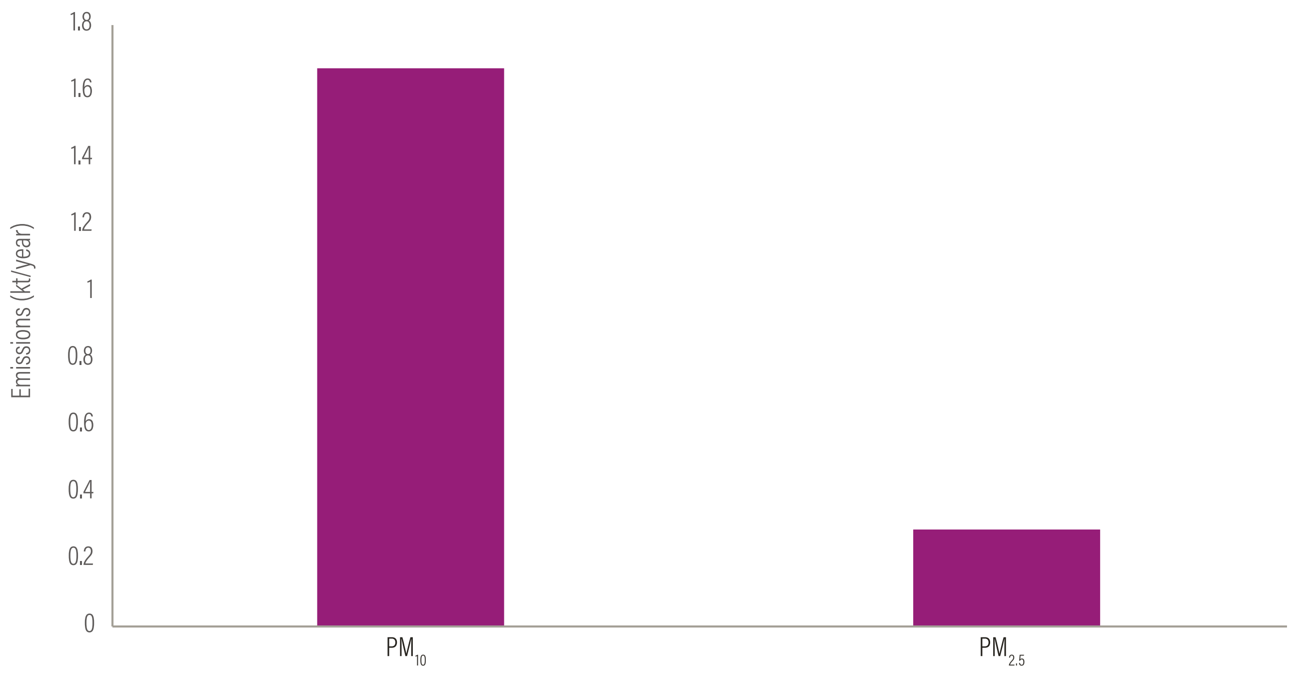
>> CONSTRUCTION

7.1. EMISSION INVENTORY – CONSTRUCTION SECTOR

Construction activities are responsible for significant proportions of $PM_{2.5}$ and PM_{10} emissions, especially in urban areas[65,66]. Particulate emissions from construction activities directly link to the construction growth in the SMC area boundary. As the city grows and expands, more projects will come up. The area of construction or demolition within the study region during a specific period plays a vital role in estimating PM_{10} and $PM_{2.5}$ emissions. However, it is challenging to quantify construction and demolition and determine emissions due to a lack of data.

Using the most accurate data, TERI estimated emissions from construction activities in the SMC area. This estimation indicates that construction activities in the SMC area contribute about 1.67 kt of PM_{10} and 0.29 kt of $PM_{2.5}$ annually (**Figure 46**). This amounts to about 5% of the total PM_{10} and 2% of the total $PM_{2.5}$ emissions of the city. As per the dispersion model analysis, winter months contribute 1% PM_{10} and 0.3% $PM_{2.5,}$ whereas the summer months add 2% PM_{10} and 1% $PM_{2.5}$ of the total particulate emissions.

Figure 46: Emissions estimations for the construction sector



7.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR

As discussed in **Chapter 1**, RPI is the index number measuring the rate at which the prices of residential properties (flats, detached houses, terraced houses, etc.) purchased by households are changing over time. Only market prices are considered in this index, including the land price on which residen-

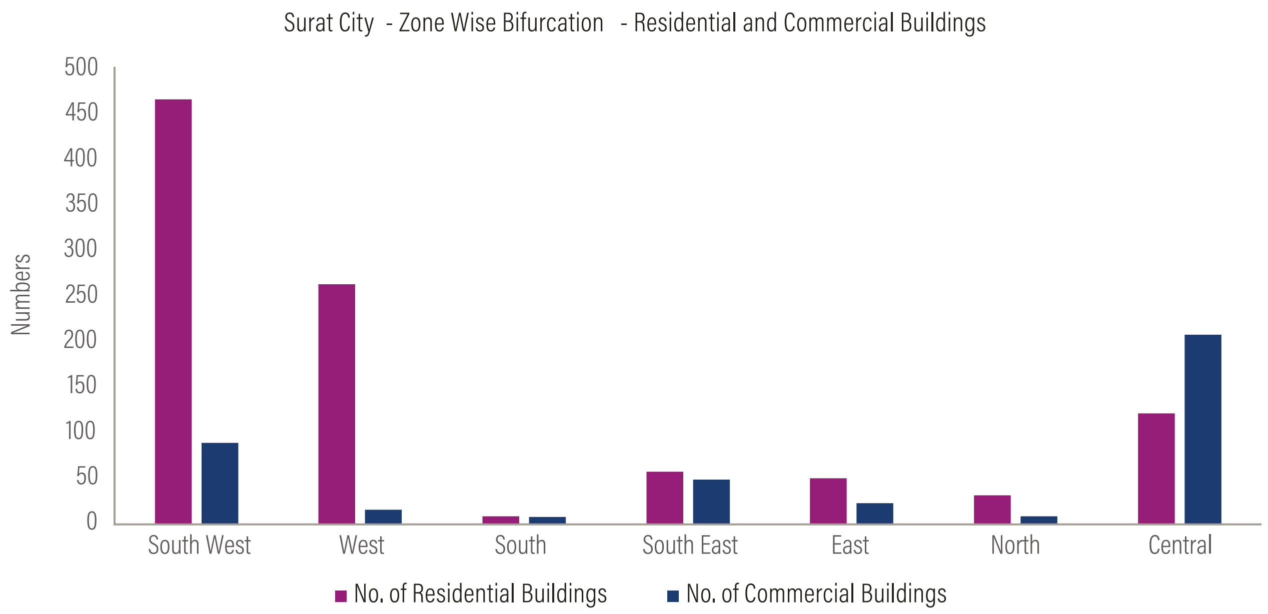
---

[65] *Central Pollution Control Board. (2019- 2020). Annual report. MOEFCC. https://cpcb.nic.in/annual-report.php.*

[66] *Guttikunda, S. K., Nishadh, K., & Jawahar, P. (2019). Air pollution knowledge assessments (APnA) for 20 Indian cities. Urban Climate, 27, 124–141. https://doi.org/10.1016/j.uclim.2018.11.005.*

tial building is located[67]. This price index controls the construction and allotment of houses and infrastructure planning in an area of any city. SMC has eight zones: Southwest, West, South, Southeast, East A, East B, North, and Central. As per the RPI of the SMC area, the southeast zone has been attracting infrastructure development options and investment from the government and private agencies alike on account of the newly developing areas, such as Piplod, Pal, and Vesu[68]. The South, Southeast, Southwest, and Central zones have higher RPIs and receive more significant retrofitting projects. However, the Central zone is saturated for new development, with a density of 49,971/km². **Figure 47** shows the distribution of residential and commercial buildings for every zone of the city. As indicative from the figure, from 2017 to 2019, on average, 425 residential, 263 commercials, and 226 mixed plots registered for development for the SMC area[69].

Figure 47: Distribution of residential and commercial complex buildings in the SMC area – Seven zones (Data Source: Surat Municipal Corporation Town Planning Department, 2017-2019)



Infrastructure projects: The details are for the projects that started between 2012 and 2019. About 78 residential projects are ongoing in the SMC area and 178 in Surat Urban Development Area (SUDA). As for the commercial allotments, there are 33 major ongoing commercial infrastructure projects in the SMC area, while the SUDA limit allows small-sized allocations of 17 projects only. This section discusses the current allotments of construction projects combining SMC area and SUDA limits. These include residential and commercial building projects and social and physical infrastructure development or redevelopment work by the state government and the SMC. This indicates a significant share of private development as well as redevelopment work[70].

[67] *OECD. (2019). Statistical Insights: Location - House price developments across and within OECD countries. Statistics and Data Directorate - OECD.*

[68] *NHB Residex Booklet. (2018). National Housing Bank, India.*

[69] *Development Plan 2035 SUDA. (2017).*

[70] *Infrastructure Policy & Finance Division | Department of Economic Affairs | Ministry of Finance | Government of India. (2019-2020). Department of Economic Affairs. https://dea.gov.in/divisionbranch/infrastructure-and-energy-division.*

- A total of 12 major energy infrastructure development projects are ongoing (with 2012 being the tender allotment date for most projects) worth INR 12,709 crore, with six projects completed during 2017-2019.
- There are four major ongoing social infrastructure projects - healthcare facilities, schools, other educational institutions, water, and sanitation - with a fund allocation of INR 809 crore.
- There are 32 novel construction or redevelopment of transportation projects addressing the growing need of commuters; six were completed during 2015-2018. These projects drew an investment of INR 6,877 crore.
- There are 11 projects on water infrastructure, of which three were completed in the year 2018, with an investment chunk of INR 823 crore.

Road construction in the SMC area: As per the City Development Plan 2035 (Year of Publication - 2017), the SMC area has 1,859 km of city roads cut across eight zones. The highest amount of construction material goes into building National and State Highways[71]. **Table 27** lists the different types of roads within a single zone in the city. This information is based on the different types of roads present within the city; the average length for each type of road has been considered for a single zone. While there are many parallel considerations to have different lengths by type, the Town Planning Department of the SMC adheres to the lengths presented in **Table 27** as representative for a zone:

Table 27: Representative length of roads (rate of addition in a year) as per their type – SMC area (Source: Surat Municipal Corporation Building Department Data 2020)

Sr.No.	Type of Road	Length in Km (addition per annum - data for 2018-2019-2020)
A.	**Bituminous Carpet**	**201**
1.	Arterial Road	22.90
2.	Sub-arterial Road	21.64
3.	Collector Road	46
4.	Residential Street Road	110.56
B.	**Metal Grouting**	**32.4**
5.	Arterial Road	0
6.	Sub-arterial Road	2
7.	Collector Road	1.4
8.	Residential Street Road	29
C.	**Total (A and B)**	**233.51**

Budget allocations for infrastructure-related projects: The SMC had allocated INR 827 crore specifically for new construction and redevelopment of roads and government-owned buildings and the development of physical infrastructure required for transportation and commodities supply facilities

[71] *Guidelines for IRC Standards (First Revision), Indian Road Congress, Ministry of Road Transport and Highway, SP:36-2018-19. http://www.irc.nic.in/.*

for FY 2020-2021. These projects are under the sole jurisdiction of SMC. With regard to road development, SMC is taking care to incorporate micro-processing of the newly constructed roads and

sustainable initiatives, such as incorporating plastic in construction material. However, in large-scale residential and commercial aspects projects, apart from the Diamond Research and Mercantile (DREAM) City project, no sustainable construction practices are taking place at the construction sites owned by the SMC.

7.3. MAJOR ISSUES RELEVANT TO THE SECTOR

- Surat is expanding, mainly due to a rise in the business owned by the city. A sizable visiting population from Gujarat as well as other states visits the city and uses the facilities provided by the city corporation during its stay. To keep up with the growing demand, the infrastructure and operations of residential and commercial entities need to expand.
- Thus, the SMC area has emerged as the hub of infrastructure-related project development with state-of-the-art flyovers, roads, and river crossover bridges. Pal and Vesu are a few areas that have the highest expansion rates, and that add residential units on a daily basis.
- As indicated in **Chapter 2**, road dust adds a significant proportion of particulate matter, primarily airborne, due to the construction of roads and other buildings. This is mainly because the construction material used has a higher dust generation capacity. At the city's construction sites, the raw material adds a significant amount of particulate matter to the city's air, which eventually settles on the roads owing to the fact that pavements constitute 88% of the built-up area. The heavy vehicular traffic makes particulate matter airborne, which is harmful to those commuting in open vehicles, such as auto-rickshaws, motorbikes, and bicycles.
- Although the SMC area will have more sustainable buildings once the IGBC norms are applied, these opportunities lie only in commercial buildings. Despite this, the newly built residential buildings, which form 60% (GUJRERA 2019 data) of the new establishments, do not follow sustainable construction practices.
- As discussed in the later section of the chapter, although SMC has established a construction and demolition waste processing facility, the builders/construction companies often do not access this facility. The reason was given by the construction and contracting agencies that the demolition material from one site is being reused in new building construction happening in the SMC area. However, a significant chunk of construction and demolition waste from the city continues to be dumped in the open at the city's outskirts.
- In addition to the above point, vehicles carrying construction and demolition waste are not being checked for fugitive emissions from the material.
- The construction companies and city authorities (SMC and GPCB RO) have limited reach to ensure occupational health facilities, especially for workers at construction sites. There is no data on the number of construction workers who do not wear masks to protect them from harmful effects of the particulate matter.

7.4. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

7.4.1. Assessment of Policies Pertaining to Construction Processes in the SMC Area

Several air pollution mitigation measures have been drawn up for the construction sector in India. The following measures are currently effective in the SMC area:

- For construction projects having an area greater than 20,000 m^2, it is mandatory to take environment clearance from State Level Environment Impact Assessment Authority (SEIAA), as recommended by the Environment Protection Act 1986, the Water (Prevention and Control of Pollution) Act 1974, and Environment Impact Assessment (EIA) notification 2020. More than 44 such projects are under evaluation. These include residential, commercial, and service enhancement infrastructure projects[72].

- The Surat chapter of the contractors' independent authority, Confederation of Real Estate Developers Association of India (CREDAI), controls the administrative resources for small, medium, and large construction companies. Civil contractors from CREDAI have been able to push for compliance with prevailing Rules and Acts, leading to safe construction practices at the project sites. A few of the initiatives are listed as follows:
  - Annual update and review of construction practices and implementable procedures at all the construction sites
  - Implementation of safe transportation practices for construction materials
  - Provide metal facade for covering all entrances and open ends at construction sites to control escaping dust – mandatory for contractors engaged in multi-layer buildings
  - Provision of a sprinkler system at construction sites, wherever possible

- SMC is operationalizing a construction and demolition waste collection and recycling management plant, Surat Green Precast Pvt. Ltd, at Kosad block, Amroli, in public-private partnership (PPP) mode. The plant aims to scientifically manage all construction and demolition waste from ongoing construction projects within SMC area limits and produce various building by-products, such as bricks, pavers, and blocks. The plant has a specialized segregation system, a debris handling system, a crusher, and other required units, including a multiple-section screening unit.

- The plant at Surat Green Precast is equipped with state-of-the-art technology and has a limited adverse impact on the environment. Recycling construction and demolition waste reduces mining for aggregates, such as sand and blue metal, and saves valuable land otherwise wasted as a dumping ground.

- The SMC has also performed better than other ULBs of western Indian cities. In 2018, it received the Green Business Certification Inc.-Leadership in Energy and Environmental Design (LEED)

[72] *GPCB, Annual Report. Gujarat Pollution Control Board. https://gpcb.gujarat.gov.in/webcontroller/page/annual-report.*

Platinum certification. The SMC is the first city corporation in India to receive a LEED city certification under the platinum level. It received a score of 87 out of 100 points on Arc[73]. Using Arc, the city could benchmark itself against similar cities globally and locally on 14 metrics based on their performance in energy, water, waste, transportation, and human experience. The certification programs revolutionize the way cities and communities are planned, developed, and operated to improve their overall sustainability and quality of life. The LEED framework encompasses social, economic, and environmental performance indicators and strategies with a clear, data-driven means of benchmarking and communicating progress. The program is aligned with the United Nations (UN) Sustainable Development Goals (SDGs) and is influenced by its engagement with hundreds of cities and communities worldwide[74].

7.4.2. Challenges

- There is inadequate knowledge and awareness of construction-related air pollution among the builders and developers in the SMC area. Discussions with sectoral experts revealed that limited initiative had been undertaken to mitigate pollution from construction dust. As part of the environmental clearance process, several mitigation measures have been drawn up by builders to manage dust pollution at construction sites. However, on-ground implementation and monitoring of these measures on construction sites are negligible.
- Collaboration between the local builders' association and GPCB regional office, and SMC to mitigate air pollution at construction sites is poor. A strong partnership could bring all major stakeholders on a common platform to control air pollution from the construction sites. In addition, the public health system of the SMC area can be utilized under this partnership to create awareness of the health effects of construction-related air pollution on public health in general and persons working on the sites specifically.
- The most important yet most neglected aspect of the city is its reducing green cover. According to a study conducted in partnership with the district forest office and Nature Club, the SMC area is losing its green cover of an average of 40 years of aged trees. This can be explained in the sense that trees responsible for settling the particulate matter and sequestration of other emissions after achieving maturity are being lost due to limited efforts to conserve these through scientific relocation methods.

7.4.3. Opportunities

- The regional office of GPCB has maintained an interactive database of construction companies that are willing to initiate their work within city limits. The authority here diligently screens these contracting companies for their environmental compliances, which is mandatory for initiating construction.
- The enforcement of provisions under Gujarat Town Planning and Regional Development Act 1976 pertaining to construction dust management at site and during the transportation is required,

---

[73] Arc Skoru Inc is a technology company that is affiliated with Green Business Certification, Inc and the U.S. Green Building Council. Arc Skoru Inc. believes that performance is the future of green building and created the "Arc" performance platform to help create better buildings and places for people and the environment. Arc empowers its users to understand and enhance their sustainability performance, promote human health and well-being and contribute to a higher quality of life. - Source: https://arcskoru.com/

[74] LEED rating system. (https://www.usgbc.org/leed/rating-systems/leed-for-cities).

besides deploying machines for cleaning road dust, planting trees, and paving roadsides. These initiatives are being maintained well by the SUDA in their newly added areas of development.

- SMC has set up a state-of-the-art construction and demolition waste plant within city limits. This plant is operational at 330 TPD, and construction companies and contracting agencies can transport their construction waste here for processing at subsidized rates. The waste is then converted to soil aggregates, which can further be used by the construction companies in processes such as soil treatment and mulching. Solid aggregates can also be used to manufacture high mineral compound fertilizers used for city corporation gardens. The reuse potential of construction and demolition waste, currently at 22%, can be enhanced, and contractors are availing recycled aggregates from the plant for use in new construction processes.
- The Bureau of Indian Standards allows the use of concrete made from processed (construction and demolition) C&D waste, which is also mandated by the Construction and Demolition Waste Rules and Regulations, 2016. A thorough implementation of the rules would increase awareness regarding sectoral particulate emissions. Awareness among all stakeholders would help achieve the objective of reducing sectoral emissions.

7.5. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

As part of the air quality improvement program, GPCB has implemented policies to mitigate construction emissions. These policies and programs are explained in **Table 28.**

Table 28: Current programs and policies of GPCB (Source: Surat –Air Pollution Control Action Plan, https://cpcb.nic.in/Actionplan/Surat.pdf)

Sr.No.	Action Points	Implementation Status
1.	Enforcement of Construction and Demolition Waste Rules,	Recycling of C&D wastes plant is operational for the last two years in the SMC area.
2.	Controlling fugitive emissions from material handling- conveying and screening operations through water sprinkling, curtains, barriers, and dust suppression units.	As per the GPCB's directive, SMC has incorporated conditions in its development permissions and monitored fugitive emissions at the ULB controlled sites.
3.	Ensure Carriage of construction material in closed/ covered vessels.	No steps have been taken for the control of fugitive emissions or the monitoring of the same.

7.6. CONTROL MEASURES IDENTIFIED DURING OPPORTUNTIY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

The following were the major discussion points at the November 2019 workshop titled Target Approach – Construction Sector. These points also paved the way for the sectoral assessment in this project.

- A centralized command center is needed in the SMC area boundary, which would address stressors (including air pollution) related to particulate matter dispersion in the SMC area.

- SMC has a C&D waste processing facility at Kosad block. This C&D waste management plant would be an added efficiency measure for treating pollution from the construction sector.
- Continuous monitoring at the construction sites would be key to reducing air pollution specific to the sector. Monitoring would underline the recognition of sectoral contribution to the city's air, and specific engineering controls such as wet processes and exhaust ventilation can be applied at the construction sites.
- Ready-mix concrete (RMC) shall be promoted to replace the conventional mixing methods at the construction sites.
- As a part of the SCAP project, hot spots have been identified in the SMC area. These hot spots are those locations where construction dust is more airborne, and new construction is coming up. As targeted actions, wet processes (sprinkler systems and mulching) can be applied in these hot spots, and all construction sites can be provided with metal enclosures.
- The health of off-site communities is an essential factor and indicator for reducing emissions from construction processes. Many of the construction sites in the SMC area are polluting the surrounding areas, which was visible through documentation (photos and complaints registered in the Surat Smart City application) in the form of dust accumulated on mobile and immobile surfaces. Having an enclosure for construction sites, applying wet processes, and implementing effective dust capture measures would protect vulnerable off-site communities.

7.7. STRATEGIES TO MITIGATE AIR POLLUTION

Based on the assessment of existing air pollution mitigation measures, a stakeholder consultation, and an analysis of the challenges and opportunities, the following interventions are proposed for the SMC area to mitigate air pollution from construction sites:

7.7.1. Air Quality Monitoring

Monitoring ambient air quality during different construction activities is the most critical step in controlling air pollution emissions. Having a state-of-the-art air pollution monitoring system in place would be the best option to do this. However, as various construction activities cause air pollution, the location of these activities can differ as per their characteristics, which would require context-specific solutions. Following are a few processes that indicate the importance of monitoring air quality at construction sites:

- **Preparation and implementation of Ambient Air Quality Monitoring Plan for construction sites**: Implementing an air quality monitoring plan will ensure that construction activities do not contribute to the excess levels of air pollution in the area. All monitoring results must be cross verified with the background concentration and concentration of other city monitoring locations as part of this process. An effective air quality plan will ensure the efficiency of the air quality management measures at construction sites and assess the loopholes in policy and mitigation actions. It will also enable the identification of the unrecognized or missing air pollution sources associated with construction activities. With a continuous ambient air quality monitoring plan (AAQMP) in place, authorities can alert the construction company, the contractor, and the local pollution control organizations with evidence.

Effectively implemented ambient and personal air quality monitoring plans at construction sites will provide a backup to construction companies, contractors, and authorities alike when claims related to occupational health conditions are raised by on-site professionals or members of the communities in the vicinity. Additionally, the monitoring plan will create space for improvement in providing engineering and administrative controls for on-site workers and measures that the construction company can take in the interest of the neighboring communities as a part of their social responsibility drive. Thus, having an air monitoring plan in place will prove beneficial to construction companies in the long run.

- **Development of construction sector-specific monitoring toolkit**: As mentioned above, implementing an AAQMP will allow the implementation of dust mitigation practices across the city, thus allowing contractors and construction companies to understand the efficacy of different dust management practices. Targeting effective dust mitigation measures will allow savings on capital resources. For example, the silica content in airborne dust is a significant concern when considering exposure to $PM_{2.5/10}$ from any source. This is because it can cause serious health issues in those who are exposed to it. Identifying and triaging activities/processes that generate more airborne dust will keep the implementation of engineering or administrative controls more focused.

  This can be achieved by the development of a sector-specific monitoring toolkit. This toolkit will be specific to the construction sector and will have a detailed assessment of the sector, focusing on sources, pollutants, and hot spots, for the SMC area. In the leadership of SMC and GPCB, this toolkit can be developed within one year, starting from November 2021.

- **Enhancing monitoring capacity by increasing Continuous Ambient Air Quality Monitoring Station**: Air quality monitoring at the construction site will also help construction companies avoid invoking the government’s ban on their sites if they follow all the norms and do not contribute substantially to air pollution. However, this can only be achieved if adequate air quality monitoring stations are allocated for the entire SMC area and what the construction companies/contractors have been suggested to deploy in **Point 1** of this subsection. Currently, there are ten stations in the SMC area, out of which only 2 are Continuous Ambient Air Quality Monitoring Stations (CAAQMS) and provide AQI results online. Increasing the number of CAAQMS stations in the SMC area would offer an integrated platform formation wherein the analysis would be more technical and have lesser human interference. This will help reduce ambient air quality monitoring errors, which will help with future development plans.

- **Integrating air quality monitoring in future plans of city development**: As mentioned in the previous point, CAAQMS can develop an automated SMC area level platform wherein automatically generated air quality data can be integrated for the daily ambient air quality concentrations. Such a database can be used to identify and further used in the decision-making process to adjust the development plan for the SMC area. As per the micro plan, this type of CAAQMS can be deployed on strategic sites, keeping in mind the areas of the city that have more construction sites. Such areas would be targeted for permanent yet cost-effective measures, such as green area development, conservation of trees, waterbody conservation, and implementation of IGBC norms.

7.7.2. Air Pollution Mitigation by Implementing Engineering Controls

Engineering controls are the most effective tools in controlling emissions at the source. They are easy to implement and require lesser human interference, which leads to reduced human exposure. In the thematic area of occupation, safety, and health, engineering controls are considered the first defense against occupational exposure to particulate matter and emissions from other industrial processes. A similar approach can be applied for constructing buildings since the process collates different small activities that considerably point sources for the particulate matter. These include tasks that employ building up or demolishing something with force (for example, hammering, loading-unloading, and stacking, material movement). A few of the measures that employ engineering controls at construction sites in the SMC area are listed as follows:

- **Implementation of inputs given in 'The Handbook of Clean Construction Practices for Surat 2020:** WRI India has published a guide for the SMC titled 'The Handbook of Clean Construction Practices for Surat 2020' as part of the SCAP project to mitigate air pollution from construction activities. This handbook discusses various measures and practices to mitigate air pollution from construction activities. The different emission sources and possible control measures to minimize air pollution emissions from construction activities discussed in the handbook are outlined in **Table 29**. These practices can be followed on all construction sites by closely referring to the guidelines given in WRI India's handbook.

Table 29: Specific reduction of emissions by implementing engineering controls at the construction site (Source: The Handbook of Clean Construction Practices for Surat 2020)

Type of Emission	Control Measure to maintain AAQ	*Average Reduction in SPM 2.5 (%)	Consequences if Not Controlled
Dust/particulate matter from the soil	Ventilation System (in a controlled environment)	Up to - 82%	1. Severe respiratory problems among on-site workers
			2. Mild to seasonal respiratory problems among the community in the vicinity of construction sites
	Blower System for Air Exchange (in a controlled environment)	Up to – 47%	3. Accumulation of dust on vehicles and inside homes
	Blue Sheet Covering (in-side-outside measurement)	Up to – 47%	4. Mechanical failure of vehicles and other motorized equipment engaged in construction activity
	Green Mesh Covering	Up to – 22%	
	Wet Processes	Up to – 65%	
	Wet cover during within the site Transportation	Up to – 60%	
DPM (Diesel Particulate Matter)	Engineering Control at the exhaust of vehicle or DG set	Up to – 92%	1. Severe respiratory problems among on-site workers
			2. Breathing issues among communities in the vicinity
			3. Film formation on surrounding trees, leading to a reduction in tree cover due to the toxic effects of diesel
			4. Nuisance of cleaning surfaces due to excessive oil film formation.

Type of Emission	Control Measure to maintain AAQ	*Average Reduction in SPM 2.5 (%)	Consequences if Not Controlled
Welding fumes	Local Exhaust Ventilation	Up to – 92%	1. Cardiovascular diseases
			2. Severe damage to vision
	Covering welding location in an air exchanged enclosure by the wet green carpet or blue fiber sheets	Up to – 47% + 47%	3. Allergic reaction if generated in higher concentrations, even among those who are living in the vicinity
Odor/ Foul smell/ Fog	Wet Spraying	Up to – 25%	1. Headache and nausea among workers on site
	Covering of Enclosure of Odour Causing Material at the site	Up to – 55%	2. Aesthetic value of the site will be degraded because of the foul smell

In addition to the measures mentioned in **Table 29**, some rules and regulations refer to multiple program-level adoptable measures. These can be employed specifically for the SMC area. These rules are explained in WRI India's handbook.

- **Promotion of RMC over the conventional concrete preparation process:** Concrete is one of the most critical components used in the construction industry and accounts for 30-50% of the total cost of any structure[75]. The quality of concrete used directly impacts the strength and durability of the structure, and in this context, RMC plays an important role. The advantages of using RMC are manifold; it helps improve efficiency and reduce wastage of resources involved in the construction process. The preparation of cement on the site involves a lot of risk due to dust emission and exposure to radiant heat. RMC reduces all these risks along with lower expenditure due to the reduced requirement of human resources.
- **Promotion of fogging machines at construction sites:** Fogging machines are dust capture units running on conventional energy with a heavy capacity, wherein a dust suppression system, which is a technology that uses high-pressure water fogging combined with airflow, is used to settle the dispersed dust particles. Fogging machines are generally a one-time investment, and with the heavy budgets of construction sites, these types of equipment can be easily procured. Fogging machines and other engineering controls, such as metal enclosures and wet spraying machines, can create a controlled environment wherein dust-generating activities can quickly be suppressed.

7.7.3. Air Emissions Mitigation through Administrative Management Controls for the Construction Process

Apart from the two strategies described in subsections **7.7.1** and **7.7.2**, in which emissions from construction sites are generally managed at the source, administrative management controls employ a more holistic approach of engaging more stakeholders and evaluation methods off-site rather than on-site. A few SMC-specific measures by which construction sector emissions can be mitigated are listed as follows:

[75] *WRI India. (2020). The Handbook of Clean Construction Practices in Surat: developed under Surat Clean Air Action Plan 2020. https://wri-india.org/events/handbook-clean-construction-practices-surat-developed-under-surat-clean-air-action-plan-2020.*

- **Best practices – Clean Construction Practices and Monitoring Mechanisms – pilot sites development for SMC area**: The Handbook of Clean Construction Practices for Surat 2020 mentions several current practices in clean construction through which sectoral particulate emission mitigation can be achieved. These best practices are listed in the rules and acts produced by the state and central governments as mandatory guiding actions for stakeholders in construction processes. Developing two model pilot practice sites based on the operational guideline of the Central Command Center, which is discussed later in this list, will provide an opportunity to build the capacity of contractors, construction professionals, and institutional participants (researchers and students). These sites will function as capacity-building resources and a ready reference for professionals willing to follow sustainable construction practices norms in their projects.

- **Assessment of exposed, vulnerable population**: This assessment will help identify the population exposed to higher amounts of air pollution emitted by a specific source, which in this case is the construction site. This assessment can be conducted within one year, starting from 2021. The leading indicators in the assessment would be density, vehicular movement, and construction activities of all types. A hazard–risk–vulnerability assessment (HRVA) would be conducted, prioritizing the exposed community's 'emergency' based on the identified construction site. A specific template will be used to prepare the method statement, involve human and environmental resources, make an interim assessment of exposure, and conduct a health risk assessment.

- **Air Quality Index Alert System (through SMAC center)**: The SMC can develop a relaying message system based on ambient pollution near construction activity zones for construction activities. This alert system will be based on the data collected from the manual air monitoring stations and the automated data feed of the CAAQMS. The alert can follow the format of temperature and cyclone alert system, which is already operational in the SMC area; however, this would be very specific to the particulate emissions of $PM_{2.5}$ from construction sites, for which the data would be collected at ward level. This system is expected to be useful for the on-site working population, contracting agencies/construction companies, and those living in the vicinity of these construction sites.

- **Formation of Central Command Centre– Collaborative Action Unit in operational partnership of SMC, GPCB, and Builders' Association of Surat**: Since there are several dust generation sources in the sector spread across the SMC area, it is important to have a collaborative command center from which all activities listed in the previous points in this strategy can be operationalized. It could be named the Central Command Centre (CCC). This collaborative action unit will be co-owned by authorities such as the SMC and the GPCB. It would be beneficial to have CREDAI Surat included in the operation of this center to increase its transparency and effectiveness, as many of the construction sites across the SMC area regularly connect with the latter organization. The center will mainly overlook tasks such as the following:
    - Inventorization of construction sites in the SMC area as per their categories, investment (INR 50 crore or less and INR 100 crore or more), size, zones, and wards of the city
    - Needs assessment of engineering controls, administrative controls, and capacity building modules
    - Ensuring AAQMP is prepared and operationalized for every registered construction company
    - Creating a database for each construction site in the SMC area of the requirements through which the 'zero particulate emission' target can be achieved.

- ☐ Creating ownership in the partnering agencies – SMC, GPCB, and CREDAI – for achieving emission reduction targets
- ☐ Overseeing the annual activity calendar for the construction companies and hiring competent agencies whose continuous engagement will ensure emission reduction targets for the SMC area
- ☐ Monitoring and managing the private entities' CSR funds, especially for the off-site emission reduction activities and capacity building module implementations
- ☐ Channelizing continuous dialogue-based processes in the SMC area through which construction companies can utilize resources such as SGPPL (the C&D waste processing facility)

7.7.4. Enhancing the Technical Capacity of Personnel through Capacity Building Modules

It would be important to build the technical knowledge base of the personnel involved in the construction processes for particulate emission mitigation as one of the significant tasks. This can be achieved through CCC activities focusing mainly on those engaged in the construction processes in the SMC area on-site and off-site. The pilot sites displaying clean construction practices and monitoring mechanisms will also be utilized for this mitigation measure.

7.8. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

The micro-level plans are area-specific air pollution mitigation measures that have been populated based on primary and secondary assessments done for the construction sector. Since many of these construction sites are time-bound and resource-specific (availability at a particular area), it is essential to have existing and proposed mechanisms for emissions reductions compartmentalized as per the 'hot-spots across the SMC area to channel better efforts.

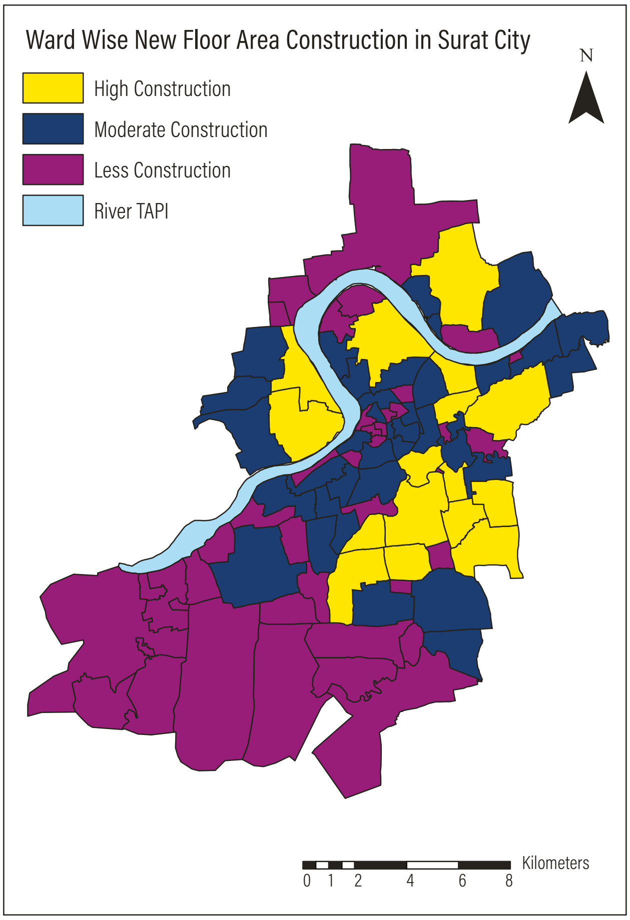
7.8.1. Current Micro-Level Plan by GPCB

- SMC has been able to deploy seven vehicles for carrying C&D waste. Although directives have been provided to control fugitive emissions, no records of monitoring results were found available.
- Restricting the storage of construction materials along the road, covering the construction site, having a separate aisle for carrying construction material within the facility, promoting the use of prefabricated blocks for building construction, placing control measures for fugitive emissions from material handling-conveying, and conducting screening operations at facilities are the proposed mitigation measures. Yet, no monitoring mechanisms were observed to be operational within the SMC area for implementing these measures.
- Develop and implement dust control measures for all construction activities in commercial facility buildings, especially in the newly developed zones such as Vesu and Pal.
- Restrictions have been enforced on C&D activities in highly dense areas, such as the SMC area's central, north, and east zones, wherein particulate exposure will be comparatively higher if these activities are allowed.

7.8.2. Micro-Level Plan Recommendations

- To effectively implement the various measures, it is crucial to assess the construction activities in a more detailed manner and develop relevant strategies. In this regard, we have identified the areas within the SMC area boundaries where construction activities are high in number and require immediate attention to protect the health of residents.
- As per SUDA's official report, a total of 88 buildings were added to the SMC limits in 2019, and 48 construction projects were initiated in 2020. The latter is yet to be completed. These projects are primarily in the south, southwest, and east zones – Vesu, Pal, Piplod, Hazira, Udhana, Sachin, and Kamrej - of the city wherein adequate land is available with an appropriate user base and access to other service level infrastructure is somewhat easier than in other zones.
- Using data from the National Sample Survey Organisation (NSSO) and Census of India, we have estimated the new floor area constructed during recent years in the SMC area's different wards (**Figure 48)**. Wards such as Pal, Adajan, Kataargam, Piplod, and Vesu (area) have upcoming construction areas and have been at the forefront of approving new town planning schemes. The RPI of the wards situated in the south, southwest, and eastern parts of the south zone has been significantly higher.
- A pilot site with best practices disclosures in an area with a high number of construction activities would help builders apply the best practices in mitigating air pollution. These areas can be used for the flagship projects to enhance the technical understanding of knowledge partners. If the area caters to a larger audience, it will benefit the administrative rectification of emissions from construction sites.
- Interventions such as providing wet sprinkling machines would be easy to install or operationalize in Vesu, Rander, and Tunki, expanding rapidly in the vicinity of the Tapi river. Their proximity to the river would enable the supply of water during high tide days. Other processes, such as the treatment of surfaces with water at construction sites, would become easy.

Figure 48: Micro area planning map – Construction sector processes



7.9. TECHNO-ECONOMIC ANALYSIS

Here we assessed the trough techno-economic cost of the air pollution mitigation interventions proposed for the construction sector. Two types of mitigation measures are proposed with respect to implementation coverage, mitigation measures at the SMC level and for construction sites **(Table 30)**.

7.9.1. Implementation Costs of Proposed Policies and Programs

For the construction site level mitigation measures, additional costs are taken up as part of the main budget of the total construction project. The cost of the air pollution mitigation measures presented here is the additional cost required in the construction project as a whole. The main bifurcation is between the projects that cost less than INR 50 crore and those that have a budget of more than INR 50 crore.

Table 30: Institutional financial implications for particulate emissions from construction processes

<table>
<tr><th>Sr. No.</th><th>Proposed Policy or Criteria</th><th>Implementation Time</th><th>Responsible Agency (Type of Mitigation Measure)</th><th>Total Cost (INR lakhs)</th><th>Expected Outcome</th></tr>
<tr><td>1.</td><td>Preparation and Implementation of Ambient Air Quality Monitoring Plan (AAQMP)</td><td>2021- 2025</td><td>CREDAI

(SMC area level while applicable to all construction sites)</td><td>35</td><td rowspan="12">• Improved professional knowledge and enhanced recyclability of articles related to Construction and Demolition activities (e.g., waste and MoC)

• Bare minimum application of best practices in day-to-day activities

• Enhanced ambient air monitoring infrastructure for the city

• Enhanced user base and individual ownership for the particulate monitoring

• Internalization of air monitoring data into robust city development plans in the future

• Enhanced implementation of rules and regulations pertaining to construction and demolition activities in the city

• Identification of worst affected population - particulate matter ambient air exposure from construction sector - and implementation of mitigation measures through public health bylaws

• Improvised knowledge base and algorithms based on real-time air quality data and other weather parameters to be integrated into other citizen-centric smart ITC solutions in the future</td></tr>
<tr><td colspan="5">Remarks: Hiring of competent person/agency, procurement of technical goods, and employing action research would cost the responsible agency INR 5 lakhs/year with an additional INR 1 lakh cost per year for maintenance and other parallel works.</td></tr>
<tr><td>2.</td><td>Development of construction sector-specific monitoring toolkit</td><td>2021-2025</td><td>GPCB, SMC, CREDAI

(SMC area level)</td><td>20</td></tr>
<tr><td colspan="5">Remarks: The development process is anticipated to cost the authorities a bare minimum of INR 10 lakhs for the identified construction site. An additional INR 2 lakhs every year will have to be spent on the up-gradation of the database, monitoring protocols, and capacity building modules if any. The cost is marginally higher on account of hiring a competent authority or agency following due processes.</td></tr>
<tr><td>3.</td><td>Creation of Pilot Prototype Site – demonstrating best practices</td><td>2021- 2025</td><td>CREDAI, SMC, GPCB

(SMC area level)</td><td>55</td></tr>
<tr><td colspan="5">Remarks: A pilot construction site for best practices will be operationalized at an SMC-owned site at the cost of INR 10 lakhs/year and an additional INR 1 lakh as an indirect cost.</td></tr>
<tr><td>4.</td><td>Prototype Best Practices Monitoring Site</td><td>2021- 2025</td><td>CREDAI, GPCB, SMC

(SMC area level)</td><td>80</td></tr>
<tr><td colspan="5">Remarks: A pilot construction site for best practices will be operationalized at an SMC-owned site at the cost of INR 15 lakhs/year and an additional INR 1 lakh as an indirect cost. The procurement of state-of-the-art monitoring equipment and operations (calibration and maintenance included) will cost an additional INR 5 lakhs.</td></tr>
<tr><td>5.</td><td>Enclosure provision / Covering of Construction Site</td><td>2021- 2025</td><td>CREDAI, SMC, GPCB

(Applicable to construction sites)</td><td>65</td></tr>
<tr><td colspan="5">Remarks: The costing stated here is only for one site, with a budget of more than INR 50. Such a site will have to employ multiple enclosures of blue metal sheets and green mesh. For a site operating for 5 years, the cost estimated is INR 12 lakhs/year and an additional INR 1 lakh per year to maintain the enclosures at the site. It is to be noted that these costs would vary as per the material of construction and market trends.</td></tr>
<tr><td>6.</td><td>Proactive Disclosure of Dust Mitigation Activities at Construction Sites</td><td>2021- 2025</td><td>GPCB, CREDAI, SMC

(Applicable to construction sites)</td><td>55</td></tr>
<tr><td colspan="5">Remarks: The proactive disclosures are for the maintenance of transparency wherein the unit owner would be displaying different materials and processes they have employed at their site, which would have hazardous implications for those engaging with space in any manner. This step will include displaying information on the amount of construction material used, processes employed, engineering controls employed, and specific staff or human resources hired at the site. The cost of the display panels at every entrance and at the heavy movement points within the construction site is INR 10 lakhs/year for a site and an additional INR 1 lakh for maintenance of the same.</td></tr>
</table>

<table>
<tr><th>Sr. No.</th><th>Proposed Policy or Criteria</th><th>Implementation Time</th><th>Responsible Agency (Type of Mitigation Measure)</th><th>Total Cost (INR lakhs)</th><th>Expected Outcome</th></tr>
<tr><td>7.</td><td>Promotion of procurement of fogging machine</td><td>2021-2025</td><td>SMC, CREDAI, GPCB, and Competent Agency

(Applicable to construction sites)</td><td>15</td><td rowspan="14"></td></tr>
<tr><td colspan="5">Remarks: This mitigation measure will have a mobile fogging machine procurement as a one-time investment at a price of approximately INR 15 lakhs for the construction site.</td></tr>
<tr><td>8.</td><td>Promotion of RMC</td><td>2021- 2025</td><td>SMC, CREDAI, Industries Associations

(SMC area level)</td><td>110</td></tr>
<tr><td colspan="5">Remarks: RMC is beneficial for easing out the process of concrete preparation. From procurement to the point of transportation of RMCs for the construction site, INR 21 lakhs will be spent per year, with an additional INR 1 lakh for parallel work. RMC unquestionably reduces costing at the mixing stage by involving fewer human resources; it takes laborers to transport the bags from one point to another.</td></tr>
<tr><td>9.</td><td>Air Quality Index Alert System (AQ-IAS) through SMAC center</td><td>2021-2025</td><td>SMC, GPCB, CREDAI, Competent Agency

(SMC area level and applicable to all construction sites)</td><td>12</td></tr>
<tr><td colspan="5">Remarks: This mitigation measure will have an AQ-IAS system establishment at INR 12 lakhs/each, with automated sensors at the construction site for providing data feed on microclimate. A part of the cost for this mitigation measure will be directed to the project-based cost of a central command center.</td></tr>
<tr><td>10.</td><td>Engineering Controls Monitoring and Retrofitting</td><td>2021- 2025</td><td>CREDAI, GPCB, SMC and Competent Person/ Agency

(Applicable to all construction sites)</td><td>45</td></tr>
<tr><td colspan="5">Remarks: Engineering controls are small, mechanized tools that employ suction or dilution principles to reduce the concentration of particulate matter at the source. For the Indian-made engineering controls such as blowers, industrial fans, exhaust fans, and local exhaust ventilation to be employed at the loading-unloading and mixing places at any construction site, INR 8 lakhs/year will have to be spent along with INR 1 lakh/year as support cost.</td></tr>
<tr><td>11.</td><td>HRV Assessment of Off-site communities surrounding construction sites</td><td>2021- 2025</td><td>CREDAI, Competent Person/Agency

(SMC area level and applicable to all construction sites)</td><td>30</td></tr>
<tr><td colspan="5">Remarks: HRVA will have a cost implication of INR 5 lakhs/year and an additional INR 1 lakh/year as a parallel cost.</td></tr>
<tr><td>12.</td><td>Formation of central command centre</td><td>2021-2025</td><td>CREDAI, SMC, GPCB

(SMC area level)</td><td>45</td></tr>
<tr><td colspan="5">Remarks: The roles and responsibilities have been explained in 7.7.3. The costs are meant for the administrative controls and hiring of the competent person and agency.</td></tr>
<tr><td>13.</td><td>Increasing Monitoring Capacity by CAAQMS</td><td>2021- 2030</td><td>GPCB, SMC, CREDAI

(SMC area level)</td><td>150</td></tr>
<tr><td colspan="5">Remarks: An anticipated 5 CAAQMS stations will be networked to the main monitoring SMAC center algorithm every year, with the financial collaboration of SMC, GPCB, and CREDAI for a time span of 5 years as an expansion of monitoring capacity in the SMC area at a unit cost of INR 5 lakhs for one-time investment. INR 25 lakhs is anticipated to be spent for another 5 years, from 2025 to 2030, as support costs for maintaining the procured monitoring stations.</td></tr>
</table>

A total of **INR 7.17 crore** will have to be spent on dust mitigation measures at the construction site over a period of five years. However, most of these costs will be channelized by the coordinated efforts of GPCB, SMC, and CREDAI Surat chapter. Specific projects will have to be identified to evaluate these physical measures in the behavior of construction sector professionals, which have been mentioned in **Annexure 8**.

7.9.2. Health Risk Assessment

Mortality from $PM_{2.5}$ emissions in the construction sector has been discussed in **Chapter 3**; in the average annual contribution of 2% of PM2.5, construction adds 21 premature deaths in the SMC area, considering the current situation wherein no additional mitigation measures exist. To avert this premature death, a reduction in construction dust exposure can be achieved through the proposed mitigation mechanisms.

7.10. SCENARIO BUILDING

Business-as-usual (BAU) indicates the main criterion for sectoral progress would be the investment in response to the high demand for residential and commercial properties in the SMC area. To meet this demand, the spatial scope of the city is being updated; thus, it is essential to focus on internalizing the clean construction practices into the daily planning of the construction activities in the SMC area. Considering more and more people would own property in the post-pandemic economic rise, there will be a higher demand for infrastructure, which would need to be met. Projects such as the SCAP is a turning point wherein, for the first time, agencies such as CREDAI Surat have been involved in reducing sectoral emissions from construction processes. In addition, as indicated in **Table 31,** $PM_{2.5}$ was found to be 0.29 kt for 2019, which is a significant amount and signals the possibility of burdening the SMC area's public health system, which has already faced severity due to the Covid-19 response in 2020-21. Considering this, an assessment has been done based on the BAU scenario for the years 2019-20, and scenarios are based on the best practices in planning daily construction processes following the launch of the SCAP project.

Table 31: BAU with future scenarios at 3.9% investment growth rate in the sector for the SMC area

Year	PM10 (kt)		PM2.5 (kt)	
	City	District	City	District
2019	1.67	3.19	0.29	0.55
2025	2.00	3.82	0.35	0.66
2030	2.33	4.45	0.40	0.77

Scenario: Business-As-Usual (BAU)

Scenario considerations: The current BAU scenario growth at 3.9% CAGR in the sectoral investment has been considered. Since the SMC area is one of the fastest-growing areas in Gujarat, with no mitigation or regulation in sight, no reductions for the construction area used have been considered for the projections. In the BAU, only business-oriented expansions will occur for the 5th change year

(2025) and the 10th change year (2030), and minimal sustainable construction practices will be adopted. However, the SMC could enact projects such as the SCAP in 2021. This will increase emissions in the sector, with 5% of baseline emissions reaching 0.2606 kt/year in 2030 for PM_{10} and 0.453 kt/year for $PM_{2.5}$.

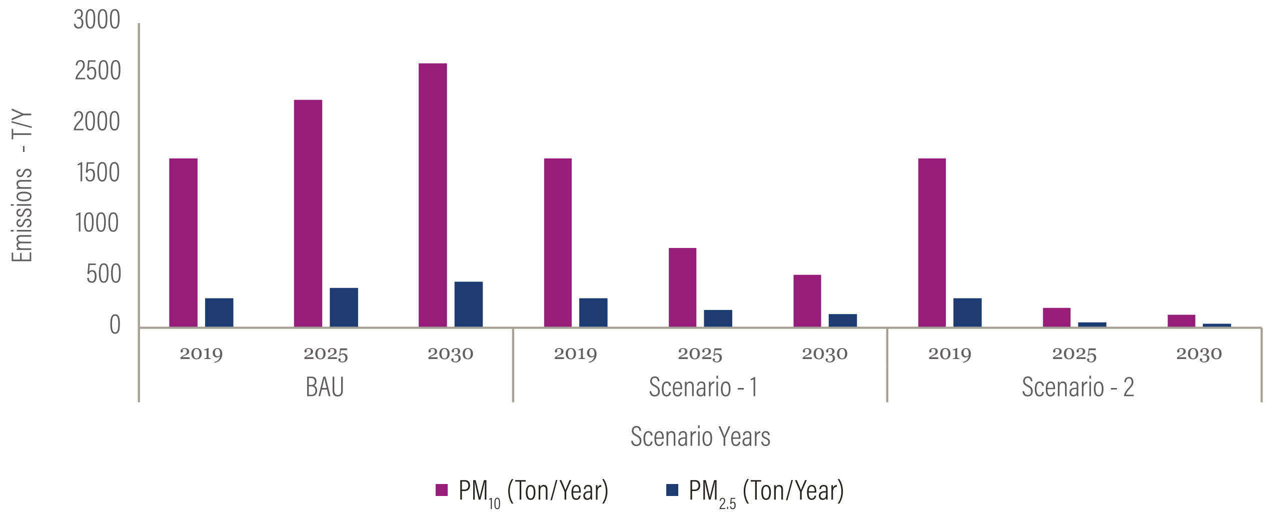
Scenario 1: Mitigative change: SCAP recommendations introduced and follow-up implementation of an extension project to enhance monitoring mechanism enhancement of SMC area

Scenario considerations: As part of the SCAP project, the first knowledge product titled 'The Handbook of Clean Construction Practices 2020 for Surat' was introduced in 2020, and its recommendations will be implemented in 2021. In 2021, as part of the SCAP project, the focus would be placed on sustainable construction practices and the channelization of efforts to strengthen the monitoring mechanisms of SMC and GPCB. By the year 2022, as per the inputs provided in the SCAP project, SMC and GPCB will commence the implementation of measures, including the operationalization of CCC and initiation of activities and the formation of Dust Control Group with strict monitoring protocols, with 75% coverage of construction sites in the SMC area by the year 2025. The monitoring protocol will also ensure that decentralized power sources – introduction and subsequent enhancement under the state's Renewable Energy Policy – are employed. First, 25% coverage of the total construction site will be ensured by 2026. It is expected that the CCC will cover 80% of the construction sites by 2026 in the area as a parallel authority and that the recommendations in the handbook of clean construction practices for Surat 2020 will be stricter for the contractors. By 2025, a 35% reduction in $PM_{2.5}$ from BAU and a 45% reduction in $PM_{2.5}$ from BAU by 2030 will be observed.

Scenario 2: Mitigative change: More awareness for conserving adaptation measures would result in retrofitting technology, clean fuel alterations, and strict adherence to IGBC norms.

Scenario considerations: In a lenient implementation for the extension of the SCAP project, the main stakeholders will have a 'human resource strengthening and capacity building approach' instead of putting restrictions on the contracting agencies. As a part of this, by mid of 2022, SMC, in collaboration with GPCB and technical support partner, will erect a pilot best practices site wherein monitoring module will be implemented in a 'case control' manner on government-owned construction sites as per the SoPs displayed in the CCP Surat Volume 2 (anticipated to be published by 2025) by 2026. CREDAI will ensure that all the SoPs authenticated from the pilot site will be internalized in the daily activities of the construction companies and contracting agencies. In addition to this, by the year 2027, to maintain the LEED Platinum Star title for the majority of the INR 100 Cr plus projects, a collaborative action research-based monitoring and evaluation module will be developed by the SMC+GPCB+Technical Support Unit. It will be ensured that SDG norms for developing physical infrastructure with the amalgamation of CCP Surat Handbook Volume 1 (yop 2021) and Volume 2 (yop 2025) would be enacted by 2028 to showcase the positive work of the clean construction practices SMC and GPCB are doing in the SMC area to the international platforms.

Figure 49: Emissions of various pollutants under different scenarios for years 2025 and 2030



As an extension to the above considerations, strict conservation of green area policy enactment for urban areas under Urban Forest Scheme (2020) will be ensured in other 5 patches in the south and southwest zones of the SMC, which will also support the success stories of the Oxygen Park Project under the Surat Smart City Mission by SSCDL. As a midterm evaluation conducted in 2025 of these adaptation activities to conserve 'mature green cover,' an impact assessment will also be done by the end of 2028 to evaluate green cover enhancement and its effect on the construction dust dispersion. The latter will be supported by the strict enactment of the monitoring module (implementation initiation in 2021), which would have covered almost 90% of the construction processes happening in the SMC area. To ensure maximum professional participation under this scenario, a 100% coverage of labor laws through the Gujarat Factories Rules 1963 for all government-owned construction activities and 60% for sites owned by private builders will be ensured by 2030. Wherein 100% of new construction activities from 2025 to 2030, will have to observe technology retrofitting or development with respect to the installation of engineering control and subsequent capacity building activities. As an anticipated achievement, there will be a 35% reduction in $PM_{2.5}$ from BAU by 2025 and a 45% reduction in PM_{10} from BAU by 2025. Further reductions in $PM_{2.5}$ and PM_{10} from BAU to 75% and 95%, respectively, by 2030 through implementing the above mitigation considerations. These emissions are presented in consolidation in **Figure 49.**

7.11. CONCLUSION

As per the source apportionment study, the construction sector accounts for 2% of the PM2.5 emissions in the SMC area. In the case of construction, the particulate matter affects the on-site worker population and those living in the vicinity of the construction site. Depending upon the nature of expansion in the SMC area, residential and commercial physical infrastructure will be in demand vastly. With interventions such as CCP Handbook 2020, the sector can draw up a regularized monitoring protocol for construction sites, reducing 45% particulate matter emissions in 5 years and 75% emissions reduction in $PM_{2.5}$ by the year 2030. In addition, administrative controls such as implementing IGBC norms will also ensure safe and clean construction practices for the SMC area in the future. However, for the city's south, southwest, and north zone expansions, a more regularized approach needs to be adopted through the proposed measures. These three zones are experiencing heavy residential and commercial expansion due to the unique social and economic situation here, including livelihood opportunities that attract a heavy influx of migrant population. Regulation under the affordable housing schemes can ensure that the emissions from the construction sector are recognized, provided the initiatives such as CCP Guidelines for Surat 2020 are followed. There is also a high potential for institutional collaborations between authorities such as SMC, GPCB, and CREDAI (Surat Chapter) for the SMC area to reduce particulate matter by 2030.

CHAPTER 08

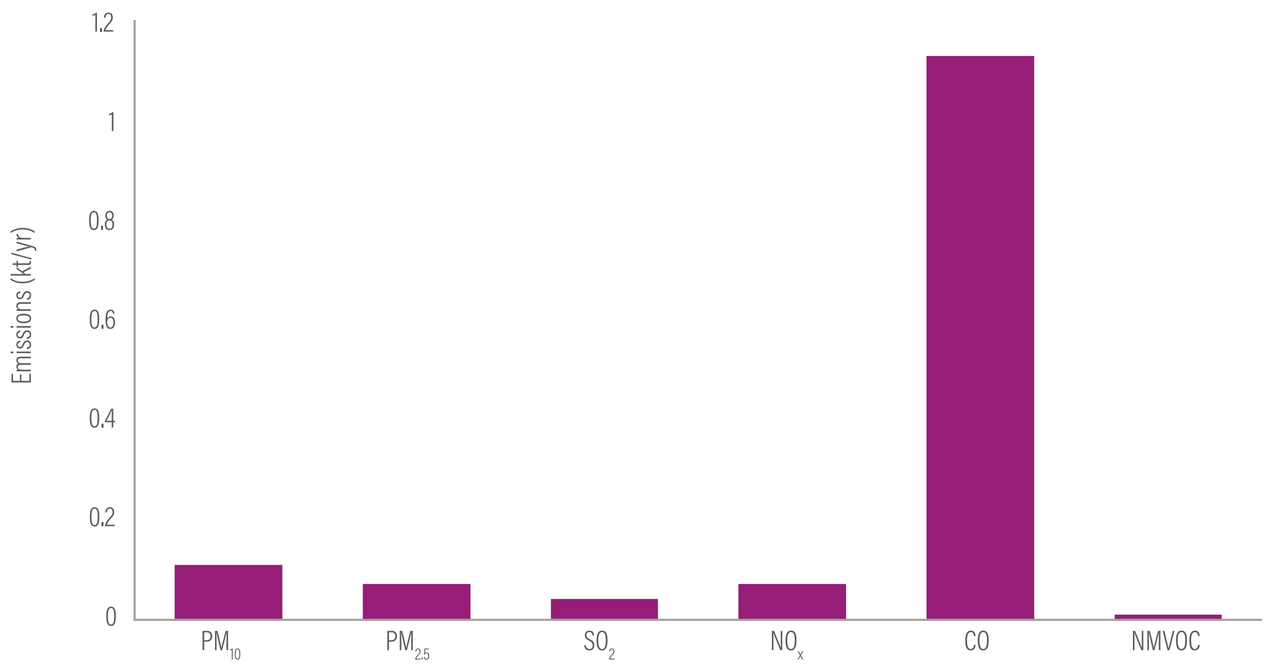
EATERIES, HOTELS AND RESTAURANTS

8.1. EMISSION INVENTORY – EATERIES SECTOR

With increasing population, migration for employment, industrial growth, and urbanization, the food service industry in Indian cities has observed significant growth. The food service industry includes formal and informal restaurants and eateries. Informal eateries are small in size and have either fewer or no permanent structures. These could be food kiosks, stalls, serving booths, pushcarts (*thela*), food vans, small-sized bakeries, sweets, snacks shops that may or may not have seating arrangements, and where people pay and have their meals either sitting inside the premises or standing outside. In general, formal and informal restaurants and eateries use firewood, coal, electricity, kerosene, and LPG for cooking. There is, however, no or limited data available about the use of different types of clean or polluting fuels in formal and informal restaurants and eateries and their contribution to air pollution in Indian cities, including the SMC area.

To develop clean air strategies for formal and informal restaurants and eateries, the steps in this study included a primary survey of restaurants and eateries in the SMC area to obtain fuel use data. Based on the primary survey and available secondary data, WRI India and TERI estimated the air pollution emissions from restaurants and eateries for the SMC area **(Chapter 2)**. The analysis indicated that in the SMC area, restaurants and eateries contributed about 0.073 kt, 0.111 kt, 0.042 kt, 0.072 kt, 1.14 kt, and 0.01 kt of $PM_{2.5}$, $PM_{10,}$ SO_2, $NO_{X,}$ CO, and NMVOC emissions, respectively, in the year 2019 (**Figure 50**). The details of data collection and clean air strategies for SMC area formal and informal restaurants and eateries are discussed in the next section.

Figure 50: Estimated emissions of $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, and NMVOC from small eateries, restaurants, and hotels in the SMC area (Source: TERI, 2021)



As per the source apportionment study, the highest PM_{10} and $PM_{2.5}$ were observed in industrial and commercial monitoring locations, which could be attributed to the coal usage in the nearby restaurants. Similarly, due to the use of wood, coal, and charcoal in restaurants/*dhaba*s and small eateries located in the vicinity of the residential-1 monitoring site, high PM_{10} and $PM_{2.5}$ were observed.

8.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR

To understand the current fuel use pattern in formal and informal restaurants and eateries and their contribution to air pollution in the SMC area and to develop air pollution mitigation strategies, we first conducted a literature review. The literature review showed that only a limited number of studies had assessed current fuel use patterns and air pollution emissions from this sector. The Indian Institute of Technology (IIT-Kanpur) study[76] found that in Delhi, tandoors used in hotels/restaurants were the dominant emission sources under commercial activities in 2016. A source apportionment study conducted in Kolkata indicates a contribution of 5% of $PM_{2.5}$ from roadside eateries and restaurants in the city's air pollution[77]. However, no studies estimate the contribution of formal and informal restaurants and eateries in the SMC area.

8.3. MAJOR ISSUES RELEVANT TO THE SECTOR

Limited literature and data gaps were found during the analysis of primary and secondary data sources. In order to obtain current data, a primary survey of small eateries was conducted by WRI India to assess the current fuel usage pattern and structure of eateries in the SMC area.

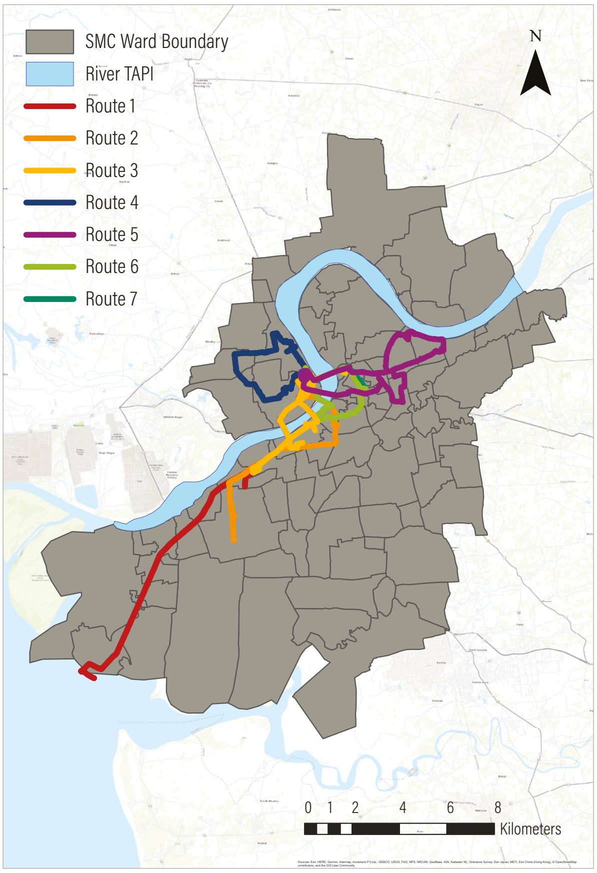
8.4. PRIMARY SURVEY OF SMALL EATERIES

WRI India conducted a transect line-based survey to collect data on the fuel use pattern and other characteristics of different restaurants and eateries in the SMC area. Different representative routes were first designed to collect the data based on the SMC area's land use pattern, accessibility, food service market, and socio-economic characteristics (**Figure 51**). SMC areas such as Chowpatty at Athwalines, Dumas beach, Dumas road, Night Bazar Piplod, Khaudra Gali at the old city, Adajan, Rander, Vesu, Nanpura, Sagrampura, Salbatpura, Wadifaliya, and other areas are covered in different transect routes (**Figure 51**). After designing the transect routes, a survey was conducted in the eateries along the transect routes using a questionnaire. Refer to **Annexure 4** for the data collection format.

[76] Sharma, M., & Dikshit, O. (2016). Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component). IIT Kanpur, Delhi Pollution Control Committee and Department of Environment.

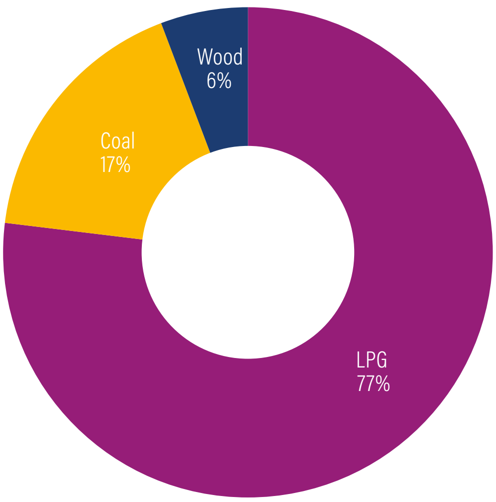
[77] CSIR-National Environmental Engineering Research Institute. (2019, December). Source Apportionment Study and Development of Emission Inventory of Twin Cities Kolkata and Howrah of West Bengal.

Figure 51: Transect routes used to conduct a primary survey of restaurants and eateries in the SMC area



The survey results indicated that out of the total surveyed eateries, 77% use LPG as primary cooking fuel, followed by coal (17%) and firewood (6%) (**Figure 52**). The use of coal and fuel wood in small eateries at central locations of the city was observed during the primary survey. Other than the WRI primary survey, TERI too carried out a questionnaire-based primary survey at 12 different grids in the Surat district, including the SMC area, to know the type of fuel used in large hotels and restaurants. The data from both surveys were extrapolated to all city-based restaurants and eateries data. The data was also used to estimate the energy consumption in the sectors and air pollution emissions.

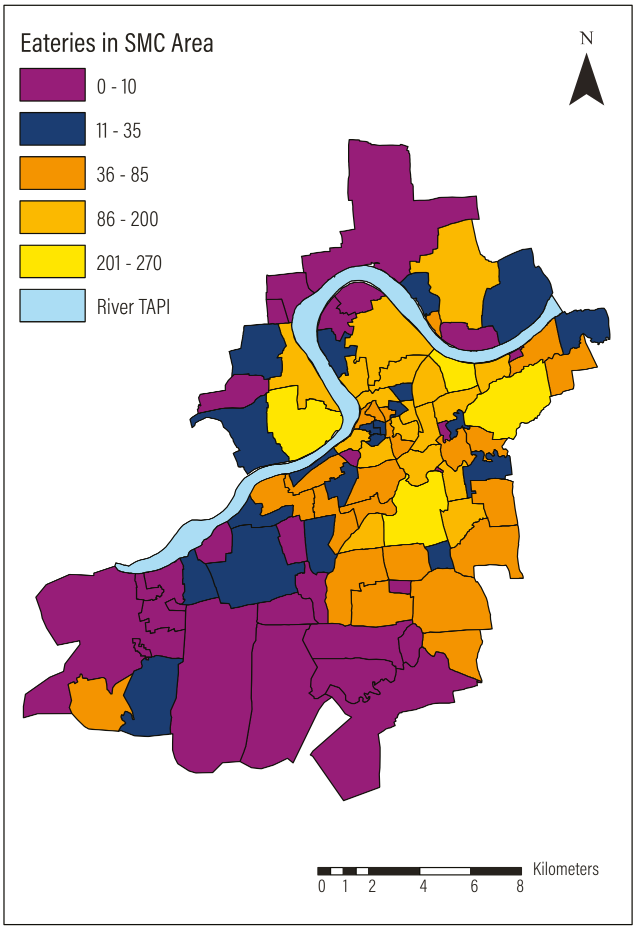
Figure 52: Percentage of small eateries using different types of fuel in the SMC area



8.4.1. Mapping Restaurants and Eateries in the SMC Area

To identify the areas with the number of different restaurants and eateries in different SMC wards, a detailed analysis of secondary data was conducted. The data from the Economic Census of India (2013-14) was extracted and mapped for all the wards. The analysis revealed that there are a total of 4,792 eateries and restaurants in the SMC area[78] (**Figure 53**).

Figure 53: Number of eateries, restaurant, dhabas and food service units in the SMC area



8.5. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

There are very few policies for formal and informal restaurants in Indian cities, especially those focusing on air pollution mitigation from the sector. However, a few state-specific policies do exist, as listed below:

[78] *Economic census of India, (2013-2014). India: Ministry of Statistics & Programme Implementation. MoSPI, (2019). Central Statistics Office, Ministry of Statistics and Programme Implementation.*

- The state Forest and Environment Department of Odisha banned raw coal in hotels and *dhaba*s in the five districts, namely Dhenkanal, Sambalpur, Angul, Jharsuguda, and Sundargarh, to mitigate air pollution levels from the source[79].

- The National Green Tribunal (NGT) ordered[80] restaurants and eateries in Murthal in Haryana to obtain the Haryana State Pollution Control Board (HSPCB) approval as per state policy for air pollution mitigation options. The compliance order of NGT related to air pollution includes the following two points:
  - Fugitive emissions should be appropriately channelized, including cooking and kitchen operations emissions, by providing a proper ducting and exhaust system. The restaurants must install APCDs such as grease filters.
  - Provide a stack for the emissions from the generator set, and the stack height is to be maintained as per the environmental standard prescribed by CPCB.

- Based on the recommendations of an air pollution source apportionment study of Delhi and NCR conducted in the year 2016, the Government of Delhi decided to provide a subsidy of either 50% of the cost or INR 5,000 per tandoor to registered eateries in Delhi as an incentive to motivate them to shift from coal-based tandoor to an electric or gas-based one[81].

Challenges: There are very few policies on mitigating air pollution from formal and informal restaurants and eateries, especially in the SMC area.

8.6. CONTROL MEASURES IDENTIFIED DURING OPPORTUNTIY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

During the primary survey and one-to-one interviews with various stakeholders, it was found that coal and fuel wood continues to be used for cooking in small eateries in some parts of the city. There is a need to create awareness among vendors to register their small eateries to implement policies and interventions in a more defined manner. Bakeries and some of the restaurants in the SMC area using coal for commercial cooking purposes should install APCDs with proper channelization of fugitive emissions. Coal and fuel wood-based tandoors should be replaced with electric-based tandoors. These points were considered while formulating the interventions for the eateries sector, as discussed in the following section.

[79] Mohapatra, D. (2017, March 22). Dhabas to feel heat for cooking in coal fire. The Times of India. https://timesofindia.indiatimes.com/city/bhubaneswar/dhabas-to-feel-heat-for-cooking-in-coal-fire/articleshow/57770669.cms.

[80] Hon'ble NGT order. (2019). Compliance of Environmental Norms by roadside eateries/restaurants and other establishments, In Compliance with the Hon'ble NGT order dated 25.11.2019 in the matter of O.A no.26/2019, Abhay Dahiya & Others v/s State of Haryana'. CPCB.

[81] DPCC. (2018). Office Order no. DPCC/RDPC/Subsidy-Tandoor/2018/2141 dated 28/09/2018 to Grant of subsidy to restaurants/Eating Houses/Banquet Halls/Hotels for Replacing/Conversion of their Coal-based Tandoors with Electricity or Gas based Tandoors. Delhi Pollution Control Board.

8.7. STRATEGIES TO MITIGATE AIR POLLUTION

- **Inventorization of formal and informal restaurants and eateries:** Based on the analysis of available data and literature, it was observed no formal data in the form of detailed characteristics of formal and informal restaurant eateries is currently available for the SMC area. There is an urgent need to develop a detailed inventory of both formal and informal eateries. This inventory will help understand the current fuel use patterns and hot spot identification of the sector. In addition, the inventories of all formal and informal eateries must be updated every two to three years to understand the progress and efficiency in implementing various policies in the sector. The inventory can be created by registering the unit or conducting a survey on current regulatory and administrative conditions. The database must include the following information:
    - Type of eatery - formal or informal
    - Structure of shop (permanent or temporary)
    - Place of eatery - fixed or non-fixed, Sitting capacity
    - Monthly income
    - Monthly expenditure
    - Types of fuel use
    - Quantity of fuel use
    - Expenditure on the fuel use
    - Location of eatery
    - Number of staff in the eateries
    - Type/s of food served
    - Type/s of cooking techniques (frying, boiling, barbeque, etc.)

- **Replacement of polluting cooking fuel with clean cooking fuels:** The primary survey revealed that about 23% of small restaurants and eateries use firewood and coal to cook and heat. To mitigate the air pollution emissions from eateries, there is a need to target the eateries and restaurants that use these fuels. During the survey, we observed that many of the small eateries' vendors could not afford LPG. The government can introduce subsidies/incentives under schemes such as Pradhan Mantri Ujjwala Yojana (PMUY) and LPG/PNG Sahay Subsidy Scheme for poor vendors.

- **Channelization of fugitive emissions**: There should be stringent norms for large hotels and restaurants to use pollution control devices, with proper channelization of fugitive emissions through exhaust systems and chimneys.

- **Decongestion and regulation of eateries**: To ensure proper ventilation, small eateries should be located in open spaces and not in narrow and congested roads and markets. Street hawkers engaged in barbecuing, grilling, and frying on movable stalls should not park in confined marketplaces and localities.

- **Promotion of LPG and electric-based tandoor:** Many hotels and restaurants continue to use coal and firewood-based tandoors**.** Those restaurants can be motivated through awareness drives to replace their old tandoor with electric and LPG-based tandoor.

Table 32: Proposed mitigation strategies

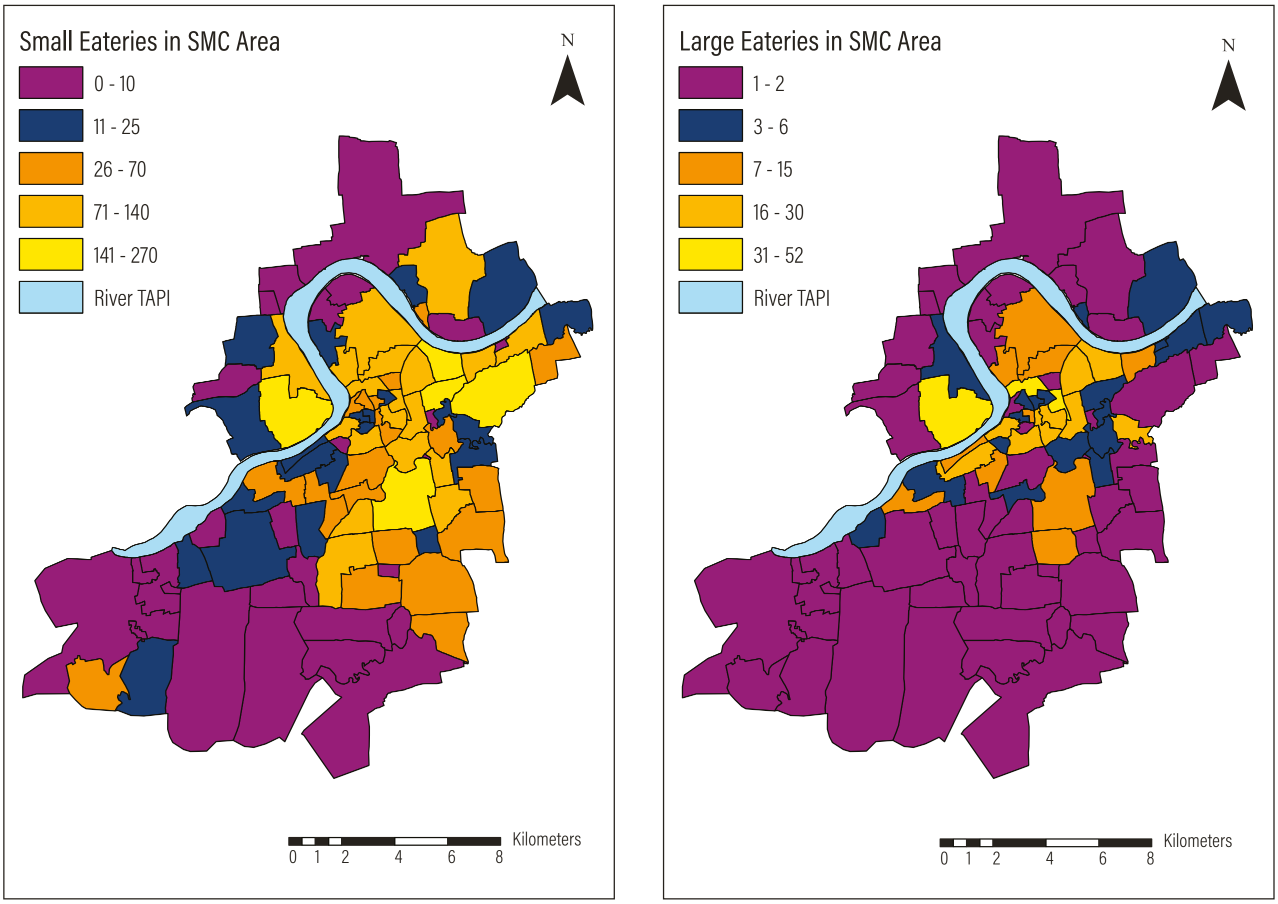
Sr.No.	Mitigation Strategies	Target			Proposed Agency for Implementation
		2022	2025	2030	
1.	**Inventorization of all formal and informal eateries**				
1.1.	Survey/registration and inventory of all formal and informal eateries of SMC	Short-but repeat every 3-5 years			SMC/Any survey agencies
2.	**Change from polluting fuel to clean fuel**				
2.1.	Create awareness among eateries owners to use clean fuel		Medium		SMC and District Administration
2.2	Provide LPG connection/refill under the schemes such as PMUY and LPG/PNG Sahay Subsidy			Long	SMC and Gujarat Govern-ment
3.	**Use pollution control devices**				
3.1.	The use of pollution control devices and proper exhaust systems should be made compulsory for restaurants		Medium		SMC
4.	**Decongest and regulate eateries**				
4.1	Regulate eateries along the curbside, espe-cially small eateries, to avoid congestion	Continuous			SMC City Traffic Dept
5.	**Promotion of interventions related to clean fuel technology**				
5.1.	Promote the use of LPG and electric tandoor/ stoves through an awareness drive	Short			SMC
6.	**Detailed emissions inventory of eateries**				
6.1	Inclusion of Eateries, restaurants, and hotels emissions along with other sources of air pollution	Short			GPCB

Creating inventories of formal and informal eateries in the SMC area is a project that has been identified under SCAP **(Annexure 8)**.

8.8. MICRO-LEVEL PLAN TO MITIGATE THE STRATEGIES

To identify the focus area with respect to implementing clean air strategies in the SMC area, we have mapped the small and large eateries having less than five and more than five employees (**Figure 54**), respectively. As coal and firewood burning is mostly observed in small eateries, the areas where small eateries are operating in large numbers can be focused upon first. With respect to awareness building, inventory development, and policy implementation, the yellow colored wards highlighted in the map (**Figure 55**) can be the influence areas where the interventions proposed in the SCAP and robust action plan of GPCB can be initiated. The identified wards are Nanpura, Sagrampura, Begumpura, Haripura, Saiyadpura, Rander, Adajan, TPS - 3 Katargam Gotalawadi, TPS - 4 Ashvanikuma Navagam, TPS - 7 Anjana, TPS - 8 Umarwada, Tunki, Katargam, Fulpada, Kapadra, Karanj, Limbayat, Dindoli, Udhana, Bamroli, Kosad, and Puna.

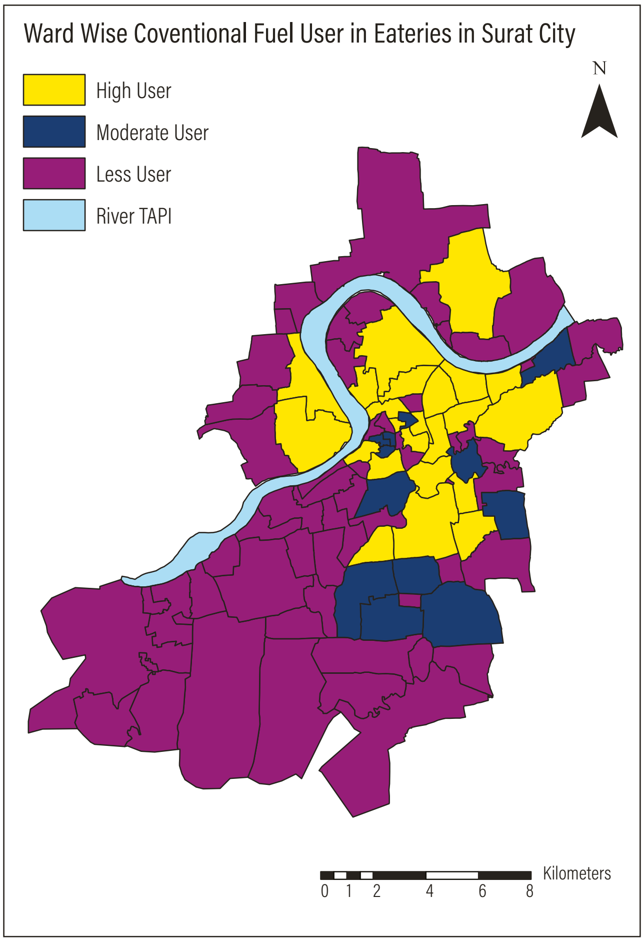
Figure 54: Number of small (less than five employees) and large (more than five employees) eateries in the SMC area



Mitigation Measures:

- Ensure the promotion and use of cleaner fuel (i.e., LPG) instead of coal-fired *chulha*s or firewood in hotels and open spaces.
- Introduce schemes for subsidizing LPG connections and provide finance to small tea vendors/ hawkers for using kerosene stoves to reduce emissions from kerosene burning.
- Mandate the use of LPG in commercial eateries.
- Mandate the use of LPG/electric in bakeries.
- Efforts are needed to provide incentives/subsidies to eateries to switch to LPG, and schemes like PMUY and LPG/PNG Sahay Subsidy Scheme should be extended to street food vendors.
- Increase awareness of the adverse health effects of using coal for cooking to discourage people from using polluting fuels.

Figure 55: Micro area planning map of the eateries sector



8.9. TECHNO-ECONOMIC ANALYSIS

The contribution of formal and informal eateries in the overall air pollution in the SMC area is comparatively less than that of other sectors; therefore, it is difficult to know the absolute number of health risks associated with emissions from this sector. The rough cost of the different proposed interventions to mitigate air pollution from formal and informal eateries was estimated. As discussed in the recommendations, subsidies can be provided to the eateries that use coal and firewood in the SMC area. A rough cost of providing LPG connections with subsidies was estimated for 23% of eateries using coal and firewood (as indicated in **Figure 52**). The cost of providing a new LPG connection is estimated to be similar to the cost of LPG under PMUY, which is INR 1,600 (includes security deposit for LPG cylinder, pressure regulator and installation charges, etc.), and an additional cost of refilling cylinder for the first time (INR 517[82]). The introduction of schemes similar to PMUY and LPG/PNG Sahay Subsidy for small eateries/street food vendors will encourage them to shift from using polluting fuels to clean fuel. Considering this a governing factor, approximately 50% of the eateries using coal and firewood are estimated to have shifted towards LPG by 2025 and 90% by 2030. The rough cost of subsidy incurred by the government for providing LPG to eateries using coal and firewood is estimated to be approximately INR 0.44 crore (**Table 33**), which may be revised with improved data.

[82] *Ministry of Petroleum and Natural Gas. (2019). Report of the Comptroller and Auditor General of India on Pradhan Mantri Ujjwala Yojana: (Performance Audit) (No. 14 of 2019). Comptroller and Auditor General of India.*

Table 33: Economic implication of proposed policies and programs – Eateries

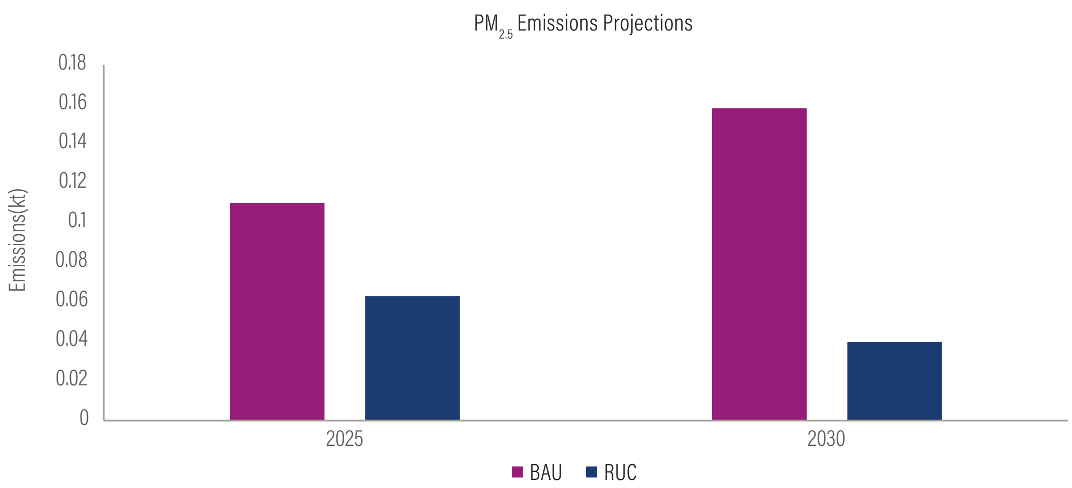
Sr. No.	Proposed Policy or Criteria	Implementation Time	Responsible Agency / Stakeholder	Subsidy (INR crore)		Expected Outcome
				2025	2030	
1.	Change from conventional to clean fuel	2021-2030	SMC, District administration, and Gujarat Govt.	0.25	0.19	Reduced emissions from eateries and they are shifting towards leaner fuel LPG
2.	Inventorization of eateries and awareness drive	2021-2030	SMC	Survey and awareness drive cost (INR crore)		
				2025	2030	
				0.03	0.04	

During the literature review in this study, it was found that data on the detailed characteristics of formal and informal restaurants and eateries was unavailable. The inventorization of all formal and informal eateries is found to be necessary, which can be done through a door-to-door survey to understand fuel use patterns, target issues, and recommendations of new mitigation measures. This type of survey can be repeated periodically, every 3-5 years (details of costing available at **Annexure 7**). LPG or electric-based tandoor/stoves should be promoted in those restaurants and eateries that can afford these but continue to use coal. While performing inventory surveys in the SMC area, awareness on using LPG can be generated by the surveyor/volunteer.

8.10. SCENARIO GENERATION

Reduce the usage of conventional fuel – Coal and wood: The scenarios were generated after considering a reduction in emissions resulting from the implementation of the proposed interventions from 2021 to 2030. Assuming that all the proposed interventions would be implemented, it was estimated that approximately 50% of eateries using coal and firewood would completely shift to LPG by 2025 and 90% by 2030. A reduction is visible in $PM_{2.5}$ in the Reduce Usage of Conventional Fuel (RUC) scenario compared with the BAU scenario for both 2025 and 2030 (**Figure 56**).

Figure 56: Estimated emissions of PM2.5, BAU scenario and reduced usage of conventional fuel (RUC) scenario for the years 2025 and 2030



8.11. CONCLUSION

There is no or limited data on the eateries and restaurant sector, which is why it is mostly not included in the emission inventories of urban areas. The primary data suggest that 23% of eateries use coal and fuel wood, and 77% use LPG for commercial cooking; hence, shifting from coal and fuel wood to LPG is necessary. The provision of subsidy/incentives is necessary for shifting from coal and fuel wood to LPG for small eateries as they cannot afford clean fuel. It is assumed that a reduction of 43% can be achieved in 2025 as per the RUC scenario as compared with BAU.

CHAPTER 09

>> TRANSPORTATION

9.1. EMISSION INVENTORY – TRANSPORTATION SECTOR

Estimated PM_{10}, $PM_{2.5}$, NOx, and CO emissions from the transportation sector in the SMC area are shown in **Figure 57** and **Figure 58**. As illustrated, 2-wheelers (42%) followed by trucks (24%), light commercial vehicles (LCVs) (11%), and 3-wheelers (7%) are the major contributors of particulate matter emissions. Trucks (32%) are the major contributors to NO_x emissions in the SMC area, followed by 2-wheelers (20%) and 3-wheelers (11%). A total of 4.31 kt/year of PM_{10}, 4.18 kt/year of $PM_{2.5}$ and 32.87 kt/year of NO_x are released from the SMC area's transportation sector.

Figure 57: PM_{10} and $PM_{2.5}$ emissions from the transport sector

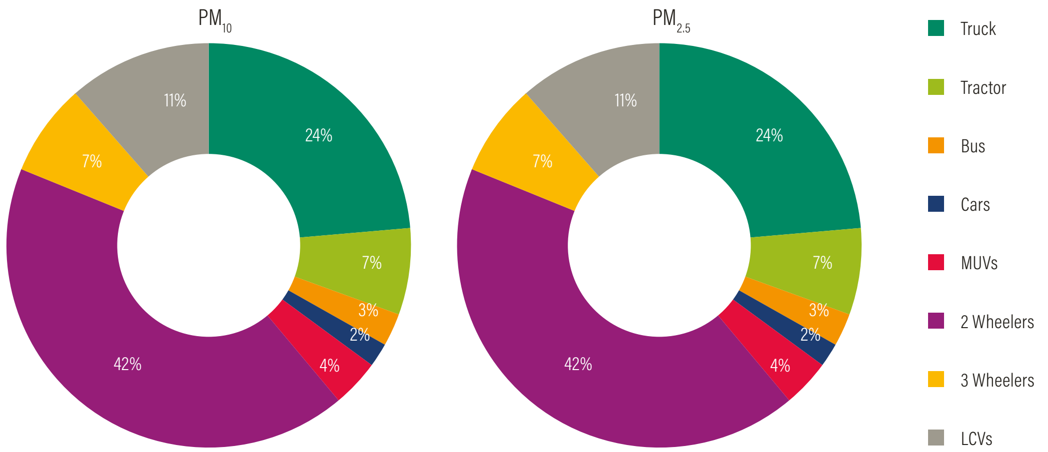
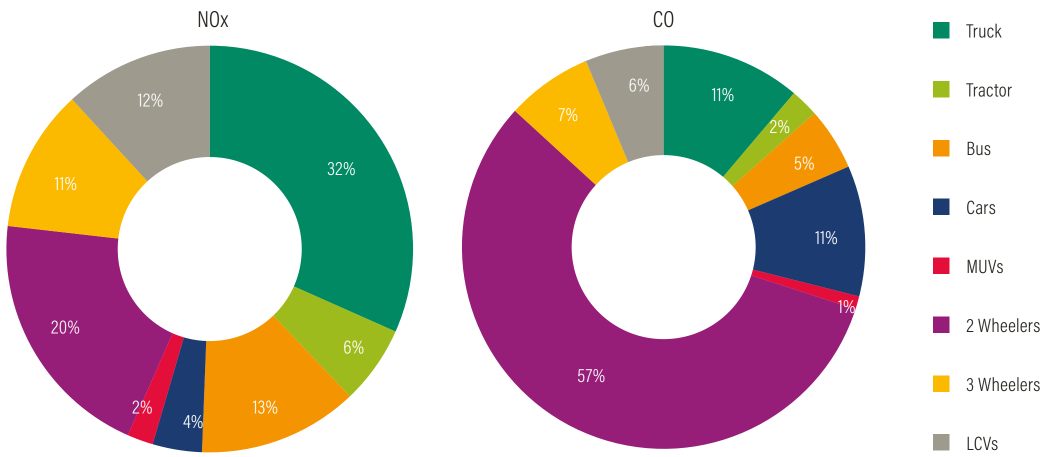


Figure 58: CO and NO_x emissions from the transport sector



The source apportionment study using receptor modeling and dispersion modeling revealed the $PM_{2.5}$ and PM_{10} contributed by the transportation sector in the summer and winter seasons. As per the dispersion model, the sector contributed $PM_{2.5}$ concentrations of 6% in summers and 16% in winters, while it was 5% in summers and 16% in winters according to the receptor model. It is important to note that the sectoral contribution of the transportation sector adds a significant amount to non-exhaust emissions too, which has been explained in **Chapter 10**.

9.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR

The SMC area is well connected with two national highways (NH-8 and NH-53) and six state highways (SH- 6, SH-167, SH-168, SH-169, SH-170, and SH-602). As these highways pass through the city of Surat, the volume of traffic entering the city is very high. The city's transportation system is predominantly road-based. The road network of the SMC area is around 1,914 km long. Although roads are generally wide, network design and development are not complete. The SMC area has a high motorization rate. The number of vehicles registered with the Surat Regional Transport Office (RTO) has risen from 0.62 lakh in 1980 to 30.09 lakh in March 2018. In the last five years alone, the growth in vehicles has been around 9% per year. In terms of the number and type of vehicles being registered, it is seen that 2-wheelers lead the growth followed by cars and 3-wheelers.

The SMC area is served by the busy North-South line of Western Railways connecting Gujarat with Mumbai and other important centers. Branches of the railway line serve areas of the Tapi district and the state of Madhya Pradesh. A dedicated goods line exists between Kosad and Hazira. The city is serviced by express, mail, passenger, and local trains. The mainline carries a high traffic volume due to the industrial belt between Ahmedabad and Mumbai and the seaports in Gujarat and Mumbai. The total broad-gauge network length in the study area is 94.32 km. Of the total 10 stations in the study area, five stations fall within the city. The main station (Surat railway station) is located just outside the walled city, abutting the ring road. The Udhana Railway Station is also an important transport node within the city. Bhesthan and Sachin railway stations towards the south of the city cater to the industrial areas of Pandesara, Unn, and Sachin. Uttran and Kosad in the northern part of the city across the Tapi river are not very significant as the development in this area is limited. The main station caters to 112 trains on an average daily (including up and down directions). Of these, 63 are daily trains. The SMC area's main railway station caters to 1.45 lakh passengers per day.

The Gujarat State Road Transport Corporation (GSRTC) operates passenger bus services within Gujarat and neighboring states. With about 398 routes and a total passenger capacity of about 15,000, Central Bus Station (CBS) near the Surat railway station is the central regional bus terminal that caters to more than 60% of the passenger traffic per day. Adajan is a new terminal that is expected to begin operating soon. Currently, it acts as an intermediate bus stop that caters to about 10,000 passengers daily. Udhna is the existing major intermediate station that acts as a terminal for passengers. It caters to about 4,500 passengers daily. Several express buses heading towards southern cities stop here. Kamrej is a significant location for intermediate stops, operates as a terminal for passengers, and is a stop for most of the express services heading towards northern cities.

Until 2004, the GSRTC operated the public transport service in the SMC area. Over the years, the routes served by the GSRTC increased, but fleet availability reduced drastically, and in May 2007, the GSRTC withdrew all urban bus operations. Later, in August 2007, private bus operations were introduced by Rainbow Tours and Travels Private Limited on a net cost contract under the supervision of SMC, which operated till August 2017. Currently, the city bus services and bus rapid transit services are being operated on a gross cost basis by Sitilink Ltd, SMC.

There are a total of 29 routes within the study area, with approximately 236 buses on the road. Bus routes are scheduled to operate at 8-20 minimum headway. Buses are serving an average of about 82,000 riders per day (February 2018). The buses for the city bus services are managed by Sitilink Ltd, a company owned by the SMC. These buses are midi buses and operated by private operators

(Aditnath, CSPL, and Maruti) on Gross Cost Contract (GCC). The city is also expecting an additional 300 midi buses, operated on City Bus Station (CBS) routes, in about three months. These would ply along the additional new city bus routes in the city, and some up-gradation in the frequencies of the existing 29 routes would be needed. Recently, the SMC area has prepared a Public Transport Operations Plan, which includes a proposal of about 550 km of the public transport network in which city bus services will be integrated with the Bus Rapid Transit System (BRTS) to be operated by Sitilink Ltd. A total of 1,000 buses are planned for this planned city bus network. Of this, 275 buses have arrived while 300 buses are expected to arrive in about three months. While currently, the city bus coverage is 73%, it is expected to cover almost 95% of the area when fully operational.

Sitilink, which inaugurated BRTS Phase I of 30 km in 2014, now operates the largest BRTS in India, with an operational network of 102 km. The BRT network currently attracts about 80,000 passengers per day. Sitilink BRTS connects major transit nodes, such as the railway station, the GSRTC terminal, residential and commercial hubs, recreational and public areas of the city, with provisions for Non-Motorised Transport (NMT) (pedestrian pathways and cycle tracks) along the corridors. The average speed of BRTS buses is 24 kmph, which is quite high as compared with the existing city bus services and auto-rickshaws. A high-quality bus operation is also underway along the 12 km Inner Ring Road, which will connect all the major radial and textile markets along the Ring Road. This corridor is being envisaged for 24-hour service, with 2-3 minutes headway during the day and 30 minutes during the night. In terms of public transport coverage, it is observed that about 87% of the SMC built-up area and about 59% of the total SMC area falls within 500 m of the catchment area of public transport.

The SMC area has been known for auto-rickshaw transportation for years. Currently, there are about 38,000 registered auto-rickshaw in the city. Most of the auto-rickshaws in the SMC area operate on fixed routes, with fixed fares based on distance. An absence of an efficient bus service has resulted in illegally operating auto-rickshaws providing point-to-point service. Around 8.6 lakh trips are being undertaken as per 2016 household surveys on these auto-rickshaws. There are about 52 shared auto-rickshaw routes identified as part of this study. The auto-rickshaws have unorganized operations and face issues of overloading and poor vehicle quality. They also contribute to congestion and pollution levels in the city. However, they offer a better frequency of service and coverage in comparison with the bus network.

The airport in the SMC area has made it to the 38th position in the list of top 50 busiest airports of India as per passenger traffic and aircraft movement in the year 2018-19. Airports Authority of India (AAI) data show passenger traffic in 2018-19 registered 81% growth. In 2018-19, 12.38 lakh passengers traveled to and from the airport in the SMC area against 6.81 lakh passengers in 2017-18. There are 76 flights on 15 different routes from this airport, connecting Surat city airbase to 15 different cities. The most popular routes connect the SMC area to Mumbai, Delhi, Bangalore, Chennai, and Hyderabad.

9.2.1. Existing Physical Infrastructure for Transportation Sector

The SMC has been regularly augmenting the infrastructure in the city. The SMC area is home to numerous flyovers and bridges across the Tapi river and its creeks. Several links are currently under construction, and many more are in the pipeline. The SMC area is the third urban agglomeration in Gujarat to have a BRTS, after Ahmedabad and Rajkot. While the BRTS in Ahmedabad is more popular and covers most locations in the city, SMC is testing new territory with the BRTS. As per the Comprehensive Mobility Plan (CMP) estimates and considering the growth trend observed in the SMC area, the city is expected to face significant challenges in urban mobility. Key challenges include the following

- It is forecast that by 2046, the SMC area will double its population, to 125 lakhs, compared with 2016 levels of 60 lakh.
- The number of personal vehicles (2-wheelers and cars) on the road is predicted to increase 2.9 times, from18 lakh in 2016 to 72 lakhs in 2046.
- The trip rate in the city is projected to increase 2.3 times, from 54.64 lakh passenger trips in 2016 to 125 lakh passenger trips by 2046.
- The congestion in the network in the city is predicted to increase from 14% to 57%.
- The city is predicted to experience a reduction in network speeds, from an average of 28 km/h to below 18 km/h.
- In turn, the average travel time in the city is projected to increase 2.6 times, from 13 minutes to about 34 minutes/trip.
- As a knock-on effect, the probability of accidents is also projected to increase 2.8 times.

9.2.2. Understanding Vehicular Population and Mode Share

As explained in the previous sections, the SMC area is well connected by road, rail, and air. Several national and state highways pass through the city, resulting in large volumes of traffic entering the city. The city's transportation system is predominantly road-based. Owing to the absence of an adequate public transport system in the city, dependence on individual modes and intermediate public transport is high. Although roads in the city are generally wide, network design and development are incomplete. **Table 34** details the vehicles registered in the SMC area during 2014-17 by vehicle type.

Table 34: Vehicle Registration in the SMC area during 2014-17 (Sources: Comprehensive Mobility Plan 2046; RTO data)

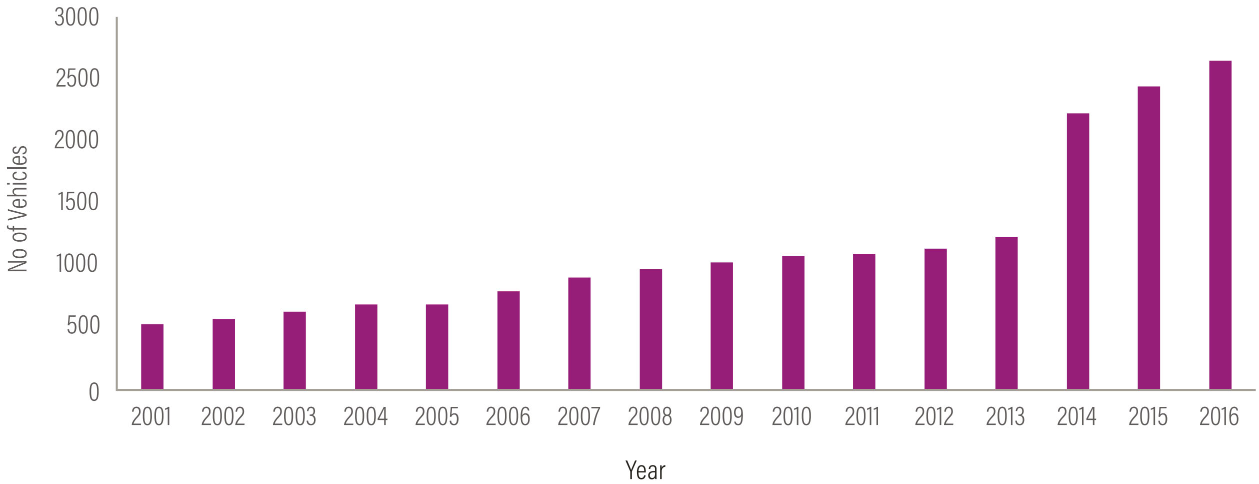
Sr.No.	Vehicle Category	Vehicle Type	2014	2015	2016	2017
1.	Goods Vehicle	Truck/ Lorries	1127	916	856	634
		Tanker	26	9	14	28
		Three Wheelers	2503	2335	2421	1632
		Other Light Weight	1986	2000	2170	1613
2.	Passenger Vehicles	Buses	234	243	590	130
		Maxi Cabs	31	33	30	17
		Cars	35785	35064	38667	31357
		Taxi	474	242	281	182
		Jeep	569	801	746	659
		Auto-rickshaw	3607	3666	3426	2066

Sr.No.	Vehicle Category	Vehicle Type	2014	2015	2016	2017
3.	2 wheelers	Motorcycle or Scooter	156066	148080	157883	124949
		Mopeds	11687	11966	12778	12251
4.	Tractors		667	360	547	455
5.	Trailers		37	167	169	76
6.	Others		187	225	218	121

Sources: Comprehensive Mobility Plan 2046; RTO data

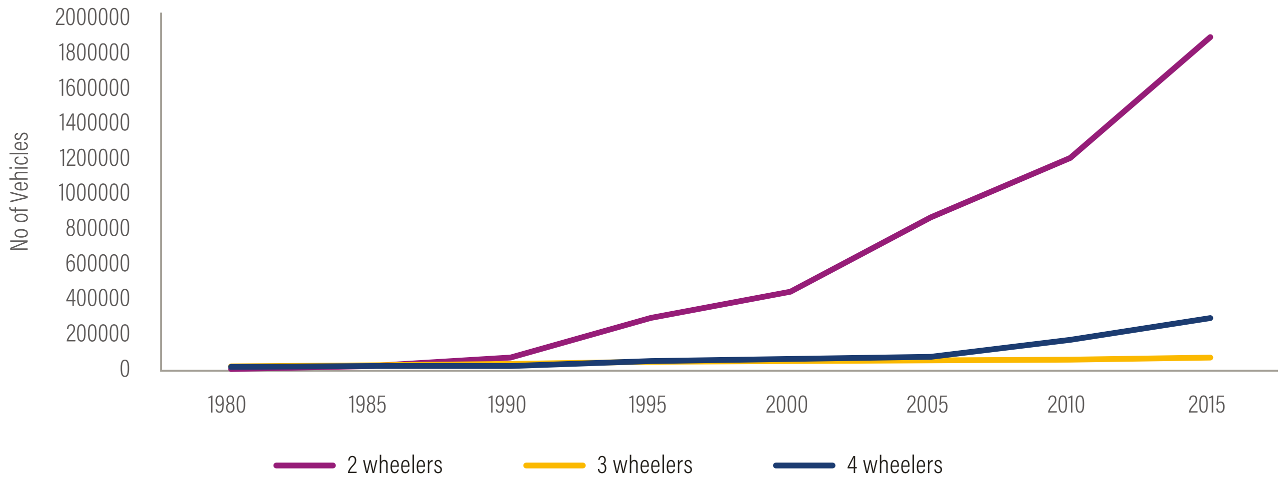
The textile and diamond polishing markets, the inherent economic drivers for the city, flourished between 2000 to 2015, growing by almost 39%. This growth has resulted in increased inter- and intra-state migration, affecting the mobility patterns within the city. The number of registered vehicles in the city has increased significantly from 2010 to 2015 due to road network improvements in the form of network redesign and road widening. Based on the Ministry of Road Transport and Highways (MoRTH) data, **Figure 59** shows the exponential growth in the number of vehicles registered in the city annually in the SMC area since 2000.

Figure 59: Total vehicle registration – 2001-16 (Source: Ministry of Road Transport and Highways (MoRTH))



The 2-wheeler is the most prevalent vehicle type in the city, accounting for 78% of the registered vehicles. The 4-wheeler population has also increased, from 10% to 18%. The increasing trend in personal vehicles has resulted in severe congestion at the city's major squares and vehicular pollution. **Figure 60** shows the composition of personal vehicles used by the citizens of the SMC area for daily travel. This data is based on CRRI Study – Transportation Profile of Surat (2017).

Figure 60: Composition of vehicle ownership – SMC (Source: Comprehensive Mobility Plan 2046)



9.2.3. Mode Share and Travel Behaviour of the City

As the city is expanding, in the share of public transport, the auto-rickshaw on the shared basis is the most prominent form of public transport in the SMC area and has a motorized mode share of 17%. Comparing the 2008 mode share, the walk mode share has increased from 35% to 40%. On the other hand, the share of the bicycle has decreased from 10% to 2%. Auto-rickshaw trips have been reduced to half, from 21% to 10%. This could be attributed to the economic growth in the city, resulting in the rise in the ownership of the 2-wheeler and an increase in its trips from 29% to 36%. **Tables 35** and **36** provide data on the share of different modes. **Table 35** compares the mode share observed in the city in 1988 and 2018, and **Table 36** highlights the mode share by trip purpose. It is evident from **Table 35** that people's travel behavior in the SMC area has changed drastically over the course of the last three decades. With the increase in purchasing power and decrease in the cost of vehicle ownership, the share of trips made on bicycles in the city has decreased by 17.2%, and those made on 2-wheelers and auto-rickshaws have increased significantly by 14.3% and 3.1%, respectively. The mode share of public transport, which was low, to begin with, has reduced even further, from 5.7% to a mere 1.4%. Car usage has only marginally increased, from 1.3% to 2%, and trips made on foot have reduced to 40.3%.

Table 35: Mode share in SMC area in 1988 and 2018 (Source: Comprehensive Mobility Plan 2046)

Mode	% Mode Share - 1988	% Mode Share - 2018	Difference
Walk	45.5	40.3	-5.2
Bus and Railway	5.7	1.4	-4.3
Car	1.3	2	0.7
2 wheelers	21.3	35.6	14.3
Bicycle	19.2	2	-17.2
Auto Rickshaw	7.2	10.3	3.1
Others	0	8	8

Table 36: Mode share by trip purpose in base year 2019 (Source: Comprehensive Mobility Plan 2046)

Mode	Walk (%)	Bicycle (%)	2 w (%)	4 w (%)	3 w (%)	Public transport (%)	Others (%)	Total
Work	6.46	1.09	28.42	1.94	4.62	0.52	0.73	43.78
Education	11.68	0.82	4.4	0.06	4.69	0.51	7.95	30.11
Others	22.01	0.03	2.68	0.13	1.19	0.04	0.03	26.11
Total	40.15	1.94	35.5	2.13	10.5	1.07	8.71	100

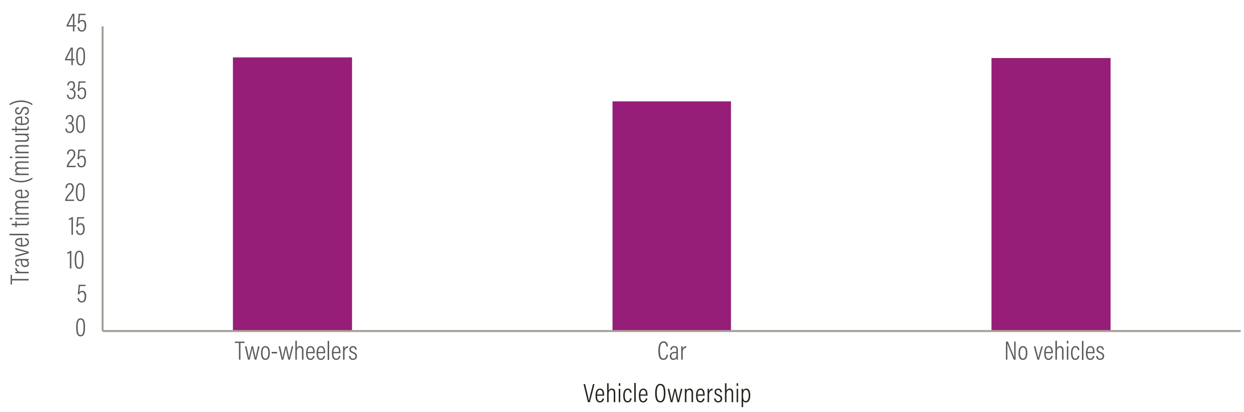
While most work trips are made on 2-wheelers, commute to educational institutions is mostly made on foot. However, it is evident from **Table 35** that public transport is the least preferred mode for work and education in the city. This issue needs to be analyzed to improve the public transport system in the city and induce a mode shift away from unsustainable and polluting private modes to public transport.

9.2.4. Assessment of Travel Behaviour

About 28% of work trips are made on 2-wheelers, whereas only 0.52 % trips are made using public transport. Work trips made on 3-wheelers contribute to 4.6 % of total trips made. For education purposes, about 13 % of trips are made on foot and by bicycle. On comparing trip purpose over the years, it is observed that the proportion of other trips in the city have increased, indicating that with the increase in incomes, residents are making more trips for reasons other than regular work and education. **Figure 61** compares the trips made and travel time by those using different types of vehicles with those who neither own nor hire any vehicle.

This analysis is done for the average number of trips made per day on a vehicle, while a parallel assessment has been done for the average time taken for completing the trips. A similar kind of assessment was done for the total vehicle kilometers traveled by type of vehicles owned as well as rented by the citizens of the SMC area. The Vehicle Kilometers Travelled (VKT) assessment, in addition to mode share shown in **Figure 61**, indicates motorbikes or motorized 2-wheelers (four strokes mostly) is the preferred option for mobility in the SMC area.

Figure 61: Travel time vs ownership of the vehicle (Source: Comprehensive Mobility Plan 2046)



In this assessment, motorcycles form a share of 35%. This is followed by scooters with 18%, three-wheelers or auto-rickshaws with 13%, and passenger cars with an 11% share. This pattern contributes to a significant share of emissions for the city. As the city population is increasing by 4.52% annually, a major reason for this expansion is that the city provides adequate business and livelihood opportunities, which can sustain not only permanent and semi-permanent residents but also those who visit the city for shorter periods. These include floating population groups who visit the city for a few months to earn money quickly and leave. As the mode of mobility and transport, these floating population groups prefer to either rent a 2-wheeler or buy it in on a shared basis. Thus, all three types of population groups prefer to travel on 2-wheelers. Owning to the fact that these 2-wheelers are generating significant congestion on crossroads and additional emissions, their increasing population affects the overall sectoral contribution. Public transport in the SMC area is rapidly expanding its reach. Although the annual VKT share of buses is insignificant in the combined assessment of passenger and goods vehicles, the diesel and CNG engine-operated buses share a large proportion of 186 VKT/day, followed by almost 104 VKT/day by auto-rickshaws, and then by passenger taxis at 52 VKT/day. **Figure 62** illustrates this assessment, which is based on data from the Census of India and NSSO. In this assessment, 2019 has been considered the base year.

Figure 62: Vehicles kilometres travelled (VKT) – Combination of passenger and goods (Source: Comprehensive Mobility Plan 2046)

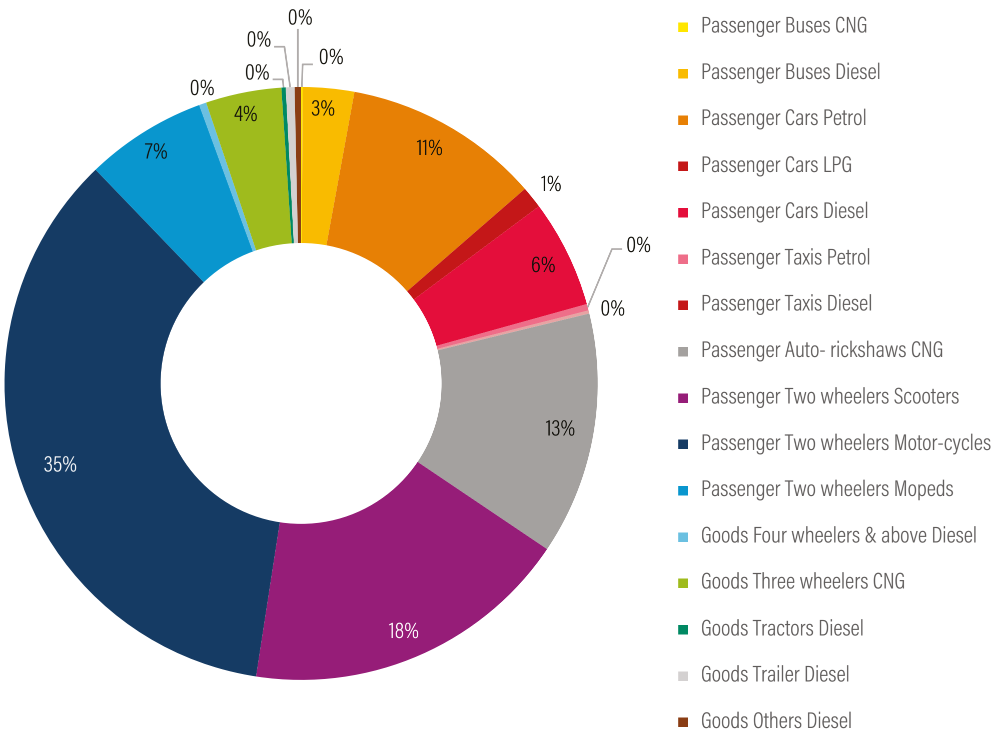
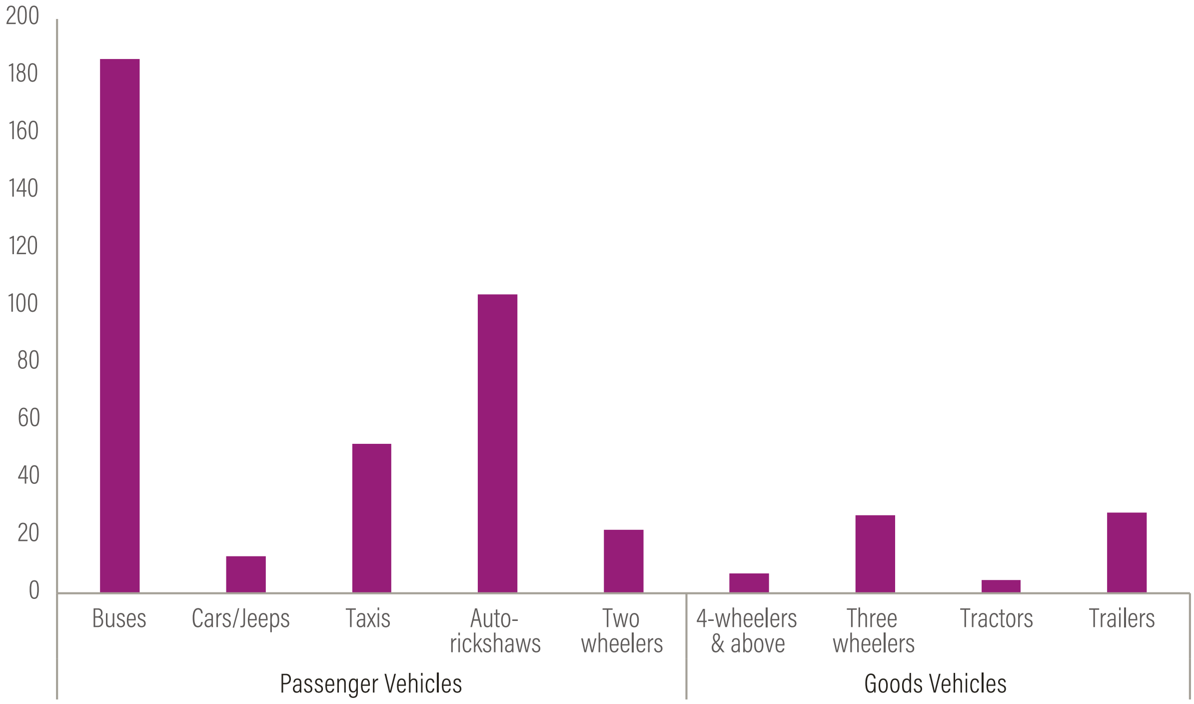


Figure 63: VKT per day – SMC (Source: Comprehensive Mobility Plan 2046)



Pedestrians in the SMC area have to cover an average trip length of 2.9 km per day. A study recorded that 29% of pedestrian trips are made for educational purposes, 16% for work, and 55% for other purposes[83]. The movement patterns of the top 50% of trips indicate that the pedestrian trips are mainly concentrated in the employment centers, such as Katargam, Ved Gam, Khodiyar Nagar, walled city areas, and Udhana–Sachin, due to the diamond and textile industries and related activities. A similar pattern is observed in the case of cycling trips, with greater concentration close to the industrial areas and the diamond market. On similar lines, the average trip length for a bicyclist in the SMC area is 4 km. The same study recorded that 42% of bicycle trips were made for educational purposes, 56% for work, and the remaining 2% for other purposes (**Figure 63**). The work trips by cycle connect residential settlements from the urban fringes to the employment centers in the city.

The maximum trips are concentrated in the walled city area, Udhana, textile market areas, Agricultural Produce Market Committee (APMC), Katargam, etc. There are shorter trips that connect the residential settlements within these industrial zones to factories/employment centers. It has been observed that workers and students prefer the bicycle as their mode of transport.

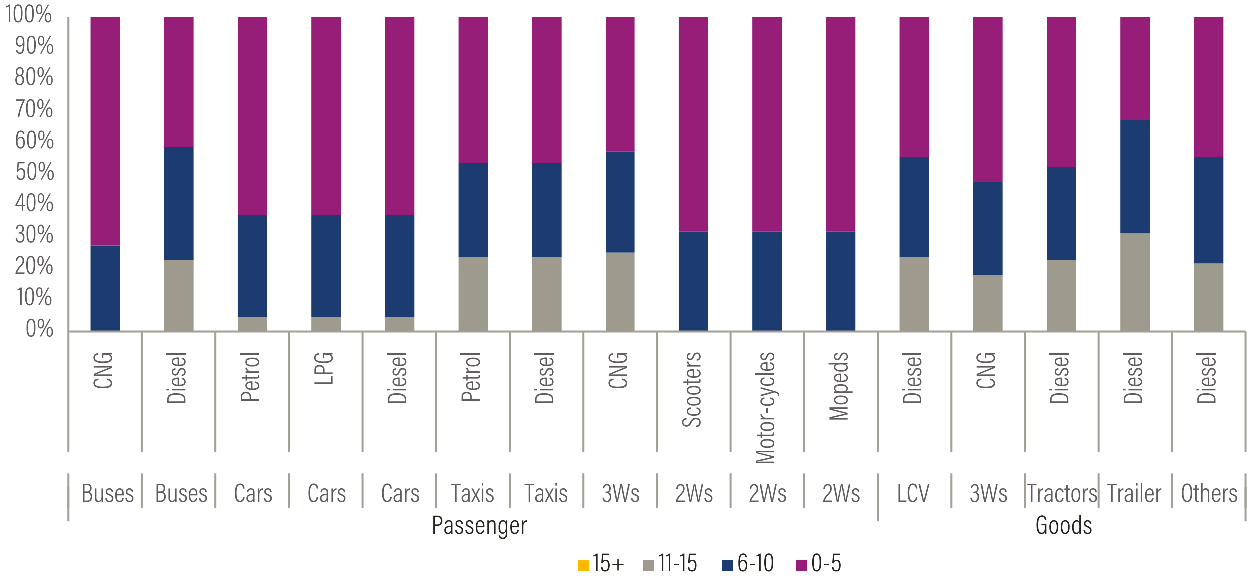
9.2.5. Vintage of Vehicles and VKT – SMC Area

Considering the above assessment as a base, vehicle age was added as a layer of analysis. This is an important factor to consider since many vehicles older than 10 years (from the year of assessment) would be emitting more than those on the road in recent years. **Figure 64** indicates the total VKT share in the SMC area with respect to their age assessed for the year 2020. From **Figure 64** following inferences can be made:

---

[83] *Comprehensive Mobility Plan 2046 – Surat. (2018). Centre of Excellence (CoE) in Urban Transport, CRDF, CEPT University. http://suratmunicipalcorporation.org:8020/News/6126_1.pdf.*

Figure 64: VKT share (%) compared with age of different vehicles. (Source: Comprehensive Mobility Plan 2046)



The new 2-wheelers registered and driven on the road from 2015 to 2020 form the largest VKT percentage share. The dynamic of the floating population, its interest in earning a livelihood in the city, and the duration for which they engage with the city are factors responsible for this share. Similarly, the average economic conditions of the city allow citizens to invest in the permanent ownership of a vehicle. This has led to the additional population of 4-wheelers in the last five years. Also, the strict rules in the SMC bars older vehicles from operating in the city. Area traffic restrictions and ease of operations too are reasons for four-wheelers older than 10 years losing their percentage share in total VKT.

Public transport buses have been taken under CNG conversion drive, especially those running under BRT Sitilink operations. As the Sitilink BRT operation was launched only a few years ago (its on-road operations commenced in 2014), its buses are effectively new. Yet, these buses do not run on comparative cleaner energy, such as CNG and electricity. In 2018, a trial was commenced to convert the entire fleet to CNG. A bus electrification drive too has been launched through which the promotion of electricity as a sustainable energy option will be explored in the BRT Sitilink program. The city thrives on small and medium-scale businesses that require freight movements within and across the district and other states. This is a major source of emissions, which is discussed in a later section. **Figure 64** illustrates the significant amount of VKT share of vehicles in the SMC area.

9.3. MAJOR ISSUES RELEVANT TO THE SECTOR

The SMC has formulated several policies for the effective mitigation of issues such as air pollution from the transportation sector, a few of which are listed as follows:

- Surat City Development Plan 2005 -12, revised 2012-17
- City Mobility Plan

- SMC Parking Policy
- Plan for NMT – Public Bike Sharing
- Surat ARUT mission SLIP (Service Level improvement Plan) - Urban Transport, 2015
- Surat Smart City Plan 2015-20
- Surat City Ring Road Development Plan
- Development Plan 2035, Surat
- GPCB submitted Surat Air Action Plan

Despite these well-designed plans, several sectoral issues hinder the administrative controls from reducing particulate pollution in the sector. These are listed as follows:

- **Road Networks:** As stated earlier, the road network has varying widths of the carriageway, as well as railway crossings, which are challenging the process of laying down proper road networks in the city. The bridges across the Tapi river, the canal, and the creeks also create problematic conditions in this process. As a result, a small part of the network acts as a major arterial road for the city.
- **Road Condition:** The city receives intense rainfall during monsoons. Roads are normally made of asphalt/bitumen top. With its climatic variations and presence of black cotton soil, the roads in this region are highly susceptible to damage. This has resulted in excessive operation and maintenance expenditures. Since 2004, the SMC has started constructing rigid pavements along major roads, which are growing at the rate of 8.6% coverage a year and have already covered 47% of the city roads.
- **Public Transport:** The absence of adequate public transport for over a decade has led to the emergence of auto-rickshaws as a popular public transport mode. An increase in personalized vehicles has also been observed. However, auto-rickshaws offering point-to-point services are illegal. Besides being unorganized, competition amongst the operators often leads to overloading, poor service, overcharging, restricted service hours, and pollution.
- **Traffic Management:** There is a need to improve intersections design as 2-wheelers and three-wheelers in the SMC area move in a haphazard manner, especially in the central zone area of the city where density is quite high as compared with the density in very narrow lanes of roads. In such areas, insufficient parking, lack of pedestrian facilities, and inadequate enforcement have compounded traffic problems. Enhancement in the number and capacity of the traffic police and related equipment is critical. A coordinated management system is functioning with the initiative of SMC and the traffic police.
- **Encroachments:** Several sections of the margins of major roads and the footpaths are encroached upon for various purposes, including informal activities. When restrictions are eased during night hours, excessive regional and goods transport vehicles, including heavy vehicles, buses, and trucks, pass through the city, resulting in congestion and fatal accidents.
- **Cycling and Walking:** Cycling and walking constitute about 40% of the total trips and is a feature that needs to be integrated within the transport initiatives. About 55% of the low-income group people adopt cycling and walking as modes of transport. Pedestrians and cyclists are

accident-prone, and hence there is a need to ensure safety through initiatives such as dedicated cycling tracks and pedestrian-friendly walkways.

- **Resource Mobilization:** Public resources have shrunk due to shifts in priorities of state and local governments over the years. Cost recovery mechanisms for infrastructure projects have also been constrained. Initiatives through public-private partnerships (PPP) need to be explored, especially for the NMT projects. These funding options are available for the motorized transport driven SPV projects, but such promotion would result in more emissions from motorized transport for the SMC area.
- **System Improvement Focus:** The focus of the comprehensive plan is to provide accessibility and enhance mobility in the city through the integration of various modes of transport and related infrastructure.
- **Institutional:**
  - Insufficient human resources within the government with knowledge of AQM and technical skills to understand and lead the process of improving air quality
  - Difficulty in securing support from other local agencies in developing and implementing SCAP
  - Lack of coordination between relevant agencies and a clear framework for implementation and enforcement – including regulatory and governance requirements, institutional arrangements, processes, and enforcement procedures for the transport sector
  - Lack of political support from decision-makers and the public and leadership of relevant stakeholders
  - Lack of public interest and awareness regarding the adverse impact of air pollution on health and the benefits and the urgent need to address the underlying problems, which might have been caused by lack of information
  - Limited information on pollutant sources emissions and air quality levels to identify effective measures to reduce pollutant concentrations
- **Financial:** Absence of separate funds/allocation in SMC's budget for SCAP, particularly for transport sector-related activities in Surat

9.4. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

The following is a list of existing policies on the transport sector in the SMC area. Based on these policies, a process and performance indicators-based framework are developed, illustrated in **Table 37.**

- National Air Quality Monitoring Program (NAMP): The government is executing a nationwide air quality monitoring program called the National Air Quality Monitoring Program.
- Forty-two action points: A comprehensive set of directions under section 18 (1) (b) of the Air (Prevention and Control of Pollution) Act, 1986 has been issued by the CPCB to ensure the implementation of 42 measures (action points) that aim to mitigate air pollution in major cities.

- Impetus on vehicular pollution: Bharat Stage IV (BS-IV) norms have been launched for mandatory implementation since 1 April 2017. The government has also proposed leapfrogging to BS-VI by 1 April 2020. Bharat Stage Emission Standards (BSES) are emission standards issued by the Government of India to regulate the output of air pollutants from internal combustion engines and spark-ignition engine equipment, including motor vehicles.
- Development Plan 2035, Surat
- GPCB Surat Clean Air Action Plan 2016
- CMUBS – Bus VGF scheme of the Government of Gujarat
- Swarnim Jayanti Mukhya Mantri Shehri Vikas Yojana
- Surat Parking Policy 2016
- Surat CDP 2005-12 & revised 2012 (initiated by the SMC under JNNURM)
- Surat Comprehensive Mobility Plan - 2046
- Surat Service Level Improvement Plan under AMRUT Mission
- Surat Smart City Proposal under Smart City Mission
- Central Motor Vehicles Act (CMVA)
- FAME-II policy document
- Integrated Public Transport Study – 2006 (assignment by the GIDB, prepared by the CES)
- Comprehensive Mobility Plan cum Bus Rapid Transit System (BRTS) Plan – 2008 and Bus Rapid Transit System (BRTS) Phases 2 & 3 – 2012
- Service Level Benchmarks in Urban Transport for Surat City – 2012 and 2015
- DPR for Introduction of City bus Services 2015, SMC/CEPT
- Performance Assessment of Public Transport in Surat – Quarterly Reports 2016–18.
- Cycle for Change competition by MoHUA 2020
- Surat Station Development projects
- DMIC report
- Surat Airport Extension Report

Table 37: Assessment Indicator Framework for evaluating existing capacities of SMC

Indicator Theme	Indicator	Source
Transport and Environmental Performance		
Effects of Transportation on Environment	Energy consumption or fuel consumption by the city's transport sector	SMC's CMP 2018 study
	Generation of hazardous emissions from the sector	CMP 2018
	The modal share of hazardous emissions – across the sector	CMP 2018 and primary data from the RTO Surat
	Exposed population through density and population projection analysis	SMC's CDP files
	% Population exposed to the harmful effect of air and noise pollution by the transport sector	Studies conducted by local institutions, such as SVNIT, on public health aspects of the transportation sector
	Fragmentation of vulnerable population pockets because of traffic congestion	Slum Upgradation Cell's annual charters; GIS map of the city; other planning study conducted by local research think tanks
	The proximity of road cross-sections with local green ecosystem	Nature Club – Surat's reports; annual coverage data of the Garden Department of the SMC
	Land grab or coverage by the transport sector – including both ULB owned roads and access routes used for leaving and entering the SMC area	Existing land use and land cover along with SUDA's updated GDCR
	Numbers of accidents and deaths that have occurred in a unit of time while using the city's mobility infrastructure, both public and private	Health Department and Road Safety Cell of SMC and annual coverage by the Fire Department
	Passenger transport congestion – by mode and purpose	CMP 2018 and SMC'S BRTS cell's annual coverage
	Freight transport congestion – by mode and goods' groups	CMP 2018
Determinants – Transportation Sector's linkages with the local ecosystem		
Accessibility and Spatial Planning	Access to basic services: average passenger journey time and length per mode, purpose (commuting, shopping, leisure), and location (urban/ rural)	CMP 2018, SUDA's GDCR, SMC's CDPs of 2017 to 2020
Supply of Transport Infrastructure Services	The capacity of transport infrastructure networks, by mode and type of infrastructure (service access roads, national road, municipal road, etc.)	CMP 2018, SMC's BRTS cell's annual coverage
	Investments in transport infrastructure/ per capita and by mode	Indicative assessment based on CMP 2018 data and Annual Budget of the SMC
Cost Association with the Transport Sector	Updates in transportation charges (average) by mode	SMC's transportation management policies and compilation of declarations and notifications in 2010 to 2020 indicating changes in tax and service incentivization for the citizens
	Local and state-level tax structure affecting pricing policies of local transportation channels – analysis by mode and fleet size	SMC's parking policy, CMP 2018, and Gujarat state's Transport Department's annual coverage and collation of notifications, particularly relating to tax and incentive structures for the ULBs

Indicator Theme	Indicator	Source
	The total annual average cost incurred by a citizen for availing services of passenger and freight transport	Transport Planning Department of SMC
	Implementation of internalization instruments, i.e., economic policy tools with a direct link with the marginal external costs of the use of different transport modes	CMP 2018 and CDP of 2015 to 2020, along with economic reforms implemented through amended budgetary requirements
	Expenditure per capita per economic groups – for the focused development of vulnerable sections of the city	Slum Upgradation Department's annual coverage and Urban Community Development (UCD) Department's annual coverage with connections to annual budget and CMP 2018
Technological Upgradation for Efficient Quotient Achievement	Overall energy efficiency for passenger and freight transport (per passenger-km and per ton-km and by mode)	Fuel discharge programs for the transportation modes for ULB and state-level operations
	Emissions per passenger-km and emissions per ton/km for PM, SOX, and NOx, if possible, by mode	CMP 2018 and GPCB's annual action plan for the city's clean air
	Occupancy rates of passenger vehicles	SMC's Statistics Department and Town Planning Department's annual coverage
	Uptake of cleaner energy/fuels (unleaded petrol, electric means, alternative fuels) and numbers of alternative-fueled vehicles	Renewable Energy Policy for the SMC area from Energy Efficiency Cell and BRTS Cell
	Size and the average age of the vehicular fleet in consideration for the assessment	BRTS cell and Transport Department's annual coverage along with CMP 2018 data
	Proportion assessments available on decided vehicular fleet size with respect to available GPCB's permissible standards of air and noise pollution	GPCB's annual coverage and updated air quality improvement plan along with BRTS cell's annual coverage data
Administrative and Management Internalization	Model city's reference for their implementation of Clean Air Action Plan wherein integrated transport planning has been considered at both supply and demand side of the management in the process of tackling particulate emissions	Vadodara, Ahmedabad, and Rajkot city's Smart City Mission statements and proposals focus on ambient air quality improvement.
	Model city's similar objectified clean air action plans focusing on coordination between Transportation Department and environment conservation in planning as well as in operation stage of their projects	AIR Plan of Ahmedabad, GPCB's annual air quality improvement plans for the cities of Ahmedabad, Vadodara, Rajkot
	Model city's action plans were published recently, pointing to the transport sector as a major contributor to particulate emissions and taking natural resource conservation actions as countermeasures	Completed city-level action plans under NCAP 2019 program

9.4.1. Challenges

- The transportation sector is affecting not only the physical built-up area but also the socio-economic dynamics of the SMC area, which is changing rapidly with the changing business seasons. In addition, vehicles form an integral part of the business community for conducting their daily engagement with the city's infrastructure. Thus, the continual updating of the emissions inventory would help determine the emissions contribution targets of the sector, which eventually feed into improved policy and program management at the city level.
- The SMC area's transport sector planning on improving the city's air quality would have to focus on the city's heavy freight management.
- The vehicles entering the city or crossing the city's six major toll booths also add significant amounts of particulate matter to the city's air, which disperses and affects people in the SMC area.

Thus, any future planning for coordinating the transportation and air quality management sectors would have to include physical and administrative planning for the external vehicular population.

- Age of 2-wheelers, 3-wheelers, and 4-wheelers would be key to determining the policy and program level implementations through which numbers of vehicles can be limited on city's roads, focusing on improving the city's air quality.
- The natural phenomenon of coastal inversion would be affecting dispersion models of emissions from the transportation sector.
- Development and redevelopment of green infrastructure and green corridors across the city at strategic road intersections would help reduce particulate emissions. However, this needs to be determined by a one-year-long comprehensive adaptation measure study supporting the SCAP project's major findings.

9.4.2. Opportunities

- The Climate Change Department of the Government of Gujarat introduced a program of battery-operated 3-wheelers (e-rickshaws) during 2018-19. According to an official document, unlike some other states, e-rickshaws aren't popular among the rickshaw drivers in Gujarat; the program was introduced with a state subsidy. In 2019-20, e-rickshaws fitted with advanced batteries came with a subsidy of INR 40,000 on a reimbursement basis. SMC can leverage this scheme and enable the electrification of the auto-rickshaws by retrofitting the current and future fleet in the city.
- A similar campaign can be developed for the electrification of taxis. The cost of the vehicle is subsidized either by reducing the interest on the total loan or by providing a discount on the total cost of the vehicle. This will enable faster adoption of electric taxis rather than fossil fuel vehicles.
- The Government of Gujarat launched the Chief Minister Urban Bus Service Scheme in 2018. The scheme provided financial support as viability gap funds (VGF) to transit agencies in urban areas to cover the gap between operation costs and earned revenue. It is applicable in 8 Municipal Corporations and 22 Class A municipalities (population more than 1 lakh) of the state where buses operate in PPP mode. The VGF provided by the State Government is INR 12.50 per km, which is to be supplemented in equal value by the transit agency. The SMC can leverage this scheme too by taking the following measures:
    - Increasing the fleet size for public transport
    - Introducing micro-transit services operated on a PPP basis
    - Providing last-mile connectivity to bus services in zones with inadequate coverage of public transport facilities
    - On-boarding midi or mini buses to operate high frequency, short-distance trips to reduce the cost of operations and hence, losses
    - Operating chartered bus services for employee transport or school/college buses to enable the transition away from private vehicle usage
- The national vehicle scrappage policy, implemented in 2021, has been formulated to promote the sales of new vehicles with improved fuel efficiency and low pollution levels and reduce India's expenditure of INR 10 lakh crore on crude imports. Around 1 crore aging vehicles are set to be

scrapped once the policy is implemented. As per the policy, all private vehicles older than 20 and commercial vehicles older than 15 would need to undergo annual fitness tests. Additionally, all vehicles older than eight years that pass the fitness test will be subjected to a green tax, implementing the ‘polluter pays principle.’ The policy also incentivizes the scrappage of older vehicles by offering subsidies for the purchase of new vehicles. This policy can be adopted by the Government of Gujarat and implemented by SMC to enable the adoption of cleaner modes of transport.

9.5. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

Under the air quality improvement program, GPCB has implemented policies to mitigate emissions from the transportation sector. These policies and programs have been outlined in **Table 38**.

Table 38: Existing programs and policies from GPCB (Source: Surat –Air Pollution Control Action Plan, https://cpcb.nic.in/Actionplan/Surat.pdf)

Sr.No.	Action Point	Implementation Status
1.	Place restrictions on plying of commercial diesel-driven vehicles older than 15 years and phase these out.	The policy will be implemented effectively, yet no monitoring data was made available at the time of this assessment.
2.	Launch an extensive drive against polluting vehicles to ensure strict compliance.	In coordination with the RTO center, reports on violations are being collected regularly.
3.	Launch a public awareness campaign for vehicle maintenance, minimizing the use of personal vehicles, lane discipline, etc.	No monitoring data was available with the RTO or GPCB office at the time of this assessment.
4.	Prevent the parking of vehicles in non-designated areas.	A revised parking policy by the SMC has been prepared and is operational. SMC area has the highest multilevel parking spots in Gujarat state.
5.	Introduce BS-VI fuels for vehicles in the city and prepare a fuel adulteration action plan to stop the fuel mixing for the vehicles.	No monitoring data was available
6.	Prepare a plan for the widening of roads and improvement of infrastructure to decongest roads.	Phase-wise bar chart to be obtained from SMC River bridge – 9, Under Construction – 1, Railway Bridges – ROB/RUB – 12, Flyover Bridge – 19, Creek Bridge – 5 Flyovers at all junctions of NH-8 completed Constructing Road Dividers – 186.68 km Restrictions on the movement of heavy vehicles and buses implemented by traffic police Proposed works: River Bridge-2 Railway Bridges: - ROB/RUB- 3, Flyover Bridge – 2, Creek Bridge – 2
7.	Formulate steps for promoting battery-operated vehicles, such as e-rickshaws and se- carts.	The EV policy is being implemented in the SMC area.

8.	Synchronize traffic movements/ introduce an intelligent traffic system for lane-driving	Technical measures have been carried out, such as constructing traffic islands and channelizers, traffic timer system, and gradation of traffic points and junctions with busy traffic.
9.	Install remote sensor-based PUC system.	A fully automated pollution control certificate fitness center for the vehicles will be operational soon in the SMC area.
10.	Augment public transport in the city.	Regularization of EV buses in the city bus service and BRT Sitilink services has been done. Fleet size has been expanded along with the corridor's numbers
11.	Monitor vehicle fitness.	At present, monitoring of 100% vehicle fitness is obtained, but conversion into EV compatibility is yet to be achieved.

9.6. CONTROL MEASURES IDENTIFIED DURING WORKSHOPS AND CONSUTATIONS

Based on a preliminary assessment, one-to-one meetings and group discussions were held with various stakeholders related to the transportation sector. In these interactions, stakeholders provided their views on issues such as congestion, safety, and adequacy of SMC's public transport coverage. At the same time, people-centric transportation planning, NMT infrastructure up-gradation, efficient mobility, and seamless connectivity were outlined as key expectation areas faced by the stakeholders. In addition, reducing congestion and air pollution and managing parking areas emerged as the priority areas, focusing on public transport systems, safety, and walkability.

As part of control measures, the following evaluation criteria were developed for a controlled environment for abating sectoral emissions:

- Develop emission reduction potential through fuel-efficient mobility in public and privately-owned passenger and freight vehicles.
- Understand the quantifiable impact on ground-level ozone formation in the city's heavy traffic zones, especially in the winter season, which might affect the exposed personnel.
- Identify the cost/economic impact of any policy or program developing the transportation system of SMC to conserve/protect the city's ecological resources.
- Ensure feasibility in implementation with respect to the political, economic, current level of control.
- Determine the duration of implementation - short-term, intermediate, and long-term
- Formulate strategies for reducing multiple pollutants with targeted intervention.
- Formulate control strategies with multiple community benefits (transit enhancement, quality growth and development, open space conservation, energy efficiency, etc.).
- Design control measures with multiple environmental benefits (air, water, solid waste, land, habitat).

9.7. STRATEGIES TO MITIGATE AIR POLLUTION

Urban transport in the SMC area has been categorized into passenger transport and urban freight for structuring mitigation efforts. The following sub-sections elaborate on the strategies to address emissions from these categories.

9.7.1. Recommendation 1: For Passenger Transport

The SMC area was traditionally known to be dominated by 2-wheeler and 3-wheeler trips. This was in part because of poor public transport connectivity. However, the SMC has made large, strategic investments in a dense network of BRT systems and a city bus service, giving citizens a more sustainable way to move around the city over the last few years. Today it has a network of about 200 km of BRT and city bus services, covering over 70% of the city. Further, the BRT and metro corridors that are being planned will likely give more options to commuters. Other measures likely to improve transport sustainability include a progressive parking policy and the state EV policy that will influence the uptake of electric vehicles in the city. This sub-section provides suggestions that can maximize the uptake of these efforts to ensure a more sustainable mobility ecosystem in the SMC area in the future. This note identifies two fundamental, broad interventions that promise to keep emission numbers from passenger mobility systems in check despite the fast-growing population, economic opportunities, and vehicle ownership in the city, which are listed below:

- A systematic transition to cleaner and more efficient vehicles
- Strategic measures to alter mode share and reduce private vehicle usage and encourage larger adoption of public transport

Intervention 1: Systematic Transition from Existing and Future Vehicles to Cleaner and More Efficient Vehicles

The SMC area has been among the few urban agglomerations where the transition to lower emission standards – BS II, BS III, and BS-IV – took place before the national rollout. The introduction and mandate of BS-VI will help curb emissions further. However, older vintage vehicles conforming to BS-II and BS III are approaching the end of their lives but contribute heavily to emissions from passenger transport. **Table 39** gives the engine type break-up of all passenger vehicles in the SMC area as of March 2020, extrapolated from the data provided in the CMP released in 2016.

Table 39: Intervention 1 – Transportation sector – Engine type proportion considerations – 2020

Engine Type	Proportion
BS III	57%
BS IV	43%
BS VI	0.0%
Electric	0.0%

Table 40: Intervention 1 – Transportation sector - Engine type proportion considerations – 2026

Engine Type	Proportion
BS III	0%
BS IV	30%
BS VI	69%
Electric	1%

Assuming that the vehicles in the SMC area will naturally phase out after having completed 15 years, BS III vehicles will phase out completely by 2025, and BS-IV vehicles will phase out completely by 2035. In 2026, **Tables 39** and **40** depict the engine composition of all passenger vehicles in 2026 in the SMC area if the Corporation takes no measures between now and then. The implicit assumption is that their BS-VI equivalent will replace vehicles phased out due to natural aging. To quantify gains in emission reduction, Intervention 1 lays down targets for the SMC area, as exhibited in **Table 41**.

Table 41: 2026 targets for Intervention 1

Target	
By 2023	Phase-out all BS-III vehicles in the SMC area
By 2026	Transition 40% of BS-IV vehicles to BS-VI or electric
	Transition 10% of bus fleet to electric
	Transition 10% of 3-wheelers to electric
	Transition 5% of 2-wheelers to electric

Intervention 1 aims to significantly alter the vehicular mix in 2026 by accelerating the phasing-out of inefficient vehicles and encouraging a shift to more efficient ones. The following combination of two approaches will help achieve this:

- Incorporate environmental costs into the operation of inefficient vehicles, and
- Develop incentive structures to encourage the replacement of older vehicles with more efficient ones.

Intervention 2: Incorporating Environmental Costs and Better Monitoring Infrastructure

In 2017, SMC released a policy on parking to improve the management of the parking inventory and use pricing as a demand management tool. Incorporating environmental costs implies having a differentiated pricing structure based on the engine type of the vehicle. In essence, inefficient vehicles pay more for parking while more efficient vehicles pay less. An example of differentiated parking pricing is demonstrated in **Table 42** and **Table 43**.

Table 42: Parking rates for 2-wheelers as proposed by the existing policy

	0 to 3 hours	3 to 6 hours	6 to 9 hours	9 to 12 hours	12 to 24 hours
2-Ws	10	15	20	25	40

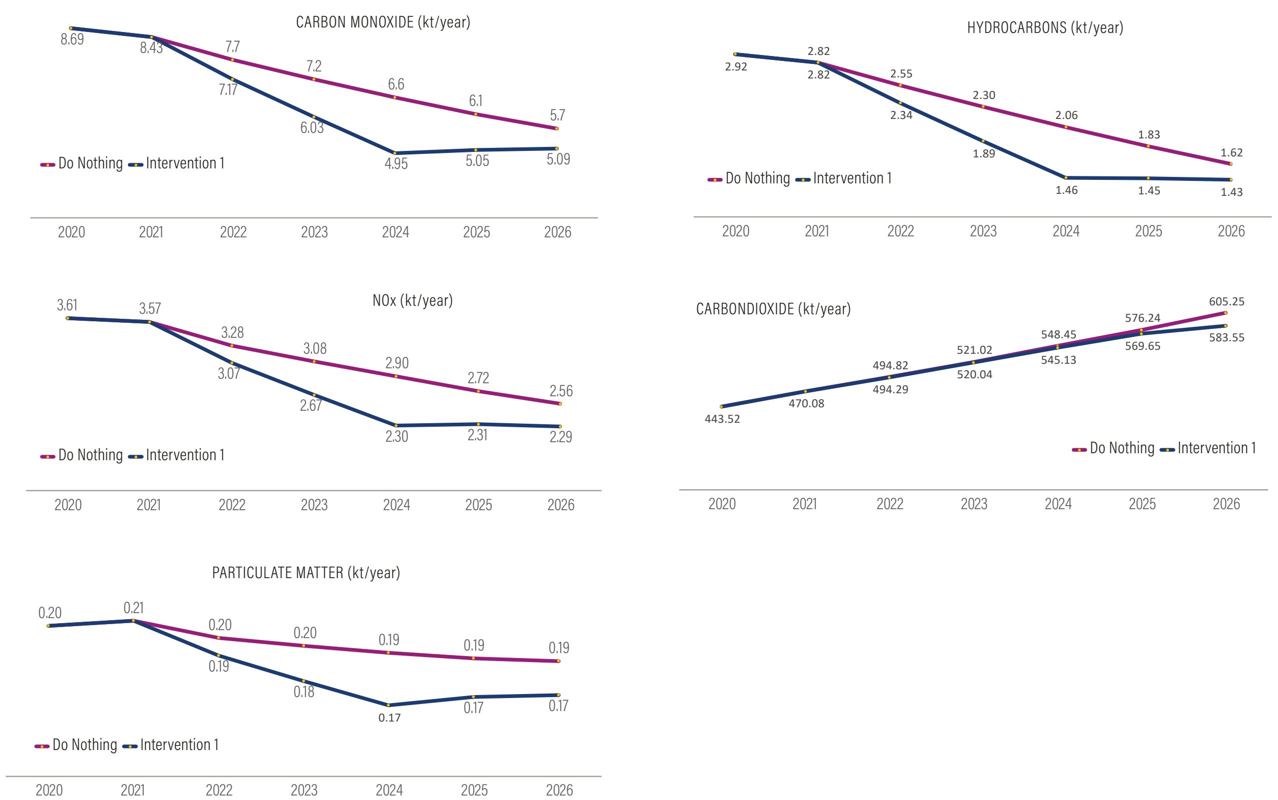
Table 43: Example of differentiated parking rates for 2-wheelers

2-Ws	0 to 3 hours	3 to 6 hours	6 to 9 hours	9 to 12 hours	12 to 24 hours
BS III	15	22	30	37	60
BS IV	12	18	25	30	52
BS VI	7	10	15	17	30
Electric	0	0	0	0	0

Implementation: The VAHAN database developed in partnership between MoHUA and NIC has successfully digitized number plates of vehicles. The database generates information on engine type and PUC validity, among other information, of all vehicles in the reference area. The VAHAN database was used to develop the differentiated pricing mechanism for parking, which can be enabled by a smartphone application that displays the engine type, PUC validity, and the associated parking rate on feeding the registration number of a vehicle.

Intervention 3: Incentive Structure to Encourage Faster and Cleaner Vehicles
Tax breaks are recommended for those who replace their pre-BS VI vehicles with BS-VI or electric to increase the share of more efficient vehicles. The idea is to offer incentive structures to discounts in road tax (state tax) and the SMC charge (municipal tax) to replace older vehicles with newer equivalents. This tax break would be only for replacement and not for fresh purchases of vehicles. A combination of incentive structures and 'polluter pays' intervention mechanisms is meant to trigger a change in engine composition if targets are achieved. Intervention 1 does not attempt to curb vehicular growth but attempts to change the composition of engine type. Gains in emission reduction can be achieved simply by simply increasing the share of more efficient vehicles. **Figure 65** exhibits an estimation of the reduction of five pollutants.

Figure 66: Criteria pollutant emissions – Transport sector



Intervention 4: Other Interventions to Support Emission Mitigation in Passenger Transport

The two measures, Intervention 2 and Intervention 3, need supporting structures. Some of these complementary measures are mentioned below:

- The SMC area has a network of about 200 PUC centers. A closer assessment of the location of these centers is warranted, and attempts must be taken to densify the PUC network for each zone. Further, vehicles at fueling stations must be checked for their PUC compliance.
- In the recent union budget, the government announced the execution of a scrappage policy. The state of Gujarat must develop a scrappage policy of its own to incentivize the scrappage of older vehicles. Scrappage incentives with tax breaks will lead to a faster transition to cleaner vehicles.
- The state EV policy of Gujarat encouraged the purchase of electric vehicles by offering subsidies for EVs. However, the EV policy must be revised before being extended till 2026, given the fresh targets of EV penetration from intervention.
- Finally, commercial vehicles have large operational annual or bi-annual costs, such as fitness certificates, insurance, and meter integrity test. For owners willing to give up their old commercial vehicles for newer ones, SMC must negotiate with the Road Transport Department of the state to subsidize annual recurring costs. This can go a long way in triggering a transition to more fuel-efficient and cleaner commercial vehicles.

Intervention 5: Strategic Measures to Alter Mode Share, Reduce Private Vehicle Usage and Encourage Larger Adoption of Public Transport

As seen in the mode share data presented in **Figure 66**, the majority of the commuters in the SMC area prefer to use the private or semi-private mode of transport, specifically 2-wheelers and auto-rickshaws, for their daily commute. It is also evident from **Figure 66** that while the majority of the trips related to education (39%) and activities other than work (84%) are made on foot, work-related trips are predominantly made on 2-wheelers, 4-wheelers, and auto-rickshaws (80%). Respectively, only 1% and 2% of the work and education-related trips are made using public transport. An assessment of the historical trend in mode share in the SMC area shows that while public transport mode share was close to 16% of all motorized trips in 1988, it reduced to less than 4% in 2016. This decreasing trend in public transport mode share has been identified to have resulted from the city's lack of adequate and convenient bus service. Erratic changes in bus operations between government and private bus operators and the high cost of operations resulted in poor and unreliable services, forcing commuters to adopt private modes of commute.

To reduce the reliance on private modes and promote the use of public transport, the Government set up BRT services along with a more stable city bus service in 2017. The BRT services and regular city bus services cover approximately 76% of the city's road network with 440 buses. However, the South and Southwest zones have the least public transport coverage. This is potentially one of the main reasons the commuters in the SMC area prefer to use privately owned, low occupancy vehicles, and public transport ridership in the city has remained extremely low, resulting in higher transport-related emissions in the city. Therefore, measures to urge commuters to transition from privately owned vehicles to public transport vehicles will help reduce air quality concerns in the city and reduce congestion and improve productivity for all commuters. Thus, this intervention focuses on implementing the following measures to enable the transition to public transport:

Currently, the city has 440 buses, which accounts for only (approximate) 7 buses per lakh population. This is significantly lower than the guideline prescribed by the MoHUA, of 30-60 buses per lakh population for cities the size of Surat. In addition, route, schedule, and fare rationalization must be done to ensure adequate bus services based on all residential and industrial areas.

- Provision of chartered bus services through contracts with major industries in the city to conveniently transition work-related trips to public transport
- Improve pedestrian and cycling infrastructure in the city and establish last mile connectivity services (potentially through PPP) to improve access to public transport services
- Operationalize congestion management strategies in the city to disincentivize the use of low occupancy private modes of transport and reduce congestion in the city
- Combining the abovementioned strategies is meant to trigger a mode shift from the currently predominant use of private modes of transport to public transport. The targets for this intervention are as presented below:

Figure 66: Mode share with purpose – SMC area

MODE	SHARE
Bus	15.0%
Four Wheeler	8.4%
Two Wheeler	57.8%
Three Wheeler	5.7%
Others	13.1%

Motorized Mode Share 2026 (E)
Do Nothing

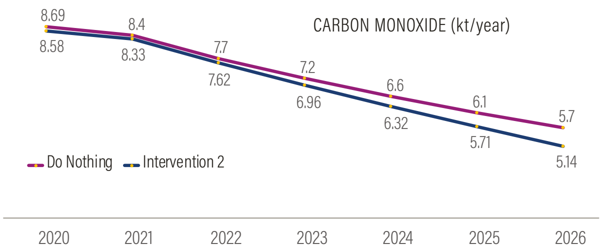
1%
9%
2%
3%

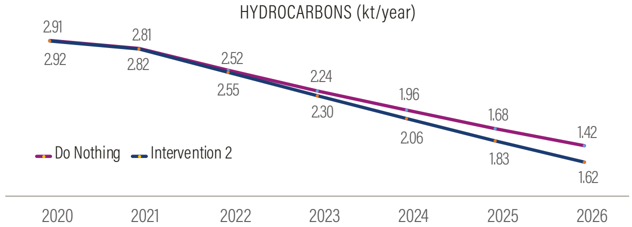
MODE	SHARE
Bus	15.0%
Four Wheeler	8.4%
Two Wheeler	57.8%
Three Wheeler	5.7%
Others	13.1%

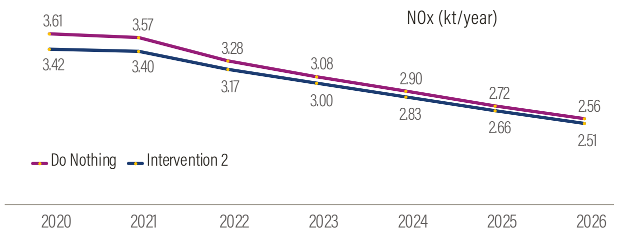
Motorized Mode Share (E) 2026
After Intervention 2

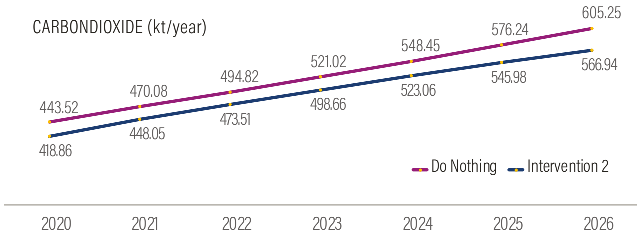
While this intervention does not attempt to change the proportion of the vehicle emission standards, it attempts to reduce the ownership and use of the private mode of transport. By simply increasing the use of higher occupancy vehicles, gains in emission reduction can be achieved. **Figure 67** exhibits an estimation of a reduction in the five pollutants discussed earlier.

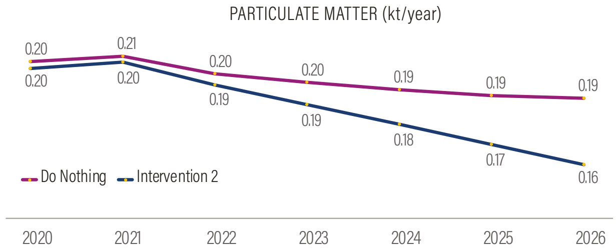
Figure 67: Emission reductions – Criteria pollutants – Transportation sector











As seen in the graphs, the increase in public transit mode share and the corresponding reduction in the mode share of the other low-occupancy modes have the potential to enable a reduction of 11% in CO levels, 14% in hydrocarbon levels, 2% in NOx levels, 7% in carbon-dioxide levels and 17% in particulate matter levels in 2026 as compared with the 2026 emissions observed in the BAU scenario. A comparison of the impacts achieved as a result of Interventions 1 and 2 shows (**Table 44)** that the emission reductions achieved as a result of Intervention 1 are higher than that of Intervention 2.

Table 44: Reduction potentials of Interventions 1 and 2

2026	Reduction of Intervention 1 compared to BAU	Reduction of Intervention 2 compared to BAU
CO	12%	11%
HC	13%	14%
NOx	13%	2%
CO2	4.15%	7%
PM	8%	17%

It is evident from the data presented in **Table 44** that while intervention 2 promotes the use of more sustainable modes of transport, by 2026, the annual emission reduction from intervention 2 is less than that from intervention 1. There is, thus, a need to combine the two interventions.

Intervention 6: Combined Strategy to Enable a Mode Shift from Private Vehicle Usage to Public Transport in Addition to the Transition to Cleaner, More Efficient Modes of Transport
Combining interventions 1 and 2 will ensure a compounding effect, resulting in reducing transport-related air pollution, congestion, and total vehicle ownership. This intervention merely intends to operationalize all strategies discussed as a part of both the abovementioned interventions, including (but not restricted to) the following:

- Incorporation of environmental costs into the operation of inefficient vehicles through the adoption of measures such a differentiated parking pricing based on vehicle emission standard and fuel type,

- Development of incentive structures to encourage replacement of older vehicles with more efficient ones in the form of tax breaks to promote the exchange of pre-BS VI vehicles with BS-VI or electric vehicles,
- Adoption of stringent scrappage policy at the state level to incentivize the scrappage of vehicles older than 15 years of age,
- Augmentation of public transport fleet and infrastructure,
- Adoption of congestion management measures,
- Operation of employee transport services using public transport buses,
- Improvement in public bus operations through rationalization efforts,
- Increased coverage of bus stops, especially in residential and industrial zones of the city,
- Improvement in NMT infrastructure, and
- Establishment of last-mile connectivity services.

The increased mode share in public transport resulting from the abovementioned strategies will enable a 15% reduction in the total passenger vehicle ownership in the city in 2026 compared with the BAU scenario (from 550 lakh to 470 lakh). Additionally, as seen in **Table 45**, the composition of vehicles based on emission standards is also improved due to the reduction in the proportion of BS4 vehicles and an increase in BS6 and electric vehicles.

Table 45: Comparison of BAU and Interventions 1 + 2

Type of Engine	BAU	Int. 1+2
BS3	0%	0%
BS4	30%	21%
BS6	69%	74%
Electric	1%	4%

Finally, the combined impact of improved vehicle technology and efficiency and the shift to public transport from private and semi-private modes of transport will result in a 25% decrease in the emission of carbon monoxide, 31% in hydrocarbons, 16% in NO_x levels, 12% in carbon-di-oxide, and 27% in the particulate matter as compared with the levels recorded for each of these pollutants in 2026 in the BAU scenario (**Figure 68**).

Figure 68: Emissions reductions – Combined impact – Criteria pollutants – Transportation sector

9.7.2. Recommendation 2: Urban Freight Policy – Efficient Movement and Performance of Freight

The Comprehensive Mobility Plan categorizes freight movement into the following:

- E-E as in origin and destination of freight movement passing through the city but having origin and destination outside the city boundaries
- E-I and I-E as in the movement of freight through the SMC area with either the origin or destination within the city boundaries
- I-I as in the freight movement in SMC area with its origin and destination within the city boundaries

As the SMC area is home to textile, chemical, and diamond industries, developing a dedicated approach to addressing emissions contributed by urban freight. Therefore, we recommend that SMC develop a comprehensive urban freight policy to identify the most appropriate measures to curb emissions from goods movement while balancing the freight demand in the city. There is little or virtually no information on the movement or demand for goods in the SMC area. Therefore, the first step will be to undertake a data collection exercise to understand the city's movement of goods and services.

Some of the data points that will be required to inform a policy include:

- The number of freight trips in the SMC area categorized as E-E, E-I & I-E and I-I
- An inventory of all commercial freight vehicles registered in the city, fuel types, engine efficiencies, etc.
- The supply chain characteristics of the textile, diamond, and chemical clusters in the SMC area. Time dependencies of movement of goods in and out of the clusters
- Current parking characteristics and estimated parking demand for freight
- Decibel levels of urban freight
- Traffic counts on different road types in the city to determine the participation of freight movement in overall vehicular movement
- Using the data collected, the SMC must assess if the current restrictions of freight movement are sufficient and the possibility and impact of additional restrictions on their movement.
- Place restrictions on the entry of goods vehicles of a certain size and load factor on different road types (such as local roads within residential communities).
- Based on vehicle inventory, design incentives, and penalty structures to encourage the transition to cleaner and more efficient goods vehicles. Structure programs to enable simple and cheap credit and exchange initiatives in collaboration with automobile dealers.
- Identify categories of urban freight and companies that can be early adopters of electric transition. Develop fiscal incentives and tax breaks for electric transition. For example, enterprise-driven models and high traffic movements like couriers, food, and package deliveries can be targeted with incentives.
- Factor in the cost of environmental externalities associated with hyperlocal, fast deliveries through pricing mechanisms.
- Since freight movement and regulation are complex, the SMC should set up an internal urban logistics management team to ensure a dedicated approach.

9.7.3. Recommendation 3: Ambitious NMT Vision

About 42% of the mode share in the SMC area is walking and cycling. Walking alone makes up more than 40% of the mode share. As household incomes increase, the share of walking and especially cycling falls as 2-wheeler, and 4-wheeler trips tend to increase. The average trip length of cyclists is around 4.1 km, close to the average trip length of 2-wheelers (5.8 km) and 3-wheelers (6.1 km). An NMT focus is especially important as walking is commonly used for first and last-mile connections to public transport corridors. People who cycle are the most likely to shift to 2 or 3-wheelers in the absence of infrastructure and as incomes rise. Some of the targets that SMC should aspire to achieve are given in **Table 46**.

Table 46: NMT 2026 Targets

Target	
By 2026	Protect and increase the walking mode share by 40%.
	Increase cycling mode share to 10%, from the current 2%.
	Increase foot path coverage to 80% and increase cycling network.

Intervention 1: Comprehensive NMT Policy for the SMC Area

Only 20% (60km) of the total road length has a footpath network, and only 8% of the city's road network has dedicated bicycle lanes. Further, only 44 of 115 major junctions are signalized. To develop a strong walking and cycling mode share by 2026, a systematic approach is suggested by developing a comprehensive NMT policy. The policy is a dedicated approach to study mobility patterns and make targeted design and infrastructure investments. Some of the considerations that should be made while developing an NMT policy are described in the following sub-sections.

Intervention 2: Data Collection and Analysis

- Create an inventory of walking infrastructure within the SMC boundaries. Undertake a zone-wise audit of the pedestrian infrastructure in the city. Parameters must be determined before the audit (such as width, length, quality, type of road, continuity, lighting, obstructions, and encroachments). SMC also has an existing PBS network. Therefore, an audit of the length and cycle pick-up points must be undertaken for the PBS infrastructure in the SMC area.
- From the household survey of 2015, assess the walking and cycling trips undertaken by members of households and the relative dependence of women and men on walking and cycling. Assess the nature of trips done on 2-wheelers and 3-wheelers from the survey data. Identify types of trips and lengths that can potentially shift to NMT modes. This assessment is also to be conducted zone-wise.

While framing the policy, the following points must be kept in mind:

- Based on the nature of a road (width of the carriageway, type of road, etc.), the SMC must develop guidelines for the design of pedestrian infrastructure and bike lanes. Guidelines must also include sufficient lighting to ensure safety, street furniture, landscaping, sufficient drainage mechanisms, etc.
- Institute protocols to prevent encroachments into NMT infrastructure (such as 2-wheelers on bicycle lanes or parking of vehicles on sidewalks). Enforcement and grievance redressal mechanisms by communities must be set up.
- Stipulate the need to include NMT infrastructure in existing and future road development plans.
- Origin and destination data from the survey must inform the design of NMT infrastructure that reduces point-to-point distances for pedestrians. Assess the need for an increase in the network, bicycles, and stands to facilitate a transition from 2- and 3-wheeler trips to cycling.
- Build capacity on NMT concepts within the SMC.
- Incorporate NMT targets into the budgeting process of SMC. Develop an NMT fund that will only address walking and cycling infrastructure investments within the SMC.

- The NMT policy must also identify and demarcate areas in can be fully pedestrianized. These areas must be identified in each of the seven zones in the city. The NMT policy must articulate zone-wise targets to be fully pedestrianized. As a part of its NMT strategy, the SMC must also aim to increase public spaces by carving out areas from the build infrastructure (like under flyovers).
- Finally, a set of metrics or indicators must be developed to measure progress annually. Some of these include the percentage increase in NMT mode share, increased pedestrian and cycling infrastructure network length, and reduced 2- and 3-wheeler trips.

Intervention 3: Congestion Management Practices
Several measures mentioned under different categories in this chapter directly or indirectly address the problem of congestion in the SMC area. Suggestions such as regulating freight movement through an urban freight policy, encouraging modal shift by investing in public transport and through the NMT policy, and parking pricing as a demand management tool, speak to this issue. This sub-section lists a few other measures that can be implemented to mitigate congestion in the city.

Some of the interventions that the SMC can consider are as follows:

- While adaptive traffic management systems work well in Western economies, they often do not work as efficiently in Indian cities because of long queues, lack of lane discipline, and mixed road use. Therefore, it is recommended that SMC employ both the adaptive and fixed time signaling system curated to the traffic patterns and variations of the SMC area. Such interventions can also be used to allow for priority movement of traffic streams that have a larger mix of public and other shared modes of transport.
- Assess the feasibility and practicality of implementing a congestion charge. A study of congestion along different road types and zones must be undertaken to assess such a charge.

Intervention 4: Investments in the Advanced Monitoring System

- There are 10 air quality monitoring stations in the SUDA region, of which only 7 are within the SMC boundary. The current number of monitoring stations is lower than the recommended figures for the population and density of the SMC area. Further, some zones like the East, North, and Northeast have no monitoring stations. The SMC should deploy more monitoring stations-based population densities in different zones to create a reliable benchmark and monitor progress.
- For other measures mentioned under different sections in this chapter, it is essential to create baseline data and update it regularly (preferably) annually to monitor progress and adjust the interventions based on evidence and insights from data updates.
- While SMC has already approved the tender for 150 electric buses in the city, greater support will be required for the successful electrification of their bus fleet. The Government of Gujarat launched the Chief Minister Urban Bus Service Scheme in 2018. The scheme provides financial support as VGF to transit agencies in urban areas to cover the gap between operation costs and revenue earned.
- SMC should run a campaign to promote the greater adoption of electric auto-rickshaws and leverage the State government subsidy.
- Congestion pricing or congestion charges is a system of surcharging users of major corridors or areas subject to congestion due to excess demand. It is a pricing mechanism that has been used

as a traffic management strategy that employs the 'polluter pays principle.' Considering the intense congestion within the old city area and within the inner ring road of the SMC area, the application of a congestion charge for all vehicles wishing to enter this zone will help reduce congestion and air pollution within the area. However, such a scheme has to be supported with improved access through public transport, improved pedestrian network, and bicycle tracks within the selected areas.

- With the strong push for the transition to electric vehicles, there is a need to provide auxiliary infrastructure to support this transition. One of the key requirements is the presence of public paid-to-charge infrastructure. SMC needs to conduct a study to ascertain the appropriate locations for these as the initial demand for these will be from IPT vehicle owners. Thus, charging stations must be located across the city, closer to auto-rickshaw and taxi stands. Additionally, SMC should integrate public charging facilities with the city's parking infrastructure.
- Fuel adulteration continues to be observed in the SMC area. Vehicles that use adulterated fuels tend to be more polluting than those that are unaltered. To combat this, the Government of India has formed the Anti-Adulteration Cell headed by a Director-General and four Deputy Directors for four zones of India. The authority is responsible for the prevention of adulteration and other mal-practices in the sale of fuel. In an auto fuel policy report, the problem of fuel adulteration has been discussed. Directions have been given to oil companies. There is a need for periodic checking of fuel pumps by the District Supply Officer (DSO) to reduce levels of fuel adulteration in the city.

Intervention 5: Additional Development of Green Corridors
Proposed Actions:

- Regular detection and filling of potholes on roads across the city
- Preparation of a plan for the creation of green buffers along major corridors in the city
- Introduction of water sprinklers at major intersections
- Construction of green walls along key traffic corridors
- Provision of white topping on major corridors to reduce dust
- Launching of a public awareness campaign to control vehicular emission, promotion of regular maintenance, PUC checks, use of public transport, and NMT

9.7.4. Recommendation 4: Improvements in Infrastructure and Capacity Building

Proposed Duration: By 2025, increase institutional capacities of different public offices for investment in technology and enforcement.

Proposed Actions:

- Increase the number of CNG stations in the SMC area from the existing 22 stations. Estimate zone-wise requirements of CNG stations based on vehicle ownership data.
- Identify points in the city to set up electric charging points. Vehicle ownership data can help inform the locations of these stations. Amend building codes to include mandatory facilities for charging electric vehicles.

- Develop a dense network of PUC stations across the SMC region. Use remote sensing mechanisms to improve efficiency. Regular random PUC checks by the RTO will be planned.
- Have random monitoring of fuel adulteration and fuel quality data.

Proposed Responsible Agencies:
SMC and the State Department would be responsible for the EV policy and the Department of Heavy Industries and the Central Government (for FAME 2 scheme).

Implications:

- With the strong push for the transition to electric vehicles, there is a need to provide auxiliary infrastructure to support this transition. One of the key requirements is the presence of public paid-to-charge infrastructure.
- SMC needs to conduct a study to ascertain the appropriate locations for these as the initial demand for these will be from IPT vehicle owners. Thus, charging stations must be located across the city, closer to auto-rickshaw and taxi stands. Additionally, SMC should integrate public charging facilities with the city's parking infrastructure

9.8. SCENARIO GENERATION

9.8.1. Transportation-Related Air Pollution – BAU

Surat's Comprehensive Mobility Plan shows that the city's population has been projected to double by 2025 and triple by 2046, compared with 2011 levels, to 85.5 lakh and 125 lakhs, respectively. Consequently, the city's transportation demands have also been projected to increase. Studies on vehicle ownership show that the SMC area has a high motorization rate[84]. The vehicle population in the city has increased from 0.15 lakh in 1985 to over 30 lakhs in 2018. A projection of this vehicle population data alongside the city's population shows that the vehicle population is projected to increase to approximately 50 lakhs by 2025. By 2030, it will increase by twice as much as 2018 levels **(Figure 69).** In the last decade alone, the data shows that the city has seen a yearly vehicle population growth of 9%, higher than that for population growth (5%). Further, analysis into the vehicle's types using historical vehicle registration data shows that 2-wheelers have the highest growth rate, followed by 3-wheelers and 4-wheelers. The data show that the 30 lakh vehicles registered in 2017-18, 240 lakhs were 2-wheelers, and 4 lakhs were 4-wheelers. While the compound annual growth rate of 2-wheeler and 4-wheeler ownership per 1000 population is 3.5% and 6.3% since 2004 levels, respectively, 3-wheelers and public transport buses are -2.1% and -6.2%. This is consistent with the mode share data for the city, with 2-wheelers being the most popular mode choice in the city and buses being the least preferred.

[84] *Comprehensive Mobility Plan 2046 – Surat. (2018). Centre of Excellence (CoE) in Urban Transport, CRDF, CEPT University. http://suratmunicipalcorporation.org:8020/News/6126_1.pdf.*

Figure 69: Vehicle population projections for SMC (Source: RTO data)

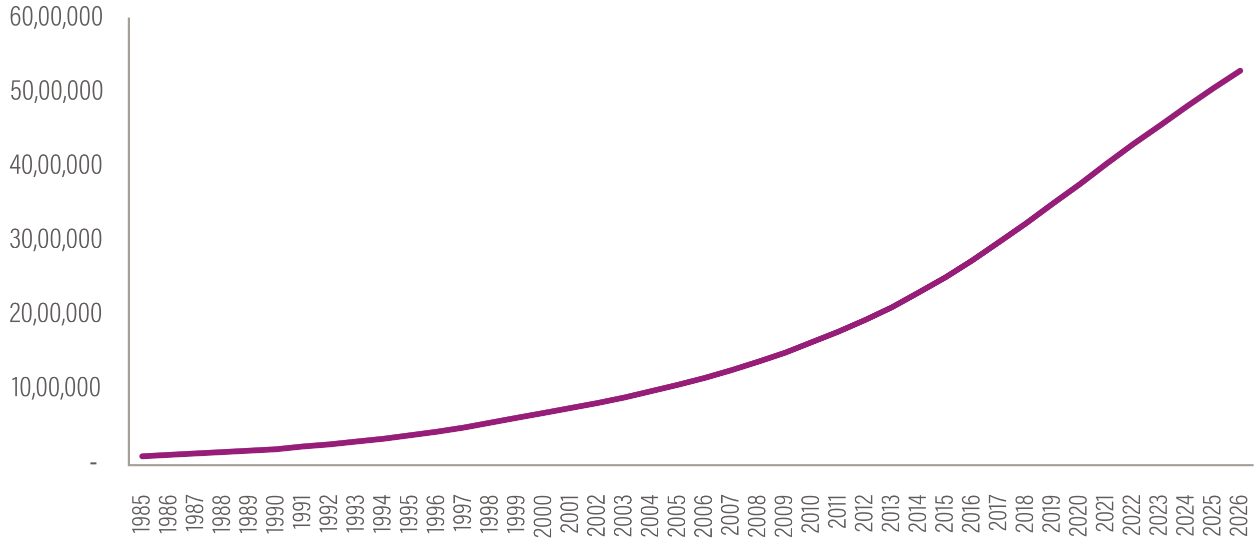
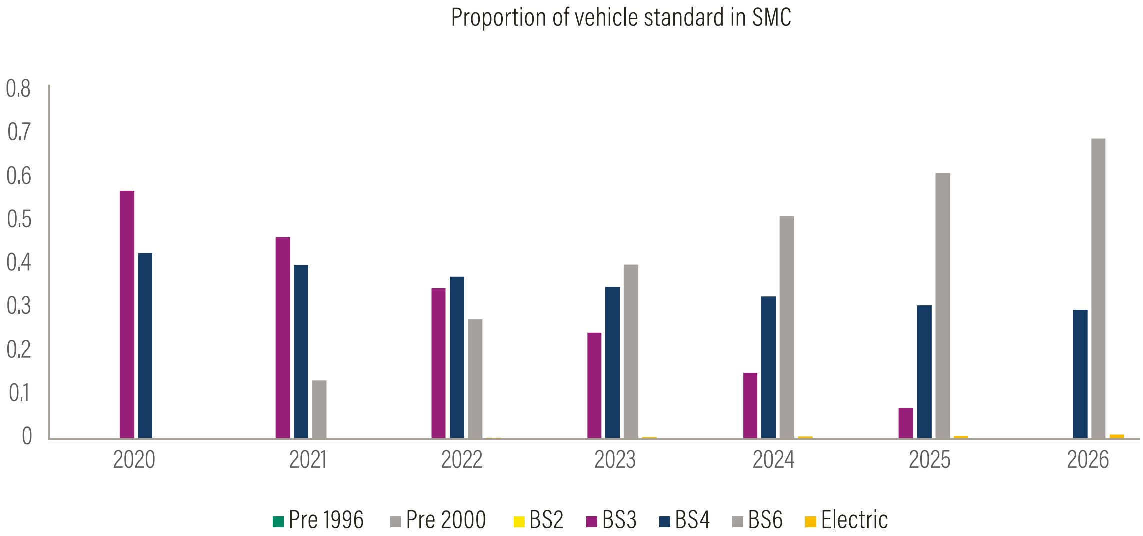


Table 47: Mode share – SMC area – Projections

Types of Vehicles	2020 Mode Share	2026 Mode Share
Bus	7.2%	15.0%
Four-Wheeler	5.6%	8.4%
Two-Wheeler	60.4%	57.8%
Three-Wheeler	13.1%	5.7%
Others	13.7%	13.1%

It is important to note here that an increasing trend in the usage of private and semi-private modes will increase congestion and air pollution in the city. There is, thus, a need to transition to more sustainable modes of transport to mitigate potential congestion and air pollution challenges in the city. With this aim, the projected emissions were analyzed by projecting historical data on the city's population, passenger trip rate, trip length by mode, and mode share. Additionally, to arrive at a more accurate assessment of the transport-related emission in the city, the current and projected composition of the vehicles based on vehicle standards and fuel type was also analyzed. This was done based on the data collected from the CMP. **Figure 70** presents the projection of the vehicle standard's proportion in the do-nothing scenario used in the CMP shows the transition from the predominant BS III and BS-IV vehicles in 2020 to the less polluting BS-VI vehicles. Additionally, considering the national and state government incentives for the faster adoption of electric vehicles, the projection also shows the use of a small percentage of electric vehicles (1%).

Figure 70: Implementation of vehicle standards for SMC

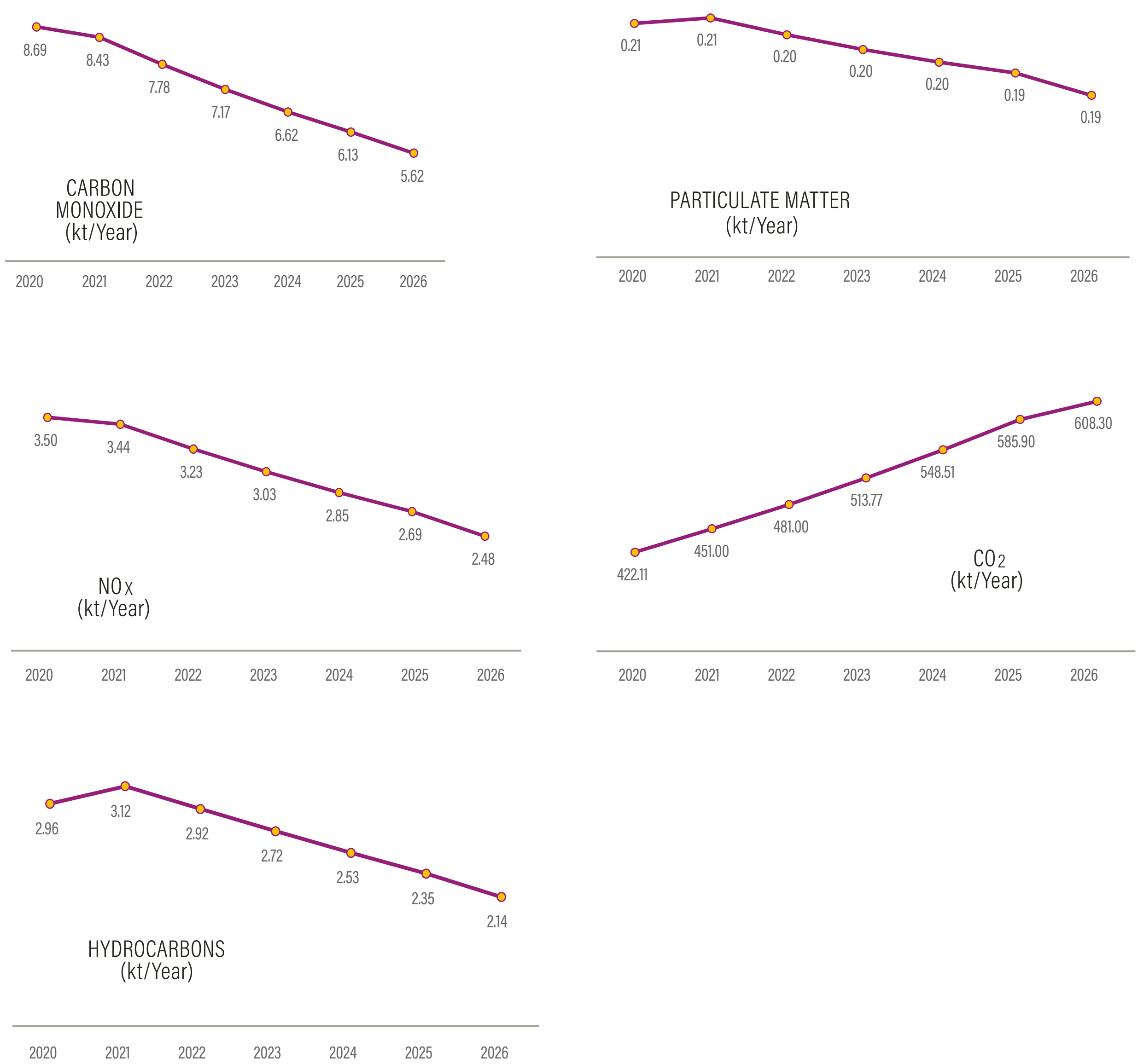


Therefore, the city's projected transport-related emissions were calculated by combining the data acquired by the projection of the above-mentioned travel characteristics and vehicle composition based on vehicle standards and the current policies and incentives offered by the government to adopt cleaner modes of vehicle transport in the city. The following graphs show the projected passenger transport-related emission of five pollutants. **(Figure 71)**

While the projections show a decreasing annual emission of all the pollutants except for carbon dioxide, the contribution of transport-related activities to the overall pollution in the city remains high. In addition to passenger transport, freight movement within the SMC area contributes to about 27 lakh VKT, forms a large part of the city's vehicular movement, and contributes to emissions. While there are restrictions on the movement of heavy commercial vehicles (HCVs) and medium commercial vehicles (MCVs) during peak hours in the core of the city, their movement is extremely complex. These are governed by rules that are different from those governing passenger transport.

Additionally, a comparison of the percentage VKT by freight vehicles in the city by the age of vehicles shows that 23.6% of the VKT is covered by vehicles aged between 11 and 15 years, 32.2% by vehicles aged between 6 and 10 years, and only 44.2% by vehicles aged less than 5 years. Currently, the average age of all freight vehicles is approximately 8.9 years. The higher age of these vehicles also indicates a lower emission standard of vehicles, indicating higher pollution levels. There is, thus, a need to structure mitigation efforts further to minimize transport-related air pollution in the SMC area.

Figure 71: Scenario generation – Transport sector



9.9. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

As discussed in the recommendations covering Intervention 2 for the uptake of public transport, it is interesting to observe the penetration of public transport services in the SMC region. While the Comprehensive Mobility Plan suggests that public transport coverage is about 87% of the city, these calculations have arrived using the Euclidean distances from the transit corridor **(Figure 72)**. The road network measurements from public transit corridors provide more realistic estimates of coverage. The road network assessment reveals that public transit covers 76% of the SMC region **(Figure 73).** This essentially indicates that a quarter of the city is not serviced well by city buses.

Figure 72: Coverage calculations using Euclidean distances

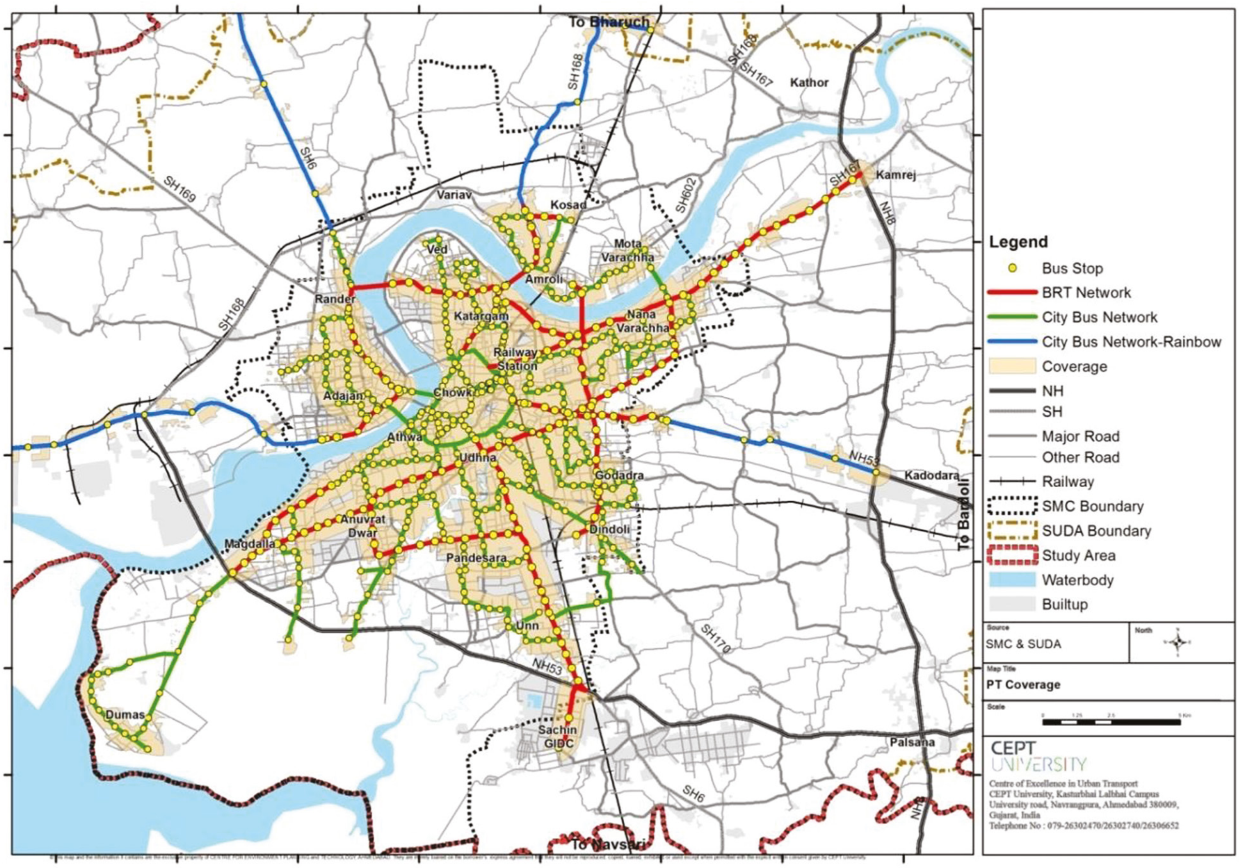


Figure 73: Coverage calculations using road network calculations

Further, a closer look at zones and public transit coverage as a percentage of the built-up area of zones identifies the South and the Southwest zones to be severely underserved. This is exhibited in **Table 48**.

Table 48: Micro area plan coverage

Zone	500 Meter Coverage	Average SMC Coverage
East	85.4%	75.9%
North	91.1%	
South	67.6%	
South-East	86.4%	
South-West	60.5%	
Central	84.8%	
West	76.3%	

While investments must be made for the city as a whole, special attention must be given to these two zones. Further assessment reveals the following characteristics of the South and Southwest zones:

- About half of the built-up area in these two zones is residential (South: 44%; Southwest: 51%)
- The south and southwest zones contribute to 1/3rd (33.6%) of the total residential land use in the SMC region.

Nearly 70% (68.3%) of all industrial land use is in these two regions, with the South particularly contributing to 62%

9.10. TECHNO-ECONOMIC ANALYSIS

Factoring in environmental costs mostly generates revenue, and the cost associated with this measure is the development of the parking rate functionality that can be integrated into the city app. This section examines the larger cost implications from the recommendations that require a closer assessment of cost implications during decision making.

9.10.1. Cost Implications of Tax Breaks (Recommendation 1: Intervention 1)

The calculations have been made based on the targets set forth by intervention and the rationalized tax structure from **Table 49,** which are only given here as an example. The costs associated with it (described in detail in this section) are only indicative. It also gives a break-up of the cost of subsidizing replacement at the municipal level (for SMC) and at the state level (for the state Road Transport Department).

Table 49: Techno-economic analysis – Intervention 1 – Cost subsidies

Cost of Subsidies (crore)					
	2022	2023	2024	2025	2026
SMC (INR)	13.55	10.05	6.89	(108.3)	(110.9)
Road Transport Department (INR)	28.52	20.58	13.41	(259.22)	(265.06)

Calculations suggest that despite the subsidies, the revenue of both the SMC and the State Road Transport Department increased till 2024. This increase is attributed to the faster replacement of BS III and BS-IV vehicles. Therefore, the net cost of the subsidy for SMC is estimated to be INR 188.74 crore and INR 461.75 crore for the State Transport Department. These estimations are the net costs over five years.

9.10.2. Cost Implication Procuring and Operating Additional Buses (Intervention 3)

The proportion of public transport buses based on emission standard and fuel type is given in **Table 50**.

Table 50: Techno-economic analysis – Intervention 3 – Cost implications

Type of ES	2020	2021	2022	2023	2024	2025	2026
BS3	6%	5%	1%	0%	0%	0%	0%
BS4	94%	94%	22%	14%	10%	7%	5%
BS6	0%	1%	76%	83%	86%	87%	85%
Electric	0%	0%	2%	2%	4%	6%	10%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Certain key assumptions have been considered in assessing the financial implications associated with the augmentation of the public bus fleet in the SMC area. These are as follows:

- All new diesel buses procured will be standard non-AC buses.
- Of all the electric buses added to the fleet annually, 50% will be standard electric buses, and 50% will be AC electric buses.
- All electric buses will be leased using a GCC contract (INR 100/km Standard E bus, INR 150/km AC E bus).
- All electric buses will be charged using slow chargers; one slow charger needs to be procured for every bus.
- All costs presented in this section do not consider any subsidy from the national or state government.

- Costs associated with the augmentation of bus infrastructure, including depots, workshops, terminals, and bus stations, have not been considered.

Table 51 shows the yearly costs associated with the operation and procurement of the augmented fleet as a part of Intervention 2.

Table 51: Techno-economic analysis – Intervention 2 – Cost implications

INR crore	2021	2022	2023	2024	2025	2026
BS3		12	8	4	0	0
BS4		205	194	184	175	166
BS6		4	1181	1363	1837	2328
Electric		0	33	66	141	298
Total	**0**	**221**	**1416**	**1618**	**2152**	**2792**

The cumulative cost of implementing scenario 3 till 2026 is INR 11,767 crore. This is 81% higher than the cost of the BAU scenario. However, this cost can further be reduced by considering a further increase in the proportion of electric buses operating in the city.

9.10.3. Health Risk Assessment

Mortalities from transportation sector emissions of $PM_{2.5}$ have been discussed in detail in **Chapter 3**; for the average annual contribution of 30% of $PM_{2.5}$, transportation as a sector adds 367 premature deaths in the SMC area, considering the current situation wherein no additional mitigation measures exist. Reducing transportation emissions exposure must be achieved through the proposed recommendations and mitigation mechanisms to avert these premature deaths.

9.11. CONCLUSION

In 2019, the transport sector was the third-highest contributor to $PM_{2.5}$ emissions in the SMC area. An analysis of primary and secondary data revealed that although the SMC has initiated a good amount of work on regularizing VKT in the city, the HCV is adding a large number of emissions in the city's airshed owing to their business orientation. Although there is a natural inversion phenomenon as the SMC area is near the coastline, it does not help much with the road dust and diesel particulate matter, which does not disperse at a great height. The regulations on 2-wheelers and private 4-wheelers are negligible, and thus, there is a heavy load on the city's road infrastructure. This can certainly be averted if the SMC strategically implements the freight vehicle, EV, and updated parking policies, which would play a huge role in changing the behavior as well as mode share to reduce the air pollution from the sector.

CHAPTER 10

>> NON-EXHAUST EMMISSIONS

10.1. EMISSION INVENTORY – NON-EXHAUST SECTOR

Non-exhaust road dust re-suspension of PM is among the largest contributors to PM pollution in the SMC area, as per dispersion and receptor-based source apportionment studies. The USEPA has pointed out that re-suspended dust is not a result of vehicular tailpipe emission; it is generated due to the movement of vehicles on dusty roads. According to TERI's assessment, non-exhaust emissions (NEE) of dust due to vehicle movement vary with the silt loading on the road surface and the average weight of the vehicles plying on the road. Therefore, the VKT and the average weight of the vehicles in the SMC area are the determining factors in estimating particulate emissions.

According to the emissions inventory database, road dust re-suspension contributes 19.55 kt/year and 4.73 kt/year of PM_{10} and $PM_{2.5,}$ respectively, in 2019. As per the dispersion-based source apportionment study, road dust accounts for 10% of $PM_{2.5}$ pollution in summers and 7% in winters, considering both in-boundary and transboundary sources. For PM_{10}, the road dust share is 12% in summers and 14% in winters. On the other hand, the receptor-based source apportionment shows a combined contribution of road dust, soil dust, and construction dust re-suspension for $PM_{2.5}$ at 32% in summers and 9% in winters for the SMC area.

10.2. ANALYSIS OF THE CURRENT PROFILE OF THE SECTOR

10.2.1. Silt Road Consideration

Four main processes are responsible for the bulk of non-exhaust emissions: the wearing down of brakes, tires, road surfaces, and the re-suspension of road dust. The amount of particulate matter emissions that a vehicle emits is determined by many factors, including vehicle weight, the material composition of brakes, tires, and roads, the amount of dust on road surfaces, and driving styles. However, uncertainty remains with respect to the amount of PM emitted from non-exhaust sources under real-world driving conditions. As pointed out earlier, NEE generally depends on the silt-load of a road, which directly relates to the quality of the material used in road construction and repair.

In addition, the numbers and types of vehicles define the quantity of dust emissions. A radial pattern of roads is among the unique characteristics of the SMC area. Moreover, the grid-iron pattern is observed in cases of local streets and minor roads. Prominent roads in SMC have a bituminous surface, yet a few are paved with RCC technology. The prestigious *Gaurav Path* constructed by the SMC is paved with a concrete surface connecting Parle point to Surat Cricket Stadium. **Figure 74** illustrates the total road distribution within the SMC area as per the Comprehensive Mobility Plan-2046 (CMP), and **Table 52** presents the numbers.

Figure 74: Road network – SMC area (Source: CMP 2046, SUDA)

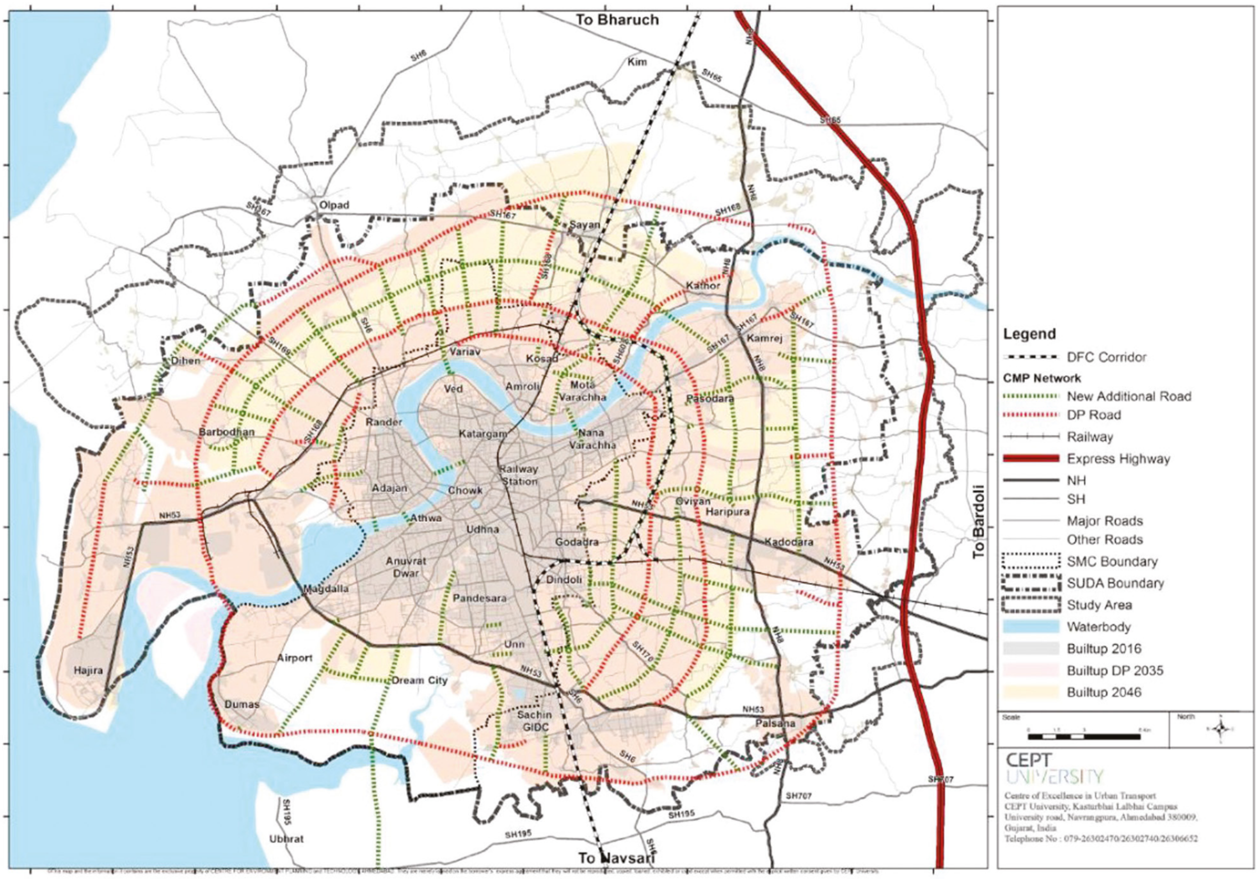


Table 52: SMC area road network growth as per the different development plans and projections (Source: SUDA-Surat Urban Development Authority; CMP 2046- Comprehensive Mobility Plan-2046; DP 2036- Draft Development Plan-2036 (Source: CMP 2046, SUDA) SUDA)

Sr.No.	Area	Existing (km)	DP 2036 (km)	CMP 2046 (km)
1.	SMC	3859	3905	3944
2.	SUDA	1411	1621	1788
3.	Rest	503	517	574
4.	Total	5733	6043	6306
5.	Built-up	228	680	832
6.	Road density (km/sq.km)	4.3	4.5	4.7

Roads in the SMC area are classified in the following categories as per their width.

- **Arterial Roads (width > 60 meters)**: The city roads, which are meant for thorough traffic, usually on a continuous route, are called arterial streets. Arterial streets are generally spaced at less than 15 km in developed business centers, whereas there may be 8 km apart in less important areas. Arterial roads are also divided highways with fully or partially controlled access. Parking, loading, and unloading are carefully regulated. Pedestrians are permitted to cross these at intersections only.

- **Sub-arterial Roads (width between 45 and 60 meters)**: The city roads, which provide a lower level of travel mobility than arterial streets, are called sub-arterial streets. Their spacing may vary from 0.5 km in central business districts to 3- 5 km in suburban areas. Loading and unloading are usually restricted. Pedestrians are allowed to cross these highways at intersections.
- **Collector streets (width between 30 and 45 meters)**: The city roads constructed to collect and distribute the traffic to and from local streets and provide access to arterial and sub-arterial streets are called collector streets. These are located in residential, business, and industrial areas. These roads are accessible from the buildings located along these roads. Parking restrictions are few, and that too only during peak hours.
- **Residential roads/Local Roads (width < 30 meters)**: The city roads that provide access to residences, business centers, and other buildings are called local streets. The traffic carried either originates or terminates along the local streets. Depending upon the adjoining areas' importance, a local street may be residential, commercial, or industrial. On these local streets, pedestrians may move freely, and parking may be permitted without any restriction.

The residential or local road type has the highest value of silt-load and is present in the majority, considering the dense residential localities and commercial locations in the SMC area **(Table 53)**. As per the OECD[85] report on road dust re-suspension emissions, particulate matter is usually generated heavily while the road is newly constructed or is not appropriately paved. **Table 53** indicates an estimation of the existing silt load based on different types of roads added every year (rate of addition as per the 2019-2020 data) in the SMC area.

Table 53: Representative length of roads (rate of addition in a year) and silt load factor in SMC area (Source: Assessment done using data from Development Plan 2035 SUDA (2017))

Sr.No.	Type of Road	Length in Km (addition per annum - data for 2018, 2029, 2020)	Silt load factor (gm/m2)
1.	Arterial Road	22.9	1.4
2.	Sub-arterial Road	23.64	2.4
3.	Collector Road	47.4	2.6
4.	Residential Street Road	139.56	2.6
	Total	**233.51**	

10.2.2. Vehicles Kilometres Travelled

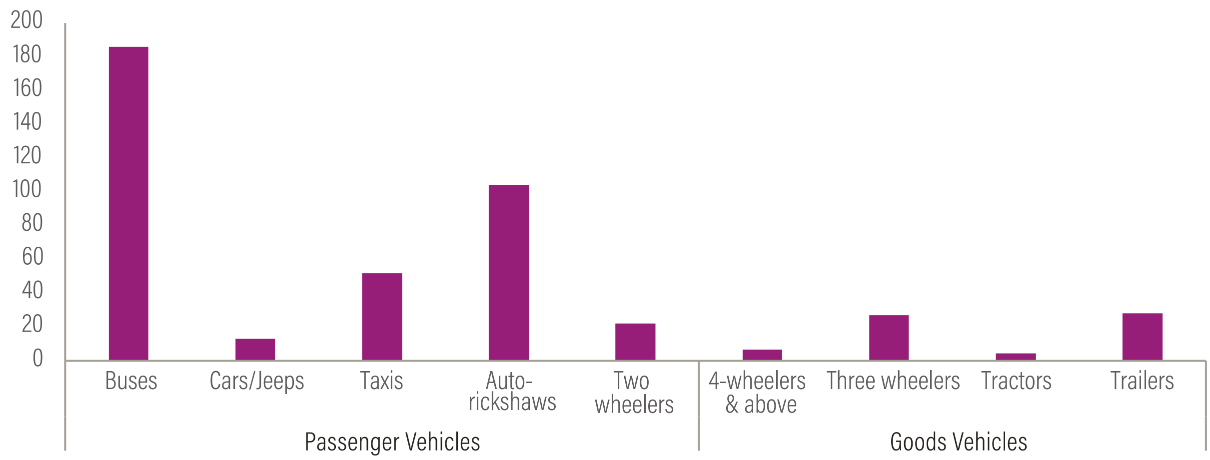
This analysis for the VKT has been done for the average number of trips made per day on a vehicle, while a parallel assessment has been done for the average time taken to complete the trips. A similar kind of assessment was done for the total VKT by types of vehicles owned and rented by the citizens

[85] *OECD iLibrary | Non-exhaust Particulate Emissions from Road Transport: An Ignored Environmental Policy Challenge. (2020). OECD. https://www.oecd-ilibrary.org/environment/non-exhaust-particulate-emissions-from-road-transport_4a4dc6ca-en.*

of the SMC area. The VKT assessment, in addition to mode share shown in **Figure 75**, indicates motorbikes or motorized 2-wheelers (four strokes primarily) are the preferred option for mobility in the SMC area. Motorcycles form a share of 35%. This is followed by scooters at 18%, 13% of 3-wheelers or auto-rickshaws, and 11% share of passenger cars. This pattern contributes to a significant share of emissions for the city. As the city population increases by 4.52% annually, the primary reason for this expansion is that the city provides enough business and livelihood opportunities to sustain permanent and semi-permanent residents and those in the city for shorter periods. These are floating population groups coming to the city for quick income generation for few months and going back to their places. The preferred mode of mobility and transport is renting a two-wheeler or owning it in sharing for a few months. Thus, all three types of population groups prefer to travel on two-wheelers. Because these two-wheelers generate significant congestions at crossroads and additional emissions, their increasing population affects the overall sectoral contributions.

Public transport in the SMC area is rapidly expanding its reach. Although the annual VKT share by buses is insignificant in the combined assessment of passenger and goods vehicles. The diesel and CNG engine-operated buses share a large amount of 186 km/day, followed by almost 104 km/day by the 3-wheeled autorickshaws and then by passenger taxis at 52 km/day, according to an analysis of Census of India and NSSO data **(Figure 75).**

Figure 75: VKT for the SMC area – Passenger vehicles and goods vehicles



Maximum trips are concentrated in the walled city area, Udhana, textile market areas, Agricultural Produce Market Committee (APMC), Katargam, etc. There are shorter trips that connect the residential settlements within these industrial zones to factories/employment centers. It has been observed that the worker population and students prefer bicycle as a mode.

10.2.3. Rapid Infrastructure Expansion – Road Junctions

The road network can mainly be split into two: one is a walled city road network with narrow lanes and secondary ones surrounded by a ring road, and the second is outside the walled city network with radial roads converging to the central business area. Station Road, which connects the link to Rander–Adajan across the river through Nehru Bridge, is a major road in the walled city. Another important road is a ring road with the fly-over bridge connecting the North and the East zones to the South zone and extending up to Magdalla through the South-West zone. The other stretch via the Sardar bridge reaches to Hazira industrial belt. The SMC area started developing its suburban area, such as Udhna, Athwa, and Fulpada, along with the various other corridors opened up in the radial pattern. In this reference, five major corridors have been expanding in the SMC area over the last five years (2015-2020), in the North Zone towards Katargam and Amroli, in the East Zone towards Kamrej crossroads, in the South-East Zone towards Bardoli road, in the South Zone towards Udhna road, in the West Zone towards Rander-Adajan road, and the South-West Zone towards Dumas Road.

10.3. MAJOR ISSUES RELEVANT TO THE SECTOR

The proportion of particulate matter emissions from non-exhaust sources has rapidly increased due to the significant infrastructure development in the SMC area in the last five years (2015-2020).

There are limited numbers of studies that analyze the factors responsible for NEE. To better understand the NEE emission in the SMC area, we reviewed these studies. A study[86] that analyzed the impact of vehicle speed on NEE found that increasing speed from 80km/hr to 120 km/hr increases NEE. Another study[87] found an essential dependence of road dust emissions on the type of vehicle tires: the particle mass concentrations behind the tire at 100 km/h were about 10 times higher than that at 20 km/h. However, these studies could not attribute the speed dependence to direct wear and tear and/or re-suspension emissions. Interestingly, the high particulate matter concentrations observed during braking and hard acceleration suggest that acceleration may also play a role in road dust emissions.

There are minimal documentation and mitigation options laid down for the linkage of vehicle weight and generation of NEE. However, this is seen by naked eyes that heavier vehicles uplift the unpaved or poorly paved surfaces. Thus, it should also be attributed to the type of vehicles when transport planning studies assess the current mobility situation and its effects on the city's air.

When it comes to providing controls, most of the policies at the national and regional level only target the tailpipe emissions from the transportation sector. However, least or almost no importance is given to NEE arising due to the movement of vehicles in the city. Over the years, as the tailpipe emissions can see the daylight of curbs due to advanced designs in vehicle designs and fuel types, a bare minimum has been done to control particulate emissions from non-exhaust sources.

Vehicle characteristic plays an essential role in tailpipe emissions. With increasing age, vehicles tend to provide more wear and tear while in operation. Vehicle compartments, such as brakes, tires, and gears, add significant units to NEE while no policy or program looks at these features strongly. To add to this problem, transport planning never considers NEE as an association to vehicle design; instead, it focuses on infrastructure planning to accommodate more people by redesigning mode shares, which does not entirely solve the issue.

[86] Lee, S. H., Kwak, J. H., Lee, S. Y., & Lee, J. H. (2015). On-road chasing and laboratory measurements of exhaust particle emissions of diesel vehicles equipped with aftertreatment technologies (DPF, urea-SCR). International Journal of Automotive Technology, 16(4), 551–559. https://doi.org/10.1007/s12239-015-0056-8.

[87] Hussein, T., Johansson, C., Karlsson, H., & Hansson, H. C. (2008). Factors affecting non-tailpipe aerosol particle emissions from paved roads: On-road measurements in Stockholm, Sweden. Atmospheric Environment, 42(4), 688–702. https://doi.org/10.1016/j.atmosenv.2007.09.064.

As per the assessment, PM_{10} and $PM_{2.5}$ are the highest attributed to NEE or road dust re-suspension. Significant studies show that $PM_{2.5}$ causes harmful effects in the lungs, and with people traveling by different mode share, NEE provides the highest exposure to them. However, most of the policies and programs direct towards controlling tail pipe emissions when providing micro-level mitigation options. Atmospheric conditions play an essential role in the dispersion of NEE. At the same time, in providing control measures, temporary solutions rather than permanent ones are adopted. In addition, issues related to the transportation sector also define a significant problem niche that needs to be worked upon.

10.4. EXISTING POLICIES AND PROGRAMS – CHALLENGES AND OPPORTUNITIES

Since the emissions are directly associated with the transportation sector, any policy pertaining to improving road and vehicular interaction or standalone retrofitting/redevelopment is assumed to affect NEE. In this section, we list the available policies and programs that impact NEE.

10.4.1. Swachh Bharat Mission

The Swachh Bharat Mission (SBM) is a national initiative of the Government of India to clean cities. It covers 4,041 statutory cities and towns. The mission aims to make India clean by providing sanitation facilities for all households, including toilets, solid and liquid waste disposal systems, and a secure and sufficient drinking water supply. This program targets waste collection and disposal, which directly impacts the sweeping of roads through programs such as road sweeping and night scrapping and sweeping. SMC has employed more than 4,000 permanent and contractual sweepers for the purpose of sweeping roads in the SMC area. As a result, SMC's waste management program is considered one of the best in the country.

10.4.2. Solid Waste Management Rules 2016

As explained in **Chapter 5,** the accumulation of waste and its management plays an essential role in the city's cleanliness. In the SMC area, the door-to-door waste collection covers 99% service area. Thus, implicating some of the activities listed in the rules would help in maintaining the junctions in the SMC area. Also, significant articles with combustion potential will be picked up to be treated in the waste management chain, thus reducing nuisance dust accumulation on the roads, eventually reducing the NEE generation in the city.

10.4.3. Road Policy of Gujarat State

Apart from the transportation-related policies prevailing in the state, the Road Policy (Development and Monitoring of Services) looks specifically at the development and expansion of the road network in the urban, peri-urban and rural sections of the state. The policy also states 'optimal resource mobilization for the construction of roads' and allocates the same work principles to the city corporations in million-plus cities and small municipalities of the Gujarat state. The Roads and Buildings Department implements the road policy through a special implementation cell to ensure speedy execution. In addition, the State Government has set up a high-level committee headed by the Chief Secretary to review the progress and implementation of the road policy. The progress made on implementing the policy will be periodically reported to the Infrastructure Development Board of the state government.

10.4.4. Vehicles Scrappage Policy 2021

The vehicle scrappage policy is a government-funded program to replace old vehicles from Indian roads. The policy is expected to reduce pollution and boost demand for new vehicles. Through this policy, the wear and tear of vehicles can be kept in check; however, the scrappage policy heavily depends on the volunteer nature of ownership.

10.4.5. SMC Area-Specific Development Plan 2035 and Comprehensive Mobility Plan (CMP) 2046

These plans are heavily articulated for the vision the authorities and stakeholders have for the SMC area in the near future. While the Development Plan 2035 covers every intricacy of the city's physical and service level development, the CMP comprehensively targets the SMC area's best options for sustainable traffic and mobility management. In both of these plans, air pollution and collaboration with the regional office of the GPCB for the abatement of the same have been mentioned. However, these plans lack detailed information in the form of a non-negotiable prerequisite for the city's future expansion. Thus, they also fall short of addressing the different sources of air pollution affecting the SMC area and its mitigation.

10.4.6. Nagar Van Scheme – Gujarat Forest Department

The Nagar Van (Urban Forests) scheme aims to develop 200 urban forests across the country in the next five years (2019 – 2025). The Warje urban forest in Pune (Maharashtra) will be considered a role model for these forest patches to be developed. At the same time, commonly available grounds across different cities will be taken up to develop forest-like patches. The scheme will be operational under the National Afforestation and Eco-Development Board and monitored by the selected cities' district forest offices. The finances will be paid for by the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) through the Compensatory Afforestation Fund (CAF) Act, 2016. The CAF Act was enacted to manage the funds collected for compensatory afforestation, managed by the ad hoc CAMPA. Compensatory afforestation implies that every time forest land is diverted for non-forest purposes, such as mining or industry, the user agency pays for planting forests over an equal area of non-forest land, or when such land is unavailable, twice the area of degraded forest land is ordered to be compensated. As per the rules, 90% of the CAF money is given to the states while the Centre retains 10%. The scheme is envisioned to enforce people's participation and collaboration between the Forest Department, municipal corporations, NGOs, corporates (CSR Partners), and local citizens. These urban forests will primarily be on the existing forest land in the selected cities or any other vacant land offered by the city corporations. It is anticipated that such allocation can be planned for the air pollution 'hot spots' in the urban spaces such as the SMC area so that particulate emissions can be averted from causing harm to people.

10.4.7. Construction and Demolition Waste Management Rules 2016

About 530 million tonnes of construction and demolition waste is generated annually. The Ministry of Environment, Forest, and Climate Change notified the Construction and Demolition Waste Management Rules, 2016, on 29 March 2016. These rules are an initiative to effectively tackle the issues of pollution and waste from construction sites, which are usually dumped within city limits or in the city's vicinity and affect the surrounding population and biodiversity alike. The rules state that there should be controlled emissions from the construction and demolition waste management processes and address the recyclability of the waste material. The SMC area has a state-of-the-art facility (ranked second in India), the Surat Green Precast Pvt. Ltd (SGPPL), which has been set up on a PPP model. These rules and SMC area-specific best practices have been collated in The Handbook of Clean Construction Practices for Surat, 2020 (by SMC-GPCB-WRI India), which was released in November 2020. The importance of these rules in controlling NEE is that they address inherent and fugitive emissions coming from the construction sites due to the mishandling of the construction and demolition process waste.

10.4.8. Challenges and Opportunities

The main challenge is to regulate the NEE in the transportation and city development plans. As mentioned in **Section 1.3**, the source apportionment has attributed the NEE as one of the highest emitting sources, recognizing this as a challenge and opportunity for laying down a specific set of standard operating procedures (SOP) in SMC's service-level benchmarks will be an added advantage. **Table 54** lists the specific set of challenges and opportunities in setting up these SOPs.

Table 54: NEE Sector – Challenges and opportunities for mitigation in the SMC area

Sr.No.	Criteria	Challenge	Opportunity
1.	Non-Regulated Emissions	Recognition in the mainframe of tailpipe and chimney emissions dependent policy and program framework	Giving due importance to micro-level urban planning by employing tactical urbanism programs is now becoming popular. In such a socially interactive planning process, NEE can be addressed as a health hazard.
2.	Decentralized Sources	NEEs are generated from vehicle road interactions and expose the commuters primarily using these roads. Thus, NEEs have a higher number of decentralized sources than other sectors.	Decentralized sources can be curbed with a centralized action of providing speed-regulated traffic zones. Implementing speed regulations in the city with strict actions, especially in the NEE-affected areas, can reduce the generation of particulate matter.
3.	Water Availability	The most effective way is to provide relatively clean and treated water for the water sprays and sprinklers to curb the dispersed particulate matter.	Fogging machines that have been proposed to be promoted in the construction sector can come in handy in NEE-affected areas on high pollution days. Water sprays and sprinklers can be provided as an alternative, with the supply of tertiary treated water (Dindoli treatment plant and CETPs of industrial clusters).
4.	Sweeping Program Coverage	Authenticating that the employees in the sweeping program perform their duties adequately though they have been registered with the third-party service provider	Authentication of presence, working hours, and job location can be made wide-ranging through Surat Smart Application. A special portal can be created for sweepers to monitor their work more effectively.
5.	Collection and disposal of dust	The source apportionment study points to dust as a major part of collected material. Silt load calculation shows heavy dust loads in the samples. This is due to the resettlement of the collected dust as no dedicated management is available in the current waste collection system.	It may prove problematic, but the collected dust from the roads and road junctions can be dumped properly in a dedicated pit in the nearest available common ground, and water can be splashed on it so that it does not disperse. For this purpose, dedicated pits for leaf collection can be used.

Sr.No.	Criteria	Challenge	Opportunity
6.	Awareness Generation	People do not follow traffic rules while driving due to a lack of awareness, which causes problems on the road.	Campaigns can be organized in the NEE-affected areas to make the public aware of the health effects of particulate matter and the importance of following traffic rules while adhering to speed regulation. A trust shall be engaged to manage traffic.
7.	NEE appropriate junction design	There are no junctions in the SMC area designed to reduce NEEs caused by heavy traffic.	Redesign junctions across the SMC area, especially in the NEE-affected areas. Wet processes proposed for the construction sector can partly be employed for the reduction of NEEs.
8.	Retreating urban green cover	The most cost-effective solution to control NEE is the conservation of mature trees to control dispersed particulate matter. The SMC's afforestation programs and plantation drives cannot suffice the mature trees 'sequestration potential.	An increasing number of people can be engaged through an urban forestation program wherein a tree census can mark the conservation of worthy trees.

10.5. CLEAN AIR ACTION STRATEGIES OF GUJARAT POLLUTION CONTROL BOARD

GPCB proposed the Air Pollution Control Action Plan for the SMC area under the Air Quality Improvement Program **(Table 55)**. As discussed in **Section 10.4**, many programs are implemented by the government to promote the partial coverage of NEE.

Table 55: Outcomes and challenges of existing policies for NEE (Source: Surat Air Pollution Control Action Plan; https://cpcb.nic.in/Actionplan/Surat.pdf)

Action Points for road dust re-suspension	Implementation Status
Regular cleaning of road dust	SMC's sanitation program is one of the best in the country, and there is an adequate number of dedicated staff to perform the duties as per the regulations.
Prepare a plan for the creation of green buffers along the traffic corridors	The development of the green belt along with the BRT corridor is an on-going process.
Maintain pothole-free roads for free flow of traffic.	SMC and the Town Planning Department are coordinating the maintenance of the roads.
Introduce water fountain at major traffic intersection wherever feasible.	As per the directives of GPCB, SMC has initiated vertical gardening and slow water fountains at four significant junctions of the city.
Greening of open areas, gardens, community places, schools, and housing societies	In the last four years (2015-2020), the Garden Department of the SMC executed the following: The Department developed 45 gardens and 6 lakes in different zones. A total of 2,67,237 trees were planted along the roadside and the road divider. A total of 3,28,778 trees were planted in a large open space as a mass plantation for shelterbelt and green belt. A children's traffic park and skating rink have been built for the citizens of the SMC area. A musical sound system, musical dancing fountains, and other fountains have been installed.

	A zoological park named Nature Park (Phase I) was opened for the public on 26 April 2003. Work on Phase II is in progress; the SMC has started promoting biodiversity in around 80 ha of land at the cost of INR 108 crore along with a creek to mitigate the impact of air pollution.
Blacktopping of metaled roads, including pavement of road shoulders	The SMC is regularly carrying out this activity

10.6. CONTROL MEASURES IDENTIFIED DURING OPPORTUNTIY WORKSHOP/INDIVIDUAL STAKEHOLDER MEETING

Following the interaction with various stakeholders and one-on-one interviews and meetings conducted as part of the process of developing the Clear Air Action Plan, we concluded the following:

- Various factors contribute to road dust re-suspension and looking at the attribution of the source; the emissions are not yet regulated or worked upon much by the authorities and technical agencies alike.
- The emissions factors provided by the US-EPA do not consider all the factors responsible for the regeneration of road dust.
- There is no clarity as to which component causes the emissions; for example, the NEE could simultaneously contribute to the transportation and construction sectors. Thus, it is important to study the source of dust from time to time.
- More impact studies involving the local population should be conducted wherein the relationship between driving behavior and health can be established by propagating the NEE concept.

10.7. STRATEGIES TO MITIGATE AIR POLLUTION

Mitigation of NEE cannot be envisioned as a standalone strategy since many other factors contribute to the dispersion of particulate matter. There are three ways to achieve effective NEE mitigation specific to the SMC area – Retract, Replace, and Regenerate.

Retract: Retracting mitigation measures implies that certain activities responsible for the NEE generation in the SMC area must be avoided. These are mostly related to the vehicular interaction with the road surface, wherein additional stressors can be avoided.

10.7.1. Reduction of VKT

NMT and increasing public sector transport options can reduce the demand for private vehicles in the SMC area. As explained in detail in **Chapter 9**, the mode share shift can prove crucial by providing comfortable and affordable public transport options to the SMC area user base. These policies, such as the parking policy of SMC, vehicle scrappage policy, road policy, and developmental policies of the state transport department, can play a critical role. The measures can consist of disincentives for private vehicle ownership and use, i.e., measures that raise their costs and/or inconvenience and incentives for alternative modes (e.g., public transit, walking, and biking).

Leveraging taxes on vehicles can play an important role in reducing private vehicle ownership. The disincentives can be either monetary or regulatory. These include one-time or recurring cost, purchase taxes, registration fees, and annual taxes. Disincentives for car use can also be in the form of operational costs, including taxes on fuel, distance-based charges, congestion, plus parking pricing. However, amongst all of these, very few taxes are putting any kind of weight on heavy vehicles to tackle NEEs in the SMC area.

Banning entry or operation of 'outside' vehicles, certain physical traits (heavy vehicles), tailpipe emissions (increased exhaust emissions), parking policy restrictions, odd-even usage on certain days of the week, and complete ban in the denser areas of the SMC can provide the significant push for the population to shift towards NMT and public transport options.

Time duration anticipated: Research and assessment can be initiated in 2021; implementation can be undertaken by 2022. By the end of 2026, it is anticipated that people would reduce 16% private VKT by shifting their mode of transport from private to public. Having mentioned this, the public transport share of VKT will increase by 68%, which is not more than 1% of the total VKT for the SMC area.

Responsible agency: SMC and State Transport Department

10.7.2. Recognition of NEE Restricted Zones by Placing Urban Vehicle Access Restrictions

Vehicles are the leading cause of NEE in any urban agglomeration. Thus, it is important to regulate the cause-effect relationship through regulating the vehicle movement in the NEE restricted zones by placing urban vehicle access restrictions (UVARs). These restrictions could be in several forms and have been adopted by a growing number of cities in recent years (e.g., Stockholm, London, Milan, Paris, and Madrid) with the primary goal of reducing congestion and exhaust emissions[88]. These include the following list of sub-set of interventions that can be adopted for the SMC area:

- Low Emission Zones (LEZ) are area-based; some are specific streets and motorways based.
- Urban Toll Schemes/Congestion Charging (CS) are usually area-based, but some are individual streets/bridges or point-based.
- Emergency air emission restrictions are based on the types of roads that have the highest traffic – highest heavy vehicles – highest junctions – highest bumps or turbulence.
- Absolute Emission Restriction Zones (AERZ) are based on the highest collector roads junctions coinciding with the density of the population. Since collector roads connect the local roads and the arterial and sub-arterial roads, they have the highest vehicle-road interaction wherein the NEE is being generated.[89]

Time duration anticipated: Research and assessment can be initiated in 2021; implementation can be undertaken by 2022. By the end of 2030, it is anticipated that the city would add five low emission

[88] PWC. (2017). Study on Urban Vehicle Access Regulations – PWC 2017. https://ec.europa.eu/transport/sites/default/files/uvar_final_report_august_28.pdf.

[89] U.S. EPA. Report on the 2015 U.S. Environmental Protection Agency (EPA) International Decontamination Research and Development Conference. U.S. Environmental Protection Agency. EPA/600/R-15/283, 2015.

zones to the existing three (Chowk, Bhagal, and Katargam). The existing vehicle restrictions in the SMC area's Central and North zones last for four hours. During this time (two hours each in the mornings and evenings), heavy vehicles are not allowed to cross through these restricted areas (based upon the area's density). The SMC has placed these restrictions.

Responsible agency: SMC and State Transport Department

10.7.3. No Implementation of Standalone EV and NMT Policy

In NEEs, it is important to know that electric vehicles pose an equal threat of emissions as conventional fuel vehicles. Thus, it is important to implement the NMT policy specific to the SMC area (proposed and approved in the CMP 2046 in 2018) and the EV policy concurrently. This is important as owing to the focus of emission reduction, EVs are often considered non-harmful, which is a fact in response to the exhaust emissions; however, when it comes to NEEs, EV buses, for example, are heavier, and once the restrictions are lifted, these buses will be pushed to take up more coverage. Similarly, emission zones would allow EVs to move freely to shift the private vehicle mode share to EV 4-wheelers. Thus, until and unless citizens recognize the importance of NMT mode share, the EV policy will only control exhaust emissions.

Time duration anticipated: Research and assessment can be initiated in 2021; implementation can be undertaken by 2022. By the end of 2025, it is anticipated that there would be an initiation of EV policy implementation with some of the restricted zones added to the urban planning schemes based on the NMT policy specific to the SMC area.

Responsible agency: SMC and State Transport Department

Replace: Reducing exhaust emissions through the proposed transportation sector policies would address the inherent NEEs generated due to the vehicle-road interaction. The core thought is replacing conventional fuel with the alternative source, replacing more fuel-efficient vehicles than conventional ones, and replacing bituminous roads with the RCC roads for the collector and local roads. This section provides options wherein replacing the conventional method with an alternative one would significantly reduce NEEs.

10.7.4. Replacing Conventional Ticketing with an Online App Based Integrated Ticketing Service for the Public Transport

The SMC has already developed an ICT platform with integrated service provision and grievance redressal through an intelligent app. Such an app, which is in the process of development, would have to have incentives (discounts), comfort (ease of booking), accessibility (Android, ios, SMS-based and call-based booking), and reliability (SMC owned and operated) as the main features for the ticket booking for public transport in the SMC area. Such ticketing services can extend additional benefits when using NMT options for the last mile connectivity (PBS system). Thus, there will be a single-window operation for those willing to take up the public transport mode share and access the NEE affected zones by walking or using the PBS system in the SMC area. The main objective is to reduce the VKT of the SMC area by increasing the mode share of NMT and PT.

Time duration anticipated: The integration will be completed by 2025.

Responsible agency: SMC and State Transport Department

10.7.5. Replacing the Freight Compactness Option from the Freight Transport Policy for the SMC Area

The SMC area is a business-oriented urban center and has heavy freight movement throughout the year. To reduce NEEs, it is important to have freight compact measures checked, which are proposed in the freight policy. The NEEs are affected by the weight of vehicles; thus, it is important to have freight movement dedicated corridors or roads for the within SMC area movement of goods. This can also be integrated with the demarcated NEE-affected areas wherein the freight vehicles would not be allowed to enter in a specific time period.

Time duration anticipated: 2025 the policy reform can be completed with standalone research by the end of 2023. By 2030, the Varachha ward of the SMC area can be provided with a pilot dedicated freight corridor through which LCVs will be allowed to operate.

Responsible agency: SMC and State Transport Department

10.7.6. Replacing Non-Operational Ornamental Installations at Junctions with Fogging Machines, Sprinkler Systems, and Mechanical Sweepers

Currently, 24 junctions have been redesigned under the expert guidance of the SMC. In these junctions, road safety principles have been observed; however, no attention has been given to the aspect of reducing road dust re-suspension. This can be taken up in an approach wherein at least 10 junctions in the city will be provided with a dust mitigation measure, such as a fogging machine or a water sprinkler system, during high pollution days continuously for 10 years. These junctions can be selected based on NEE-affected zones, and space crunch for the proposed system can be taken up from the redundant design articles at these junctions. Under the Health and Hospital Department of the SMC, three mechanical sweepers will be provided in these junctions.

Time duration anticipated: By 2025, selection and pilot testing of dust control measures will be completed at (at least) three major traffic junctions. By the end of 2030, it is anticipated that at least seven such junctions will have dust control measures installed.

Responsible agency: SMC, local institutions, State Transport Department, Dakshin Gujarat Vij Company Limited

Regenerate: The most cost-effective method of controlling NEEs is to develop green areas within the city. However, this cannot focus on afforestation; instead, it should focus on conserving the mature trees with high sequestration potential than the younger lot. The SMC area, over the years, has seen heavy end-to-end carpeting/pavement, which has proven fatal for the mature trees. In addition to this, there are limited norms followed for the control of tree felling in the SMC area, as with the rapid expansion, the trees are being cut or replaced for the parking/recreation needs of residential and commercial areas.

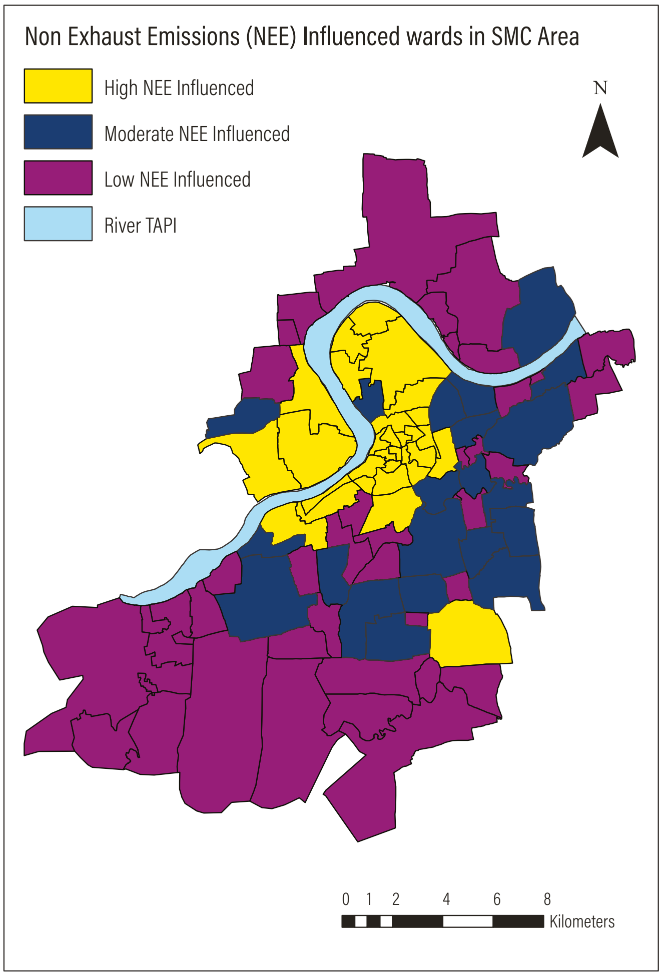
10.7.7. Regeneration of Urban Forest Patches through Urban Forest Scheme (Nagar Van Scheme)

The SMC area is rapidly expanding and losing its urban green cover as a result. This can be mitigated by the dedicated development of urban land patches wherein coordination of the local forest department would be needed to promote species with the highest particulate mitigation potential that can help develop urban forest patches. In this scheme, however, older trees with more than 30 years will be given special attention.

Time duration anticipated: In 2030, a pilot forest patch in the city light (Navsari Agriculture University Campus) area will be developed by GPCB and SMC. The oxygen park developed in the SMC area under the Surat Smart City mission will be part of this.

Responsible agency: SMC, GPCB, technical handholding agency, Navsari Agriculture University, District Forest Department

Figure 76: Non-exhaust emissions (NEE) influenced zones – Micro plan of SMC area



10.8. MICRO-LEVEL PLAN TO IMPLEMENT THE STRATEGIES

To effectively implement NEE mitigation measures, it is important to have areas identified as 'NEE-affected areas' for which micro-level strategies are implemented. These areas can be targeted to understand how many collector road junctions are present. There will be a single measurement unit wherein the highest numbers of junctions showing wards will affect NEEs. In addition to this, the parallel measurement can be added of the vicinity of these wards from the river Tapi. A third layer can be added of the presence of green cover in these primarily affected areas. **Figure 76** illustrates these NEE-affected areas in the SMC area. To curb the effects of NEE in these wards, the following measures will be implemented:

- Green patches will be developed at the arterial and collector road junctions.
- Three hours of restrictions will be imposed – from 12 noon to 3 pm – for the movement of HCVs and buses in these wards on days when the temperature is high. This can be coordinated with the implementation of the Heat and Health Action Plan for Surat city (2016)
- All dedicated junctions of arterial and sub-arterial in the vicinity of these wards will be provided with dust suppression systems. For the implementation of this step, these wards will be targeted first.
- RWA level afforestation drive will be implemented in these areas.
- Community awareness campaigns will be dedicated in these wards.
- A NEE regularization study, proposed as a part of the NMT policy and programs for the SMC area in the CMP 2046, will be conducted, targeting these wards first.
- Mechanical sweepers dedicated to these wards and dedicated pits to collect road dust will be dug at the common public places.
- Special training to the sweepers will be provided for the night scrapping in these areas.
- Information will be relayed on heatwave incident days and high pollution days for using PPEs (safety goggles, masks, and light full-body clothing) against dust accumulation on body parts as proactive measures in the NEE-affected zones.

10.9. TECHNO-ECONOMIC ANALYSIS

The TEA was conducted for the interventions described in 10.9.1 and 10.9.2 after considering their physicality and easy attribution of costs to these policies/programs. These policies have been prioritized based on their application and existing infrastructure in the SMC area (e.g., spaces and well-designed junctions of the city's south, southwest, and central zones). This section details the implementation costs estimated for the NEE sector and the health risk assessment that refers to mortality caused by exposure from the PM emissions.

10.9.1. Implementation Cost for Proposed Policies and Programs

The costs given in **Table 56** have been considered on the basis of their applicability and ease of operations with the current human resources capacity of the SMC, which will be the main implementing partner among the listed agencies in the proposed mitigation measures mentioned in the **Section 10.7**.

Table 56: Economic implications of proposed policies and programs

Sr. No.	Proposed Policy or Criteria	Implementation Time	Responsible Agency/ Stakeholder	Total Cost (INR crore)	Expected Outcome
1.	Procurement of fogging machines	2021- 2025	SMC and GPCB	0.70 for 3 units	Reduced emissions at 3 dedicated junctions
2.	Development of integrated tick-eting application	2021- 2025	SMC and state Transport Department	0.20 for the development and integration and 0.15 for the testing in the procured EVs in the SMC area	Promotion of public mode share
3.	Procurement of Mechanical Sweepers	2021-2025	SMC, Industry CSR and GPCB	4 for the first 5 years 2 for the next 5 years	Control of NEE at the worst affected road junctions

10.9.2. Health Risk Assessment

The proposed interventions have the potential to save 961 lives, which is the highest number of deaths that could be averted for the NEE sector for the SMC area. This sector attributes the heavy load of mortality to a combination of sources – construction dust, transportation activities, industrial dust – and non-regulated assessments in research studies. Not much focus is being given to NEEs as compared with exhaust emissions.

10.10. SCENARIO GENERATION

According to CMP Surat, the share of public transportation (especially buses) is expected to increase by 89% in 2025 and 93% in 2030 as compared with the share in 2019, which implies an increase in road dust by 53% in 2025 and 60% in 2030, respectively, as compared with 2019. The estimates in the years 2025 and 2030 are shown in **Table 57**.

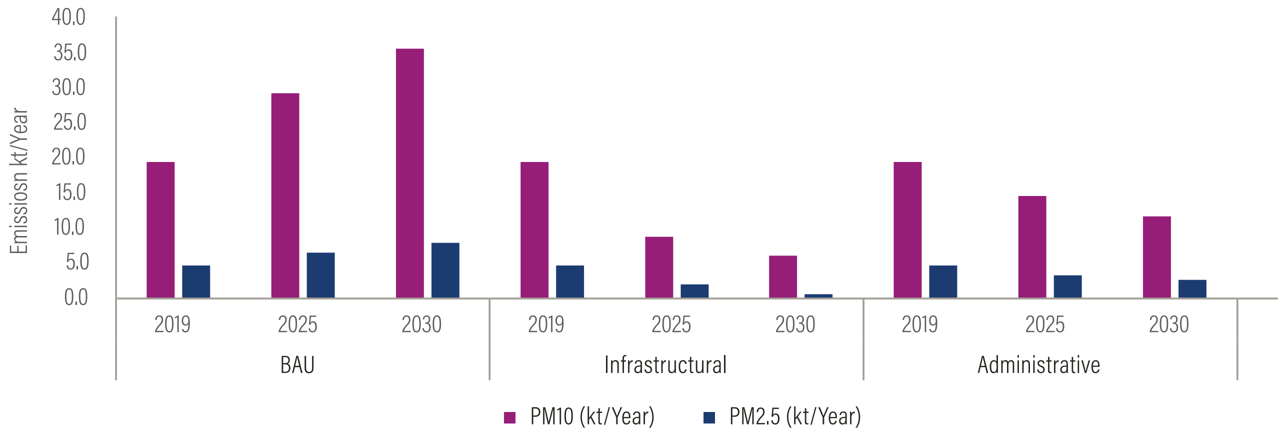
Table 57: BAU road dust

Road Dust in kt/year	2025	2030
PM_{10}	117.40	139.49
$PM_{2.5}$	28.29	33.61

Looking at the non-regulated nature of emissions from road dust re-suspension, it is important to place control measures in ways in which the authorities not only work on the provision of adequate infrastructure but also infuse behavioral change with a gradual increase in their efforts to address the problems associated with the driving conditions and conservation of the existing green cover on the major motor lanes and corridors. Considering these principles, the following scenarios can be considered for the mitigation of road dust re-suspension in the SMC area:

Administrative changes: In this scenario, administrative changes, such as capacity building, awareness campaigns on appropriate driving behavior, regular checks to reduce wear and tear of vehicles, and implementation of the parking and EV policies, will be brought into force. SMC will collaborate with the civil society active in the SMC area to implement the proposed policies effectively. For the newly developed areas, demarcation of the NEE influence zones will be identified in the early stages of the planning scheme, which will authenticate the process of incorporating air pollution data in the city development measures. Mode share regulations will also play a major role in providing effective public transport and non-motorized transport measures that will attract the population to take up public transport. It is anticipated that such measures will cover a 20% reduction in 2025 and a 30% reduction by 2030 (**Figure 77**).

Figure 77: NEE – Scenario generation



Infrastructural Changes: In this scenario, more physical measures, such as providing fogging machines at the busy junctions of the SMC area, retrofitting vertical gardens, sprinkler systems, ICT based ticketing systems, and stringent tailpipe emissions control, will be implemented. By 2025, it is anticipated that such measures will cover a 30% reduction in baseline emissions. By 2030 these reductions will reach 50% by combining these measures and the administrative changes focusing on the NEE emissions (**Figure 77**).

10.11. CONCLUSION

With contributions of 55% PM_{10} and 33% $PM_{2.5}$ emissions, NEEs contribute to one of the highest criteria pollutant emissions. This is significant because of the non-regulated nature of these emissions, wherein the major focus is usually given to the tailpipe emissions. While it is important to understand that NEE can be significantly reduced by working on the tailpipe emissions, there are certain measures, such as managing NEE influence zones in the SMC area and imparting the awareness that following traffic rules help NEE regulation, will also play an important part in controlling the sectoral emissions. While the focus should be more on the NEE emissions reductions, it is also important to control dust generation from industries and the construction sector. In addition, central, north, east, south, and southwest zones pose a greater risk of NEE emissions due to their population densities.

CHAPTER 11

>> CONCLUSION

11.1. CONTEXT

Air pollution is a major global challenge, having detrimental impacts on the environment, health, and the economy. India is at the forefront of the global struggle against air pollution as most cities where air quality is monitored in violation of the prescribed ambient air quality standards. Various research studies have shown that major cities and entire regions, such as the Indo-Gangetic plains, are being impacted by high levels of air pollution. Air pollution has a significant impact on human health and agricultural productivity, and the economy as a result. Evidently, interventions are required at both regional and city scales to control air pollution.

To control air pollution at a national scale, the Government of India launched the NCAP in 2019, with the target to reduce $PM_{2.5}$ and PM_{10} concentration levels by 20-30% by 2024. The NCAP aims to stringently implement air pollution mitigation measures to reduce air pollution concentration, strengthen the air quality monitoring network and data to support air quality management, and strengthen awareness and capacity building.

To prioritize air pollution mitigation, the CPCB has identified 124 non-attainment polluted cities where the prescribed NAAQS are not being met for a long time. These cities need immediate action for air quality mitigation. The city of Surat was identified as one of the two non-attainment cities in the state of Gujarat, and as part of the NCAP, it is expected to reduce air pollution levels of 2017 levels by 20-30% by the year 2024[90] by adapting various air pollution mitigation strategies.

As part of the NCAP, the SMC was required to prepare its city-centric clean air action plan to combat air pollution by identifying the key air pollution sources to better understand their contribution to the overall air quality. A clean air action plan is a document on air pollution mitigation actions the city needs to take, including source-specific mitigation action, policies, and programs.

WRI India and TERI, with the support of Bloomberg Philanthropies and Shakti Sustainable Energy Foundation, have developed SCAP for the SMC. To develop clean air action for the SMC, TERI first analyzed air pollution sources and their contribution to the air quality in the SMC area by using the tools available, which included emission inventories, dispersion modeling, and a receptor-based source apportionment study. After obtaining source-specific information, WRI India conducted a detailed analysis of source-specific activities contributing to air pollution, a mapping of stakeholders directly or indirectly engaged with sectoral activities, individual and group discussions with key stakeholders, and consultations with national and international sectoral experts, and developed a clean air action strategy for each air pollution contributory sector. The SMC and GPCB partnered in providing inputs in devising an approach to prepare the SCAP and supported by providing primary and secondary data.

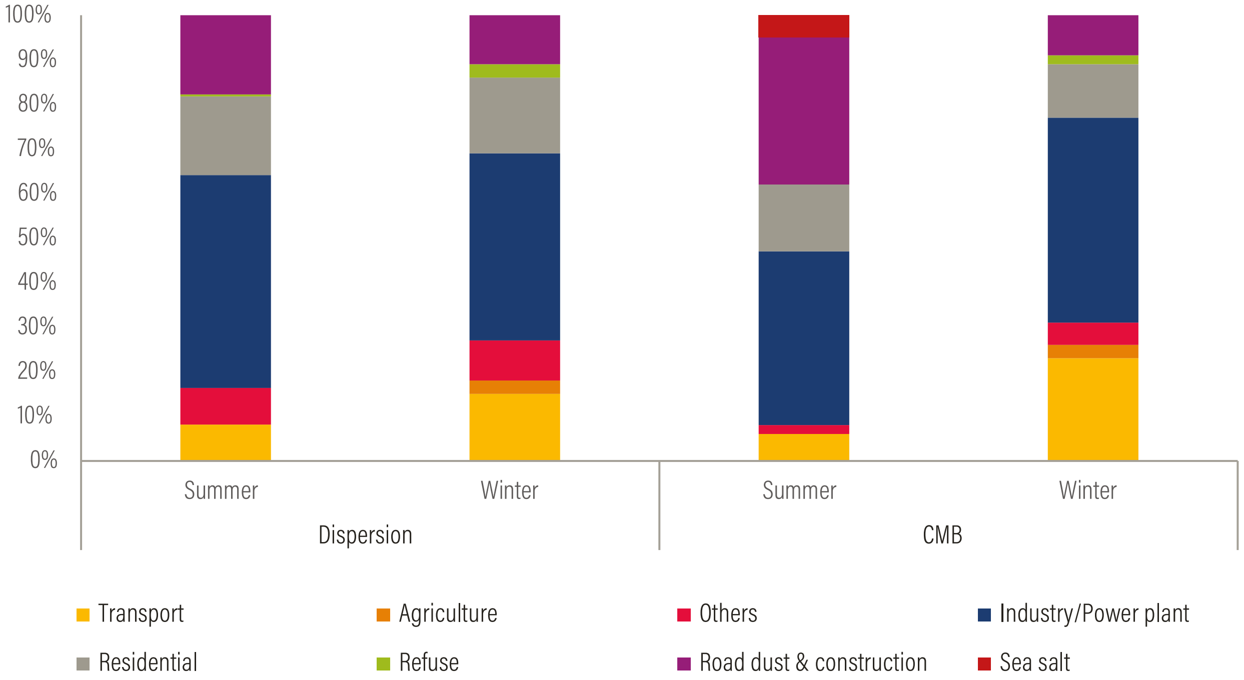
The SCAP project is a comprehensive multi-pollutant control strategy to protect public health and air quality that proposes to reduce emissions of air pollutants in all sectors through its strategies, interventions, and policies. The strategy incorporates regulatory, technological, and policy-level interventions along with public outreach programs. The action plan also includes interim milestones and financial requirements for executing these mitigation action points.

---

[90] Council on Energy, Environment and Water (n.d.).| Environment, Climate and Energy Think Tank in India. https://www.ceew.in/sites/default/files/CEEW-How-Robust-are-Urban-India%27s-Clean-Air-Plans-09Jun20_compressed_0.pdf.

The emissions inventory analysis was based on the air quality dispersion source apportionment study and receptor-based validation. This indicated that industries are the largest contributor of $PM_{2.5}$ pollution in the SMC area, followed by road and construction dust, transport, and household cooking fuel **(Figure 78)**. For improved air quality, these sectors need immediate attention and strategic action to reduce the air pollution emissions from the different activities.

Figure 78: Comparative analysis of receptor modeling (CMB) and dispersion modeling estimates of sources contributions towards ambient PM2.5 concentrations in the SMC area



The contribution of the other sectors, such as solid waste burning, crematoria, landfills, eateries, and diesel generators, are comparatively less but cannot be ignored. Each of the contributory sectors in the SMC area needs strategic air pollution mitigation action so that city can achieve the NCAP targets by 2024. It is important to note that a major proportion of air pollution in the SMC area is transboundary; therefore, the entire region needs a detailed sectoral analysis with respect to air pollution contribution and mitigation action.

The SCAP for the SMC area recommends different measures to curb air pollution from various sources and activities contributing to the degrading air quality of the city. **Table 58** summarizes the air pollution mitigation actions proposed for different air pollution sources and sectors. A majority of the policies are either for the short term or the long term, which will have a significant impact on air pollution mitigation in the SMC area. The SMC, GPCB, CREDAI, Industries' Associations, RTO, Surat District Administration, GIDC, GEDA, Food, and Civil Supplies Department, Non-Governmental Organization (NGO), RWA, Directorate of Boilers, Directorate of Industrial Safety and Health, Health Department, Forest Department, SUDA, Transport Department, Surat Smart City Development (SSCDL,)and Gujarat Energy Research and Management Institute (GERMI) are the key organizations that can play a critical role in implementing the proposed actions **(Table 58)** for various sources and sectors.

Table 58: List of proposed interventions to achieve maximum reduction potential – 2030 projections

Sector	Sr.No.	Recommended Policy Actions
Residential cooking	1.	Build community awareness (LPG cylinder stickers)
	2.	Go kerosene free
	3.	Promote induction stoves/electricity for cooking
	4.	Expand PNG network
	5.	Promote mini LPG cylinders
Construction	1.	Prepare and implement AAQMP
	2.	Develop construction sector-specific monitoring toolkit
	3.	Create pilot prototype site presenting best practices
	4.	Prototype of best practices monitoring site
	5.	Enclose provision/covering of construction site
	6.	Proactive disclosure of dust mitigation activities at construction sites
	7.	Promote procurement of fogging machine
	8.	Promote Ready-Mix Concrete (RMC)
	9.	AQ-IAS through SMAC center
	10.	Engineering controls monitoring and retrofitting
	11.	HRV Assessment of offsite communities surrounding construction sites
	12.	Form the central command center
	13;	Increase monitoring capacity by CAAQMS
Municipal Solid Waste Burning	1.	OWC for more prominent societies, colonies, etc.
	2.	Decentralized waste to compost plant
	3.	Recovery facility
	4.	Awareness program
	5.	Monitor open MSW burning
	6.	Prevent textile or thread burning (gasification plant)
	7.	Close the old dumping site Bhatar
Industries	1.	Retrofit air pollution control devices
	2.	Regularly check for resource and energy efficiency improvement
	3.	Accelerate technology transformation for automation/digitization in MSMEs
	4.	Revisit the norms for new installations
	5.	Promote cogeneration through monitoring of small boilers
	6.	Conduct carrying capacity assessment
	7.	Implement capacity-building module
	8.	Shift to alternative fuel
	9.	Increase efforts in comprehensive control of small size boilers
	10.	Provide financial and technical support to reduce emissions
	11.	Target to reduce and control emission from Industry
	12.	Relocate air polluting industries

Sector	Sr.No.	Recommended Policy Actions
Eateries	1.	Inventorize Eateries
	2.	Shift to cleaner fuel
	3.	Use pollution control options in formal eateries such as restaurants
	4.	Promote technology in the operation of eateries through the awareness drive
	5.	Decongest and enforce regulations in all eateries
	6.	Regularly prepare or update sectoral emission inventory
Transportation	1.	Promote the systemic transition of existing and future vehicles to cleaner and more efficient vehicles
	2.	Incorporate environmental costs and better monitoring infrastructure implementation
	3.	Introduce an incentive structure for faster to more efficient and cleaner vehicles
	4.	Introduce an improved process for monitoring and densification of PUC centers
	5.	Implement the newly introduced scrappage policy
	6.	Implement the EV policy in the city
	7.	Re-negotiate recurring costs on older commercial vehicles by giving up campaign
	8.	Alter mode share - reduce private mode share with the more efficient public transport mechanism
	9.	Introduce a combined strategy to enable mode share shift from private to public as well as keeping the vehicles used a cleaner and efficient
	10.	Implement the urban freight policy
	11.	Conduct major retrofitting for the implementation of NMT infrastructure and policies
	12.	Create an inventory of walking infrastructure within the SMC boundary
	13.	Conduct innovative data collection - NMT related infrastructure enhancement and supporting activities
	14.	Introduce congestion management practices
Non-Exhaust Emissions	1.	Reduce SMC area's VKT through mode share transfer and infrastructure development
	2.	Provide recognition to NEE restricted zones through UVARs
	3.	No implementation of standalone EV and NMT policy
	4.	Provide an online app-based integrated ticketing service for the public transport
	5.	Remove or tone down the freight compactness option from the freight transport policy within the SMC area
	6.	Install fogging machines and sprinklers at the major junctions of the SMC area
	7.	Regenerate urban forest patches through urban forest scheme, Nagar Van Scheme

Other than the individual policy action, many sectors require awareness in terms of air pollution mitigation activities, such as clean fuel use and ending the practice of waste burning and technological promotion in industries. After analyzing different sectors, it was also observed that the SMC needs a dedicated open data portal of different sectoral activities contributing to air pollution directly or indirectly. The data portal will enable policymakers to better understand the possible mitigation options and assess the ongoing air pollution mitigation actions.

11.2. WAY FORWARD

The SCAP project can be viewed as a ‘roadmap’ and a step towards cleaner air in the SMC area. The timely implementation of the proposed interventions as per the SCAP to mitigate the air pollution in Surat is a key step and requires a clear institutional framework and responsibilities, stakeholder coordination and communication, political support, allocation of financial resources, technical capabilities, and review and improvement. Implementing the strategies in the plan will also require the expansion of existing public-/private-sector partnerships and the creation of new ones.

A Surat Clean Air Micro Plan has also been prepared, which shall be integrated with the GPCB micro plan guidelines and Smart City proposals. A timeline for each activity has been specified in the plan.

It is recommended that a steering committee be formed to monitor the progress and implementation of activities under the action plan. The committee should comprise high-level city officials from relevant departments/stakeholders. The committee can meet on a quarterly basis and track and report on the implementation of measures and overall changes in air pollution scenarios. While monitoring the progress, the committee can review the effectiveness of the control measures available and determine if changes are needed to achieve greater reductions, address excessive costs, or amend measures appropriately.

It is also recommended that a Surat City level Air Quality Monitoring Cell (AQ cell) be established. The AQ cell will collect round-the-clock AQ data, which shall be analyzed. The cell will be responsible for implementing activities proposed in the micro-plan and will submit the ATR to the steering committee, the Commissioner, and RO of the GPCB.

It is also strongly recommended that an IEC plan and its activities be developed. As part of this plan, a website/dashboard for Surat CAP can be developed, which could present information about the plan, such as information on the activities of the steering committee and the implementation partners and their roles, PPT presentations, and minutes of meetings of the steering committee, various strategies for sectors, projects, and reports, emission results, emission reduction data, and real-time monitoring data.

>> REFERENCES

Air pollution control devices. (n.d.). *Energy Education.* https://energyeducation.ca/encyclopedia/Air_pollution_control_devices#cite_note-RE1-2

Akagi, S. K., Yokelson, R. J., Wiedinmyer, C., Alvarado, M. J., Reid, J. S., Karl, T., Crounse, J. D., & Wennberg, P. O. (2011). Emission factors for open and domestic biomass burning for use in atmospheric models. *Atmospheric Chemistry and Physics*, *11*(9), 4039–4072. https://doi.org/10.5194/acp-11-4039-2011.

Apte, J. S., Marshall, J. D., Cohen, A. J., & Brauer, M. (2015). Addressing Global Mortality from Ambient PM2.5. *Environmental Science & Technology*, *49*(13), 8057–8066. https://doi.org/10.1021/acs.est.5b01236.

Awards and Appreciations. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Home/AwardsAndAppreciations.

Balakrishnan, K., Dey, S., Gupta, T., Dhaliwal, R. S., Brauer, M., Cohen, A. J., & Dandona, L. (2019). The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. *The Lancet Planetary Health*, 3(1), e26-e39.

Balakrishnan, K., Ghosh, S., Ganguli, B., Sambandam, S., Bruce, N., Barnes, D. F., & Smith, K. R. (2013). State and national household concentrations of PM2.5 from solid cook fuel use: Results from measurements and modeling in India for estimation of the global burden of disease. *Environmental Health*, *12*(1). https://doi.org/10.1186/1476-069x-12-77.

Banerjee, M., Prasad, R., Rehman, I. H., & Gill, B. (2016). Induction stoves as an option for clean cooking in rural India. *Energy Policy*, *88*, 159–167. https://doi.org/10.1016/j.enpol.2015.10.021

Bhakkad, M. (2019). Solid Waste Management: A Case Study of Surat City. *International Journal of Management and Applied Science*, *5*, 34–36.

Bhushan, C., Sambyal, S. S., & Walani, N. (2018). *Model Framework for Segregation: Guidelines for managing municipal solid waste through segregation, reuse and recycling*. Centre for Science and Environment.

Central Pollution Control Board. (2019- 2020). *Annual report*. MOEFCC. https://cpcb.nic.in/annual-report.php

Centre material recovery facility. (2021, April 21). Surat Municipal Corporation. https://www.suratmunicipal.gov.in: https://www.suratmunicipal.gov.in/CleanSurat/Home/PastEventsAndInitiatives.

Chheti, R. C. (2017). Analysis on Integrated LPG Cook Stove and Induction Cooktop for Cooking Purposes in Bhutan. *Faculty of Engineering and Information Sciences - Papers: Part B- 623*.

Chowdhury, S., Chafe, Z. A., Pillarisetti, A., Lelieveld, J., Guttikunda, S., & Dey, S. (2018). The Contribution of Household Fuels to Ambient Air Pollution in India. *Collaborative Clean Air Policy Centre.*

Comprehensive Mobility Plan 2046 – Surat. (2018). Centre of Excellence (CoE) in Urban Transport, CRDF, CEPT University. http://suratmunicipalcorporation.org:8020/News/6126_1.pdf.

Council on Energy, Environment and Water *(n.d.).* | Environment, Climate and Energy Think Tank in India. https://www.ceew.in/sites/default/files/CEEW-How-Robust-are-Urban-India%27s-Clean-Air-Plans-09Jun20_compressed_0.pdf.

CPCB. (2010). Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Indian Cities. *Central Pollution Control Board*, Government of India.

CPCB. (2021). *Action plan Surat*. https://cpcb.nic.in/Actionplan/Surat.pdf.

CSIR-National Environmental Engineering Research Institute. (2019, December). *Source Apportionment Study and Development of Emission Inventory of Twin Cities Kolkata and Howrah of West Bengal*.

CSTEP. (2018). *Comprehensive clean air action for the city of Patna*. https://www.cstep.in/publications-details.php?id=861.

Development Plan 2035 SUDA. (2017).

DPCC. (2018). Office Order no. DPCC/RDPC/Subsidy-Tandoor/2018/2141 dated 28/09/2018 to Grant of subsidy to restaurants/Eating Houses/ Banquet Halls/Hotels for Replacing/Conversion of their Coal-based Tandoors with Electricity or Gas based Tandoors. Delhi Pollution Control Board.

Economic census of India, (2013-2014). India: Ministry of Statistics & Programme Implementation. MoSPI, (2019). Central Statistics Office, Ministry of Statistics and Programme Implementation.

FOSTTA, Annual Report (2019). Federation of Surat Textile Traders Association (FOSTTA).

Fry, K., Firestone R., & Chakraborty, N. M. (2014). Measuring Equity with Nationally Representative Wealth Quintiles. Washington, DC: PSI.

Gould, C. F., Schlesinger, S., Toasa, A. O., Thurber, M., Waters, W. F., Graham, J. P., & Jack, D. W. (2018). Government policy, clean fuel access, and persistent fuel stacking in Ecuador. *Energy for Sustainable Development*, *46*, 111–122.

Government of India, Ministry of Housing & Urban Poverty Alleviation. (December 2013). Support to Urban Street Vendors (Operational Guidelines). National Urban Livelihoods Mission.

GPCB, Annual Report. Gujarat Pollution Control Board. https://gpcb.gujarat.gov.in/webcontroller/page/annual-report.

Guidelines for IRC Standards (First Revision), Indian Road Congress, Ministry of Road Transport and Highway, SP:36-2018-19. http://www.irc.nic.in/.

Gupta, Y.K., Meenu, M., & Peshin, S. S. (2019). Aluminium utensils: Is it a concern? *The National Medical Journal of India, 32*, 1, 38- 40.

Guttikunda, S. K., & Jawahar, P. (2012). Application of SIM-air modeling tools to assess air quality in Indian cities. *Atmospheric Environment*, *62*, 551–561. https://doi.org/10.1016/j.atmosenv.2012.08.074.

Guttikunda, S. K., Goel, R., & Pant, P. (2014). Nature of air pollution, emission sources, and management in the Indian cities. *Atmo-*

spheric Environment, *95*, 501–510. https://doi.org/10.1016/j.atmosenv.2014.07.006.

Guttikunda, S. K., Nishadh, K., & Jawahar, P. (2019). Air pollution knowledge assessments (APnA) for 20 Indian cities. *Urban Climate*, *27*, 124–141. https://doi.org/10.1016/j.uclim.2018.11.005

Harish, S., & Smith. K. R. (2019). Ujjwala 2.0: From Access to Sustained Usage, Policy Brief, *CCAPC/2019/03*, Collaborative Clean Air Policy Centre.

Health Effects Institute. (2020). State of Global Air 2020. Special Report. Boston, MA: Health Effects Institute. https://fundacionio.com/wp-content/uploads/2020/10/soga-2020-report.pdf

Hon'ble NGT order. (2019). Compliance of Environmental Norms by roadside eateries/restaurants and other establishments, In Compliance with the Hon'ble NGT order dated 25.11.2019 in the matter of O.A no.26/2019, Abhay Dahiya & Others v/s State of Haryana'. CPCB.

Hussein, T., Johansson, C., Karlsson, H., & Hansson, H. C. (2008). Factors affecting non-tailpipe aerosol particle emissions from paved roads: On-road measurements in Stockholm, Sweden. *Atmospheric Environment*, *42*(4), 688–702. https://doi.org/10.1016/j.atmosenv.2007.09.064

IBEF presentation. (2019). 'Gujarat the Growth Engine of India.'

Infrastructure Policy & Finance Division | Department of Economic Affairs | Ministry of Finance | Government of India. (2019–2020). Department of Economic Affairs. https://dea.gov.in/divisionbranch/infrastructure-and-energy-division.

Jain, A., & Ramji, A. (2016). Reforming Kerosene Subsidies in India: Towards better alternatives. *The International Institute for Sustainable Development and Council on Energy, Environment, and Water*.

Jain, A., Choudhury, P., & Ganesan, K. (2015). Clean, Affordable, and Sustainable Cooking Energy for India. Possibilities and Realities beyond LPG. https://www.ceew.in/sites/default/files/CEEW-Clean-affordable-and-sustainable-cooking-energy-in-India-Feb2015.pdf.

Jain, A., Tripathi, S., Mani, S., Patnaik, S., Shahidi, T., & Ganesan, K. (2018). Access to clean cooking energy and electricity. Survey of states—2018. *Council for Energy, Environment and Water.* https://www.ceew.in/sites/default/files/CEEW-Access-to-Clean-Cooking-Energy-and-Electricity-11Jan19_0.pdf.

James, B. S., Shetty, R. S., Kamath, A., & Shetty, A. (2020). Household cooking fuel use and its health effects among rural women in southern India—A cross-sectional study. *PLOS ONE*, *15*(4), e0231757. https://doi.org/10.1371/journal.pone.0231757.

Kishore, J., Kohli, C., Kumar, N., & Gupta, N. (2017). Scales used in India to Evaluate Socio-economic Status in Medical Research: Limitations of Existing Scales and the need of a more Comprehensive One. *JIMSA, 30*(2), 66.

Kulkarni, T. (n.d.). GHG Accounting and Planning approach to Solid Waste Management from the landfills in Surat City, Gujarat. https://www.researchgate.net/publication/282642291_GHG_Accounting_and_Planning_approach_to_Solid_Waste_Management_from_the_landfills_in_Surat_City_Gujarat.

Lee, S. H., Kwak, J. H., Lee, S. Y., & Lee, J. H. (2015). On-road chasing and laboratory measurements of exhaust particle emissions of diesel vehicles equipped with aftertreatment technologies (DPF, urea-SCR). *International Journal of Automotive Technology*, *16*(4), 551–559. https://doi.org/10.1007/s12239-015-0056-8.

LEED rating system. (https://www.usgbc.org/leed/rating-systems/leed-for-cities).

Majumder, A., & Madheswaran, S. (2018). Value of Statistical Life in India: A Hedonic Wage Approach. *Working paper 407*, ISEC Bengaluru, ISBN 978-81-7791-263-0. http://www.isec.ac.in/WP%20407%20-%20Agamoni%20Majumder%20and%20Madheswaran%20-%20Final.pdf.

Mid-Year Population Estimates and Comparative of Population of India, Gujarat, Surat District and SMC from 1901 to 2011. Surat Municipal Corporation. https://www.suratmunicipal.gov.in/TheCity/City/Stml7.

Ministry of Environment, Forest and Climate Change, Government of India. (2016). *Plastic Waste Management Rules, 2016*. https://cpcb.nic.in/rules-4/

Ministry of Rural Development, Department of Rural Development, Government of India. (2019). Concept Note and Guidelines on Ease of Living Survey (PMAY-G/IAY, PMGSY, MGNREGS, DAY-NRLM, PMUY, Jan Dhan Yojana).

Ministry of Petroleum and Natural Gas. (2019). *Report of the Comptroller and Auditor General of India on Pradhan Mantri Ujjwala Yojana: (Performance Audit)* (No. 14 of 2019). Comptroller and Auditor General of India.

Mohapatra, D. (2017, March 22). *Dhabas to feel heat for cooking in coal fire*. The Times of India. https://timesofindia.indiatimes.com/city/bhubaneswar/dhabas-to-feel-heat-for-cooking-in-coal-fire/articleshow/57770669.cms

MOHUA, Advisory on Landfill reclamation. (2020). MOHUA; Government of India.

MSME Profile of Surat District. (2018). https://surat.nic.in/district-industries-centre/.

My Surat My SMC (2021, April 07). Twitter, SMC has banned all single-use plastic products along with plastic bags under 50 microns. Official Twitter handle of SMC. https://twitter.com/MySuratMySMC/status/1279025526141628416.

Nagpure, A. S., Ramaswami, A., & Russell, A. (2015). Characterizing the Spatial and Temporal Patterns of Open Burning of Municipal Solid Waste (MSW) in Indian Cities. *Environmental Science & Technology*, *49*(21), 12904–12912. https://doi.org/10.1021/acs.est.5b03243

NHB Residex Booklet. (2018). National Housing Bank, India.
OECD iLibrary | Non-exhaust Particulate Emissions from Road Transport: An Ignored Environmental Policy Challenge. (2020). OECD. https://www.oecd-ilibrary.org/environment/non-exhaust-particulate-emissions-from-road-transport_4a4dc6ca-en.

OECD. (2019). Statistical Insights: Location - House price developments across and within OECD countries. Statistics and Data Directorate - OECD.

Palit, D., Shardul, M., Brahmachari., D. (2020). Clean Fuel for Cooking: Solution to Achieve Better Air Quality. *Discussion Paper.* The Energy and Resources Institute.

Petroleum Planning & Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India. (2016). *Assessment report: Primary survey on household cooking fuel usage and willingness to convert to LPG.* PPAC. http://ppac.org.in/WriteReadData/Reports/2017.

PIB, (2015, January 5). Launch of 5 Kg LPG cylinders for BPL families. https://pib.gov.in/newsite/PrintRelease.aspx?relid=114336.

PPAC. (2019). *Ready Reckoner: Oil Industry Information at a Glance*. Petroleum Planning and Analysis Cell. Ministry of Petroleum & Natural Gas, Government of India.

Public Health Bye Laws For SMC. (2021, May 29). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Documents/WMRAndAP/PublicHealthByelawsForSMC.pdf.

PWC. (2017). Study on Urban Vehicle Access Regulations – PWC 2017. https://ec.europa.eu/transport/sites/default/files/uvar_final_report_august_28.pdf.

Rangwala, L., Burke, L., Wihanesta, R., Elias- Trostmann, K., & Chandra, M. (2018). Prepared Communities: Implementing the Urban Community Resilience Assessment in Vulnerable Neighborhoods of Three Cities. *World Resources Institute*. Cities Alliance.

SCAP target approach workshop - Construction Sector. (2019, November 25). Surat, Gujarat.

Sharma, G., Sinha, B., Pallavi, Hakkim, H., Chandra, B. P., Kumar, A., & Sinha, V. (2019). Gridded Emissions of CO, NO x, SO_2, CO_2, NH_3, HCl, CH_4, $PM_{2.5}$, PM_{10}, BC, and NMVOC from Open Municipal Waste Burning in India. *Environmental science & technology*, *53*(9), 4765-4774.

Sharma, M., & Dikshit, O. (2016). Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component). IIT Kanpur, Delhi Pollution Control Committee and Department of Environment, NCT.

Smith, K. R. (2014). LPG in India: Past, Present, and Future of Ujjwala. https://static1.squarespace.com/static/53856e1ee4b00c6f1fc1f602/t/5999ee1649fc2bee42e8f3a8/1503260202029/Ujjwala+program.pdf.

Smith, K. R., & Sagar, A. (2014). Making the clean available: Escaping India's Chulha Trap. *Energy Policy*, *75*, 410–414. https://doi.org/10.1016/j.enpol.2014.09.024

Solid Waste Management Approaches. (2021). SMC. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementApproaches.

Solid Waste Management Statistics (2021, March 10). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/Departments/SolidWasteManagementStatistics.

Swachh Bharat Mission Proposal DPR for Surat city. (November 2016). Surat Municipal Corporation. Facile Maven pvt. ltd.

Swachh Bharat Mission: We may be ODF, but not garbage free. (2021). Down to Earth. https://www.downtoearth.org.in/blog/waste/swachh-bharat-mission-we-may-be-odf-but-not-garbage-free-67101.

Swachh Survekshan. (2020). Assessment DPR, MoHUA, Government of India.

TERI. (2021). Source Apportionment Study for Surat city, Gujarat. The Energy Research Institute (TERI).

Tripathi, A., & Sagar, A. (2019). Ujjwala, V2.0. What should be done next? *Policy Brief, CCAPC/2019/02.* Collaborative Clean Air Policy Center.

U.S. EPA. Report on the 2015 U.S. Environmental Protection Agency (EPA) International Decontamination Research and Development Conference. U.S. Environmental Protection Agency. EPA/600/R-15/283, 2015.

*Waste Management Rules and Action Plans. (*2021, March 18). Surat Municipal Corporation. https://www.suratmunicipal.gov.in/CleanSurat/Home/WasteMgtRulesAndActionPlans.

WHO. (2003). The World health report: 2003: Shaping the future. World Health Organization.

Wiedinmyer, C., Yokelson, R. J., & Gullett, B. K. (2014). Global Emissions of Trace Gases, Particulate Matter, and Hazardous Air Pollutants from Open Burning of Domestic Waste. *Environmental Science & Technology,* 48(16), 9523–9530. https://doi.org/10.1021/es502250z

World health statistics overview 2019. Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2019. https://apps.who.int/iris/bitstream/handle/10665/311696/WHO-DAD-2019.1-eng.pdf.

WRI India. (2020). The Handbook of Clean Construction Practices in Surat: developed under Surat Clean Air Action Plan 2020. https://wri-india.org/events/handbook-clean-construction-practices-surat-developed-under-surat-clean-air-action-plan-2020.

ANNEXURES

ANNEXURE 1: FORMATION OF CLEAN AIR ACTION PLAN COMMITTEE BY THE GOVT. OF GUJARAT

Constitution of State Level Clean Air Programme Committees (SCAP)

Government of Gujarat
Forests and Environment Department
G.R. No. ENV-10.2019- 97-T
Sachivalaya, Gandhinagar
Date 12-06-2019

G. P. C. Board
M. S. CELL
Inward No: 2024
Date: 13-6-19

Preamble :

The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India (GoI) has finalized and launched the National Clean Air Program (NCAP) on 10th January, 2019 as a time bound national levels strategy for PAN India implementation to tackle the air pollution problem across the country in a comprehensive manner.

Resolution :

State Government of Gujarat is hereby constitute three Committees at State level to ensure effective implementation of National Clean Air Program in cities of Surat and Ahmedabad as under :-

A Steering Committee at State Level :-

Sr. No.	Details	Designation
1.	Chief Secretary, Govt. of Gujarat.	Chairman
2.	Additional Chief Secretary, Department of Forests & Environment, Govt. of Gujarat.	Member
3.	Principal Secretary / Additional Chief Secretary, Department of Energy & Petrochemicals, Govt. of Gujarat.	Member
4.	Principal Secretary / Additional Chief Secretary, Department of Agriculture, Govt. of Gujarat.	Member
5.	Principal Secretary / Additional Chief Secretary, Department of Urban Development, Govt. of Gujarat.	Member
6.	Principal Secretary, Department of Transport, Govt. of Gujarat.	Member
7.	Secretary, Home Department, Govt. of Gujarat.	Member

1

Following the launch of NCAP in 2019, it was decided that three standalone committees would be formed to implement and monitor the progress of the program in Gujarat. The following snapshot of the committee report document shows details of these committees:

8.	Member Secretary, Gujarat Pollution Control Board, Gandhinagar	Member
9.	Prof. H. M. Swamy, CEPT University, Ahmedabad	Member
10.	Prof. G.H. Bun, L. D. College of Engineering	Member
11.	Director (Environment), Department of Forests & Environment, Govt. of Gujarat.	Member Secretary

This Steering Committee would provide overall guidance for the programme closely and review it on quarterly basis

B. Monitoring Committee at State level .

Sr. No.	Details	Designation
1.	Principal Secretary / Additional Chief Secretary, Department of Forests & Environment, Govt. of Gujarat.	Chairman
2.	Principal Secretary / Additional Chief Secretary, Department of Urban Development, Govt. of Gujarat.	Member
3.	Commissioner, Transport Department, Department of Ports and Transport, Govt. of Gujarat.	Member
4.	Industries Commissioner, Department of Industries & Mines, Govt. of Gujarat.	Member
5.	Director (Environment), Department of Forests & Environment, Govt. of Gujarat.	Member
6.	Joint Commissioner of Police (Traffic), Ahmedabad, Home Department, Govt. of Gujarat.	Member
7.	Deputy Commissioner of Surat Municipal Corporation, Municipal Corporation, Surat	Member
8.	Commissioner of Ahmedabad Municipal Corporation,Municipal Corporation, Ahmedabad	Member
9.	Regional Officer, Gujarat Pollution Control Board, Surat	Member
10.	Regional Officer, Gujarat Pollution Control Board, Ahmedabad	Member
11.	Member Secretary, Gujarat Pollution Control Board, Gandhinagar	Member Secretary

This Monitoring Committee would monitor the programme closely and meet on monthly basis.

2

C. Implementation Committee

C1 Implementation Committee of Surat City :-

Sr. No.	Details	Designation
1.	Commissioner of Surat Municipal Corporation, Surat	Chairman
2.	Regional Transport Officer, RTO, Surat	Member
3.	General Manager, District Industries Center, Surat	Member
4.	District Supply Officer (DSO), District Collector Office, Surat	Member
5.	Joint Commissioner of Police, Traffic Department, Surat	Member
6.	Regional Officer, Gujarat Pollution Control Board, Surat	Member Secretary

C2 Implementation Committee of Ahmedabad City :-

Sr. No.	Details	Designation
1.	Commissioner of Ahmedabad Municipal Corporation, Surat	Chairman
2.	Regional Transport Officer, RTO, Ahmedabad	Member
3.	General Manager, District Industries Center, Ahmedabad	Member
4.	District Supply Officer (DSO), District Collector Office, Ahmedabad	Member
5.	Joint Commissioner of Police, Traffic Department, Ahmedabad	Member
6.	Regional Officer, Gujarat Pollution Control Board, Ahmedabad	Member Secretary

These Implementation Committees would be responsible for the day-to-day monitoring and implementation of the programme.

The Terms and Conditions shall be as follows:

1) The Committees shall meet as and when required in addition to the minimum criteria as specified above.

3 -

2) The Committees shall be responsible for implementation of "National Clean Air Programme" for non-attainment cities Surat & Ahmedabad.

3) The Chairman of above individual committee may co-opt the members and the subject experts as per the requirements.

4) All expenses of the above committees shall be borne by Gujarat Pollution Control Board.

By order and in the name of the Governor of Gujarat,

(S. M. Saiyad)

Director (Environment) and Additional Secretary to the Government

To,

(1) *The Principal Secretary to H.E. the Governor of Gujarat, Raj Bhavan, Gandhinagar. (* By Letter)

(2) The Principal Secretary to the Chief Minister, SS-1, Gandhinagar.

(3) The Personal Secretary to the Deputy Chief Minister, SS-1, Gandhinagar

(4) Personal Secretary to the Minister of State (Environment), SS-2, Gandhinagar

(5) All members of State Level Clean Air Programme Committees.

ANNEXURE 2: STAKEHOLDERS CONSULTATIONS (APPROACH) – SCAP PROJECT

To effectively implement the project of preparing the SCAP, robust planning was done wherein the mapped stakeholders met with WRI India on various occasions. These meetings provided WRI India the guidance required before initiating the project in the SMC area. These meetings were conducted while performing scoping exercises prior to the major stakeholder events. During these meetings the industry associations and other institutional stakeholders assured support for setting up air quality monitoring stations in 10 different locations in the SMC area.

The WRI India team interviewed several stakeholders, officials of the GPCB Surat region office, SMC officials, including the Commissioner, Mayor, Chairman Standing Committee, officials at the Waste Management Department, Smart City, Town Planning Department, GIS department, Transport (BRTS/SitiLink), Surat PBS, health officials, Traffic Police, Indian Railways, Gujarat State Road Transport Authority, RTO, Surat Urban Development Authority (SUDA), educational institutions such as SVNIT, Sarvajanik Education Society, Architecture College, industry, builders' association, Chamber of Commerce, and elected representatives to gauge views and assess the situation on air pollution in the SMC area and the related activities. Some of the prominent officials who were consulted throughout the duration of the SCAP project are listed below:

- Mr M. Thenarassan, Former Commissioner, SMC
- Mr Banchhanidhi Pani, Commissioner, SMC
- Mr P. U. Dave, RO, GPCPB, Surat
- Dr Sharma, Scientist, GPCB, Surat
- Dr R. J. Pandya, Deputy Municipal Commissioner, SMC
- Mr Dalal, Former City Engineer, SMC
- Mr E. H. Pathan, Environment Engineer, SMC
- Mr Jawalant Naik, Environment Engineer, SMC
- Mr Kamlesh Naik (General Manager, Sitilink- Surat BRTS)
- Mr Kamlesh Yagnik, Chief Resilient Officer, Surat Resilient Society
- Mr C. Y. Bhatt CEO, Smart City Surat and Deputy Municipal Commissioner, SMC
- Mr Jivan Patel, Former Town Planning Officer
- Dr S. A. Channiwala, Professor, Mechanical Dept, SVNIT
- Dr K D Yadav, Registrar, SVNIT
- Dr Jagdish Patel, Former Mayor, Surat
- Mr Jitubhai Vakharia, President, Surat Industries
- Prof Rajesh Mehta, Principal, Bhagwan Mahavir Swami Arch College

- Dr Vikas Desai, Director, Urban Health and Climate Resilience Centre of Excellence
- Officials of Indian Railways, GSRTC, RTO and Traffic Police
- Meeting with officials of CREDAI lead by Jasmatbhai Vidia and Sureshbhai Patel.
- Mr Vignesh Kaneria
- Mr Vimal Trivedi, Centre for Social Studies, Veer Narmad South Gujarat University, Surat
- Mr Sameer MacWan, Navsarjan Trust, Surat
- Mr Ghanshyam Patel, Affordable Housing Department, SMC
- Mr Chirag Shah, Destiny Group Pvt. Ltd
- Mr Jagdish Italiya and Mr. Sanjay Punjabi, UTurn
- Mr Trushit Desai and Mr. Amit Desai, Geostone Consulting Pvt. Ltd
- Mr Aditya Patel and Ms. Priyanka Tiwary, Surat Urban Development Authority, Surat
- Dr Swapnil Patel, Dr. Fenil Patel, and Dr. Ashish Naik- Health department, SMC
- Mr Vignesh Kaneria, Prkruti Consulting Agency
- Mr Prabal Bharadwaj and Mr. A P Singhal, Representatives, JB ECOTEX

Opportunity Framing Workshop and Sectoral Target Approach Events

After having detailed consultations with the stakeholders of the SCAP project, the scoping exercises identified there should be standalone networking meetings. Reason being these standalone discussions would streamline the ongoing processes. This would help in source apportionment and narrowing down mitigation measures for the different sectors.

Opportunity Framing Workshop for SCAP Project – July 2019

A two-day stakeholder workshop to discuss and design the implementation of the SCAP took place on 25 and 26 July 2019 in Surat at Hotel Taj Gateway (renamed The Marriot in 2020). The workshop was led by WRI India in collaboration with GPCB and SMC and supported by Bloomberg Philanthropies and Shakti Sustainable Energy Foundation. The workshop was attended by professionals from the Town Planning Department, BRTS Department, Transportation Department, City Civil Hospitals, RTO Department, and Environmental Cell at SMC. Various professionals too attended the event to contribute to the development of the SCAP. The GPCB presented a situation analysis of the SMC area wherein they explained the work done for the city and recommended actions required in addition to regular monitoring of the city's particulate matter. Experts from Surat-based think tanks, such as UH-CRCE, SCET College, and SVNIT, too were present to share their views on the opportunities present for the SMC area that could be explored as a part of this project. On the second day of the workshop, as part of the vision sharing exercise, participants were organized into four groups who then presented the sectoral opportunities to achieve the overall target of PM_{10} and $PM_{2.5}$ reduction.

Delivering the keynote address, the former Mayor of Surat, Dr Jagdish Patel, said, "Surat is greatly invested in managing its pollution levels even though the city does not face any major air pollution-related problems yet." He also said, "Aiming to make our city better and safer for its citizen, the SMC is taking several proactive steps to control air pollution. As a part of the Smart Cities program, we have taken up projects to monitor the quality of our air; we are investing in mass transit services like city buses and BRTS, reducing the use of individual vehicles. We are working on having electric buses soon and have started massive plantation activities in this city. Further, to understand various sources of air pollution, we have initiated a systematic source apportionment study with WRI India and TERI." M. Thennarasan, former Commissioner, SMC, said that the SMC area was as focused and interested as the other cities in the world today in building green and clean policies for a cleaner future.

The participants studied best practices from across the globe and discussed solutions that the city could adopt. Atmospheric scientist Beatriz Cárdenas, who is also a senior Air Quality member at WRI and the former General Director of Air Quality Management in Mexico City, drew parallels between SMC area and Mexico City and shared her experiences in clean air projects and the lessons learned. "Cleaning the air is not a one-time action since cities are continuously changing, with a constant ebb and flow of people, pressures of development, and economic flux. Climate change adds further stress to the urban environment, contributing to air pollution," Dr Cárdenas said. Describing how focused actions helped Mexico City clean its air, she added, "Cities can share best practices and learn from each other regularly on how to constantly improve, monitor, and maintain their air quality levels, thereby forming a holistic learning and adapting loop globally."

Participants also discussed the outcomes of 'summer season air quality monitoring' conducted during May-June 2019. This was the first part of a comprehensive, ongoing study by TERI to analyze the sources contributing to air pollution and how it affects various locations over two seasons. Talking about the study, Dr Sumit Sharma, Director, Earth Sciences and Climate Change Division, TERI, said, "Considering the enormity of the problem of air pollution, it becomes important to understand the contribution of emission sources, chemistry and movement of the pollutants. Based on these analyses, and using state-of-the-art modeling-based techniques, we can devise ideal, long-term, air quality management solutions for Surat." The second part of this assessment will be conducted in the winter (October 2019 to February 2020).

Mr D. R. Rathore, Deputy Environmental Engineer, GPCB, presented the draft of SCAP and discussed about the new strategies planned, such as the ETS to combat air pollution. A few priority projects and medium- and long-term activities across sectors such as energy, transport, waste management, and urban development were identified. Simultaneously the stakeholder institutions/organizations that would lead these projects were also highlighted. The control measures to mitigate air pollution and the projected risks, key activities, and personnel requirements to roll out these measures were also discussed.

Ms Priya Shankar, head of India Air Pollution Programs, Bloomberg Philanthropies, said, "Reducing air pollution and improving public health is a core focus of Bloomberg Philanthropies' work across the globe, and we're excited to support the SCAP and further these efforts in India. By working together with citizens, businesses, experts, and civil society partners to clean its air, Surat has the opportunity to demonstrate leadership and improve quality of life for its residents."

Addressing the workshop participants, Dr Ajay Singh Nagpure, head, Air Quality Program, WRI India Ross Center for Sustainable Cities, said, "Surat's emissions inventory identifies vehicular pollution, road dust, bio-mass burning, industrial emissions, and construction activities as some of the major contributors to air pollution. A range of stakeholders and policymakers need to join the action plan, considering that we have to tackle pollutants from varied sources. This workshop is the first step at building an aware stakeholder community that actively works towards cleaning India's air by implementing NCAP. Other cities will soon follow Surat's example." This event flagged off the SCAP project. As part of this project, three **target approach** events were organized. These are described below.

SCAP Target Approach – Construction Sector – November 2019

On 25 November 2019, a one-day workshop was organized in collaboration with SMC and GPCB, which focused on the construction sector as a source of PM_{10} and $PM_{2.5}$ emissions. The objective of the workshop was to have common control measures identified by the sectoral experts and builder association. As the focus of the workshop was issues pertaining to air quality in construction activities, the speakers and participants were from the field of construction and allied fields. More than 90 professionals participated in the workshop. Most of the participants were civil engineers, leading architects, building energy professionals, and construction contractors from the Surat chapter of CREDAI. Officials from the Town Planning Department, Urban Development Department (SUDA), Environment Cell (SMC), and Ring Road Construction Managing Authority (URDCL) of SMC too participated. In addition, various professionals from institutes such as SCET and SVNIT were also present and contributed with the sector-specific action plans and SOPs related to construction activities in the SMC area through their insights. The Gujarat chapter of IGBC and local think tanks such as UHCRCE and ITPI also participated and shared their views on the administrative processes that needed to be adopted to improve engineering controls in construction activities as a part of the SCAP.

The major outcome of the workshop was the development of a guideline on clean construction practices named Clean Construction Practices Guidelines for Surat City by WRI India in active collaboration with the Surat chapter of CREDAI, SMC, and GPCB. This document is based on the inputs given by experts and participants at the workshop. One of the main inputs received at the workshop was the need for a collation of the different control and mitigation mechanisms prescribed in the government's rules and regulations but not adhered to by construction companies and contractors. The guidance document was released a year later, in November 2020. Details of this guideline are given in **Annexure 3**.

SCAP Target Approach – MSW Sector – February 2020

Taking another step forward in addressing sector-specific emissions and exploring particular mitigation options, WRI India organized a one-day stakeholder consultation on profiling of open burning of MSW as a sector and the mitigation options for the SMC area. The focus of the workshop was the link between air pollution and municipal solid waste management activities in the SMC area. speakers and participants were selected from the close group who can put forward points for an effective action plan that can target the issue of waste burning and other emission additions to the city's air due to processing of municipal solid waste. More than 80 professionals participated in the workshop. The group was a diverse mix, ranging from leaders at private firms engaged in recycling waste to community group leaders promoting waste collection practices in the SMC area. Participants who attended the workshop belonged to public health management, hospital management, town planning department, environment cell (SMC), local institutions engaged in socio-technical research on waste pickers and non-government organizations working with waste pickers.

In addition, various professionals from consulting agencies working on waste minimization projects contributed during the workshop through their insights on framing sector-specific action plans and SOPs. The workshop was an opportunity for all participating agencies and individuals to understand the current scenario of managing municipal solid waste in the SMC area and to discuss this issue that has been left unaddressed due to lack of citizen engagement. The main output of this workshop was the laying down of a pathway for coordination and action for the SMC area, wherein a large number of people could be engaged in the efforts to bring about behavior change, which would in turn lead to improved MSW management and reduction in the practice of open burning of MSW. The Hon. Municipal Commissioner, SMC, promised to increase the amount of fine imposed on burning MSW in the open. This was to be supported by the need-based approach to be laid down, for the waste pickers. It was discussed that the latter would improve livelihoods of these marginalized communities and engage them in a collaborative waste segregation activity led by the SBM cell of the SMC.

SCAP Target Approach – Air Pollution and Industries Sector – Exploring Pathways for Reducing Emissions – November 2020

On 5 November 2020, WRI India organized a virtual meeting of different stakeholders associated with the industries sector to address sector-specific emissions and explore mitigation options. Key stakeholders including SMC, GPCB, GEDA, GERMI, GIDC, and the Industries Associations and Textiles Processors Association of the SMC area met to charter the mitigation measures drafted by the WRI India team on the basis of the assessment made by it. The number of stakeholders invited was small so that feedback could be taken from a focus group. Feedback was given by SMC, GPCB, GEDA, and SGTPA. Mr Vishal Budhiya of STEAMHOUSE Pvt Ltd, Surat, presented an innovation case study on cogeneration potential as a way to reduce air emission from industries and conserve resources efficiency.

The major output of this event was to bring consensus among key stakeholders for SMC area specific mitigation options for the industries sector with the objective of engaging better resource efficiency that coexist with the local supply chain of fuels. This approach was earmarked as SMC area industry sector emissions are mainly dependent on fuel usage pattern. A document that was a collation of specific mitigation options was shared with experts on energy efficiency, eco-industrial planning, and alternative energy resources at various institutions. On the basis of their feedback, the 12 policies proposed in the SCAP were formulated. These have been covered in the chapters in this report.

ANNEXURE 3: THE HANDBOOK OF CLEAN CONSTRUCTION PRACTICES GUIDELINES 2020

The Preparation Process

Construction materials and the building sector are responsible for more than 40% of global resource consumption. The emission of particulate matter at construction sites has a negative impact on human health and the surrounding ecosystem. The generation of dust, gaseous pollutants, particulate matter, noise, and other atmospheric contaminants result either indirectly or directly from building construction activities.

In the SMC area, road dust has been found to be one of the major contributors to air pollution. The SMC with support from WRI India launched the Handbook of Clean Construction Practices on 26 November 2020. The knowledge product focuses on the existing rules, regulations, and mitigation actions for the construction sector. It provides information on the legal provisions in the country for control of SPM at construction sites. The handbook collates sections on the dust control (particulate matter) measures from available rules and acts, some of which are,

- Model Dust Mitigation Plan at Construction Site, as per The Environment (Protection) Amendment Rules, 2018
- C&D Waste Management Rules, 2016 for $PM_{2.5/10}$ Control
- Environment and Natural Resource Conservation at 'During and Post – Construction' Activities
- Management of Buffer Area Surrounding Construction and Demolition Waste Processing Plant – As per C&D Waste Management Rules, 2016
- Municipal Solid Waste Management Rules, 2016
- Air Pollution Concerns Highlighted Under Construction and Demolition Waste Management Rules, 2016
- The Air (Prevention of Pollution) Act, 1981
- The Water (Prevention of Pollution) Act, 1974) on Ready to Mix Concrete Use at Construction Site.

The handbook also lists various management options, enforcement mechanisms, and monitoring systems and provides a check list for dust suppression at construction sites.

The Release Event

The release event of the handbook was organized in November 2020 by WRI India in close coordination with the SMC, GPCB and, the Surat chapter of CREDAI. The event was presided by the Hon. Mayor of Surat city, Dr. Jagdish Patel. The opening remarks were made by Mr. O.P. Agarwal, CEO, WRI India, and the keynote address was by the Hon. Municipal Commissioner Mr. Banchhanidhi Pani (I.A.S). Key representatives of the SMC, GPCB, the Surat chapter of CREDAI, Shakti Sustainable Energy Foundation, Bloomberg Philanthropies, and other organizations such as JSI India, AFD Global, EDF India, University of Cincinnati (Ohio, USA), and ASSOCHAM India were present at the event. Deputy Municipal Commissioner Mr. R J Pandya, Executive Engineer (Drainage) Mr. E H Pathan, and Mr. Jwalant Naik (Environment Engineer – SMC) were also present at the release event in person. Ms.

Priya Shankar from Bloomberg Philanthropies made the concluding remarks. The event was organized by utilizing physical and virtual meeting platforms.

Web link for the handbook: https://wri-india.org/events/handbook-clean-construction-practices-surat-developed-under-surat-clean-air-action-plan-2020

Figure 79: Frontpage of CCP Guideline Document 2020 for Surat

Way Forward

The handbook has been circulated widely among practitioner architects, engineers, builders, and all CREDAI members in the SMC area, and they have been directed to use it. With an agreement to stringently adhere to the collated rules at construction sites, the inputs will be used to develop a project wherein best practices will be demonstrated at a pilot site and monitoring protocols will

ANNEXURE 4: SECTORAL PRIMARY STUDIES

Open Burning of MSW Sector

Objectives

- To address the gap in data on MSW burning through field surveys
- To understand the contribution of MSW burning to the air quality of the SMC area
- To study the spatial and temporal character of MSW burning in the SMC area
- To understand the extent of various aspects of MSW burning through different socio-economic statuses at the neighborhood level
- To analyze the relationship between waste burning, land use, and human population at different spatial scales

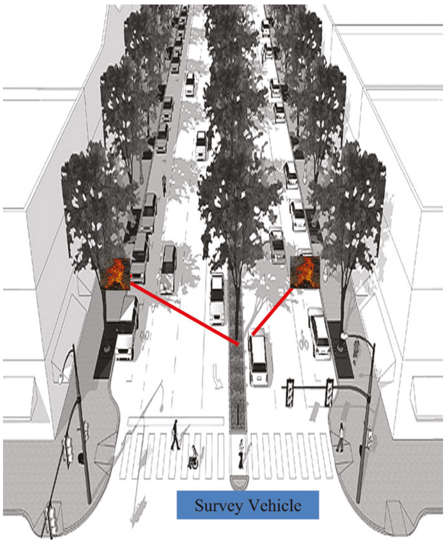
Methodology

- Primary data on MSW burning was collected using the transect method developed by Nagpure et al. (2015). This is discussed in **Chapter 5** of this report. In the transect method, the frequency of MSW burning incidents is estimated and these are measured spatially with respect to the composition and volume/rough mass of the waste burnt for the neighborhood and extrapolated to the entire SMC area.
- As a part of this method, the transect routes covered the different streets and roads of each zone (covered 54 wards of the SMC), representing the survey area's socio-economic status (SES) and land-use characteristics. All transect routes in the sample wards were covered either on foot or by a vehicle in the morning and evening hours for three consecutive days during the winter (January 2020) and summer (June 2019) seasons.
- The transect method (route) is designed for a minimum of 10- 40% of the neighborhood area comprising all SES and types of land use, such as residential, commercial, public and semi-public industrial, with mixed and multiple types of streets and locality roads.
- The per capita incidents of MSW burning and mass were calculated for each zone and then applied to the population of the remaining similar zones in the SMC and scaled up.

Socio-Economic Considerations for Scaling-Up Study Findings

The SES of wards in the SMC area was derived from the Census of India 2011 data on household amenities and assets. Data on access to basic amenities, such as electricity, drinking water, toilet facility, and drainage facility, has been extracted for constructing the Relative Wealth Index. The index helped in the application of the ranking system, providing scores (1-27) in all categories of SES as per amenities [High (24-27) availability, Medium (18-23) availability, Low (1-17) availability], and ranking these to define the SES[91]. Using these criteria, SMC wards were categorized into wards with high, medium, and low socio-economic sources/amenities[92]. After defining the SES of wards, wards were again classified on the basis of dominant land use activity - residential, commercial, and industrial.

Figure 80: Transect walk methodology – Walkway selection



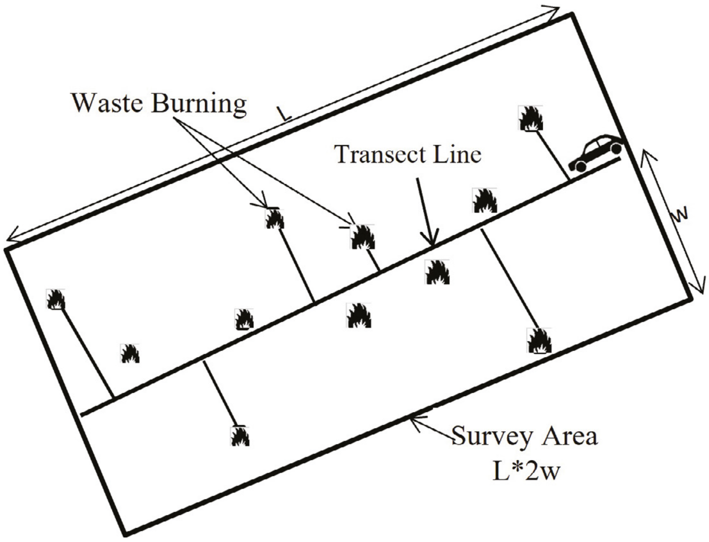


Table 59: Wards in the SMC area as socio-economic status and land use activity

SES	SES & Land Use Activity	Name of Ward
High SES Neighbourhood	Residential High	Nanpura, Athwa, Adajan, TPS - 2 Nanpura, TPS - 5 Athwa – Umara, TPS - 9 Majura, Umara, Piplod, Pisad, Bharthana – Vesu, Vesu, Magdalla
Middle SES Neighbourhood	Residential Middle	Sagrampura, Salabatpura, Haripura, Mahidharpura, Gopipura, Wadifalia, Sonifalia, Nanavat, Shahpor, Rander (this ward consist 13 wards), TPS - 3 Katargam Gotalawadi, , Katargam, Nanavarachha, Dumbhal, Althan, Jahangirabad, Jahangirpura, Pal, Motavarachha, Sarthana, Simada, Magob, Sarsana and Rundh
	Commercial Middle	Begumpura, Saiyadpura, TPS - 6 Majura – Khatodara
Low SES Neighbourhood	Residential Low	Nanavarachha Water Works, TPS - 1 Laldarwaja, Singanpor, Dabholi, Ved, Fulpada, Karanj, Magob, Anjana, Dindoli, Bamroli, Bhatar, Palanpor, Variyav, Chhapara Bhatha, Kosad, Amroli, Utran, Puna, Parvat, Godadara, Dindoli, Unn, Sonari, Budiya, Jiyav, Vadod, Bamroli (Part), Bhimrad, Khajod, Abhava, Vanta, Dumas, Sultanabad, and Bhimpor
	Commercial Low	TPS - 7 Anjana, TPS - 8 Umarwada
Industrial (considered in Low SES)		TPS - 4 Ashvanikuma Navagam, Tunki, Kapadra, Umarwada, Limbayat, Bhedvad, Bhestan, Pandesara, Udhana, Majura, Vadod, Gabheni, Gaviyar

[91] *Kishore, J., Kohli, C., Kumar, N., & Gupta, N. (2017). Scales used in India to Evaluate Socio-economic Status in Medical Research: Limitations of Existing Scales and the need of a more Comprehensive One. JIMSA, 30(2), 66.*

[92] *Fry, K., Firestone R., & Chakraborty, N. M. (2014). Measuring Equity with Nationally Representative Wealth Quintiles. Washington, DC: PSI.*

Results

The results have been discussed in detail in the specific chapters on sectors. As per the findings, the areas falling in low SES did not fare well with respect to open burning of waste and were found to burn large amounts of MSW in both summers and winters. Since the waste composition played a vital role in the emissions from the sector, industrial areas were surveyed with specific interest. These industrial areas ranked next to the low SES areas.

Photography

Location: Bhatar
SES: Low
Land Use: Industrial

24 June 2019 morning

24 June 2019 evening

Location: City Light
SES: High
Land Use: Residential

Burning at night

Burning during the day

Location: Vadod near Pandesara GIDC
Land Use: Industrial

21 June 2019 morning

24 June 2019 morning

Location: Althan
SES: Middle
Land Use: Residential


Location: Althan
SES: Middle
Land Use: Residential


Location: Ashawani Kumar (Uttal Nagar)
SES: Low
Land Use: Residential + Industrial


Location: Adajan
SES: High
Land Use: Residential


Location: Jahangirabad
SES: Medium
Land Use: Commercial


Location: Pandesara
SES: Low
Land Use: Residential (Slum)


Location: Udhna
SES: Low
Land Use: Residential + Industrial


Location: Adajan
SES: High
Land Use: Residential


Location: Althan
SES: Medium
Land Use: Residential

Eateries Sector

Objectives

- To assess the fuel usage composition for all types of eateries in the SMC area
- To fill the gaps in data by validating primary research focusing on the emissions from the eateries sector
- To analyze the contribution of the eateries sector in the source apportionment

Scope

The WRI India team carried out a survey based on transect line to collect data on fuel use pattern and other characteristics of the restaurants and eateries in the SMC area. First, different representative routes were to collect the data based on the land use pattern, accessibility, foodservice market, and socio-economic characteristics in the SMC area. Then, a questionnaire-based survey was conducted to collect data from the eateries along the transect routes. Details of methodology are given in **Chapter 8**. The format of the questionnaire is presented in **Table 60**.

Format of Questionnaire

Table 60: Questionnaire used in survey on eateries

Sr.No.	Eateries Survey								
1.	Date:								
2.	Shift:	Morning		Evening					
3.	Area/Ward/ Locality/Street:								
4.	Land use:	Commercial	Residential	Mixed use	Recreational	Public/Semi Public Space	Others		
5.	Socio-economic condition:	High	Medium	Low	Slum				
6.	Name of restaurant/ hotel/ kiosk/stall/booth:								
7.	No. of people employed:								
8.	Type of fuel used in kg:	LPG	CNG	Coal	Wood	Electricity	Steam	Solar	Others
9.	Coal consumed in kg:								
10.	Fuel consumption per day:								
10a.	Electricity consumed in unit:		Total bill (amount):		Per unit cost:				
10b.	Wood consumed in kg:		Per kg cost:						
10c.	Other fuel:		Cost per unit kg:						

Sr.No.	Eateries Survey						
11.	No of working hours:						
12.	Amount of waste generation per day:						
13.	Disposal of solid waste:	SMC collects regularly	Disposed to a predefined landfill	Disposed irregu-larly	Disposed to the river/lake/ Water bodies	Burning	Others

Results

The survey results indicated that out of the total surveyed eateries, 77% use LPG as primary cooking fuel, followed by coal (17%) and firewood (6%). The use of coal and fuelwood in small eateries at central locations of the city was observed during the primary survey. Other details have been discussed in the sectoral chapter.

Photographs

Location: Street Food Vendors, Dumas Road Vesu
Fuel Used: LPG

Location: Dosa Shop, Khaudra Gali Kamrej

Fuel Used: Coal

Location: North Indian Food Shop, Night Bazar Piplod

Fuel Used: Coal

Location: Corn Shop, Dumas Beach

Fuel Used: Wood

Location: KGN Tea Centre, Rander

Fuel Used: LPG

ANNEXURE 5: SCAP – REVIEW PROCESS

To ensure that the SCAP report is a high-quality document, the draft was circulated among all stakeholders and a multistage review was undertaken. The review process was designed to assess the quality and validity of data and facts. Eminent subject matter experts (**Table 61**) were entrusted with the review. Here, the term 'internal reviewers' refers to the experts from WRI India while external refers to all other subject matter experts.

Table 61: List of reviewers for the SCAP final draft

Sr.No.	Name	Institute	Area of Expertise
1.	Dr. Neeru Bansal	CEPT University, Ahmedabad	Industries/ Emissions
2.	Dr. R A Christian	SVNIT, Surat	Municipal Wastewater Engineering Heavy Construction and Project Management Industrial Safety and Environment Biological Processes Air Pollution and Control
3.	Dr. Pallavi Pant	HEI, Boston (USA)	Air Pollution
4.	Mr. Trushit Desai	Geostone Corporation, Surat	Urban Planning, Air Pollution, Urban Transport, Sustainability
5.	Mr. Deepak Krishnan	WRI India, Bengaluru	Industries/ Emissions
6.	Mr. Prashant Bachu	WRI India (Visiting), New Delhi	Urban Transport
7.	Mr. Ravi Punnappureddy	WRI India, Bengaluru	Urban Planning and Transport Planning
8.	Ms. Prerna Mehta	WRI India, Mumbai	Urban Planning
9.	Dr. Jignesh Patel	CREDAI Surat Chapter, Surat	Urban Planning
10.	Mr. Mehul Patel	IUC, Surat	Climate Change
11.	Dr. Vimal Trivedi	CSS-VNSGU, Surat	SWM and Landfill Site Management
12.	Dr. Raj Lal	University of Michigan, USA	Air Quality and Modelling
13.	Mr. Chirag Gajjar	WRI India, Mumbai	Energy/ Climate Change
14.	Mr. Shwetal Shah	Climate Change Department Government of Gujarat, Gandhinagar	Energy/Climate Change
15.	Mr. Subrata Chakrabarty	WRI India, New Delhi	SWM/Emission
16.	Dr. Swati Singh Sambyal	UNHABITAT, New Delhi	SWM
17.	Dr. Subhargu Goswami	CEPT University, Ahmedabad	SWM
18.	Dr. Ashwini Kumar	CEPT University, Ahmedabad	SWM/Landfill Site Management
19.	Dr. Namrata D. Jariwala	SVNIT, Surat	SWM/ Air Pollution
20.	Dr. Gulrez Shah Azhar	IHME, Washington DC	HIA, Public Health, Urban Planning
21.	Ms. Avni Agrawal	WRI India, Mumbai	Climate Change, Emission Inventory

The comments/suggestions/inputs from the reviewers are presented in **Table 62**,

Table 62: External review process – Comments from reviewers

Sr.No.	Chapter	Reviewing Agency/Individual	Feedback
1.	Industries	Dr. Deepak Krishnan (WRI India) Dr. Trushit Desai (Geostone Corporation) Dr. Neeru Bansal (CEPT University) Dr. Pallavi Pant (HEI, Boston, USA)	In order to understand air quality in all areas of the SMC, it would be necessary to estimate the number of monitoring stations required for the city. This should be done immediately so that air quality can be monitored thoroughly. Similarly, new sources of pollution should be inventorized. In proportion to the total number of industries in the SMC area, the industries registered (CEPI Index and CEMS portal) with GPCB is a small fraction. Data collation of GPCB with the Industries Department can bring the other polluting industries under the purview of the Air (Prevention of Pollution) Act, 1981.
			The numeric data on air quality in the SMC area needs to be linked to spatial data for development and land use in the city. The identification of hot spots is a necessary step in understanding the cause and effect (emission and receptor) relationship. In the current format, the entire SMC area is managed uniformly, leading to a generalized approach and poor air quality for the city. The disaggregated-level analysis proposed will help take specific actions in the areas where air quality is observed to be poor.
			The integration of SCAP with the District Environment Plan, the recommendations of the 15th Finance Commission Report, City Clean Air Action Plan, the source apportionment study, and the National and State Ambient Air Quality Monitoring Plans are necessary to make significant progress in this area.
			The air quality data should be regularly collected, collated, and analyzed to know the impact of actions taken on air quality. This should be done at the disaggregated level in the city so that hot spots can be focused on and specific actions for reducing pollution levels at these hot spots can be taken for improvement.
			The staff of the government agencies is generally busy in their day-to-day responsibilities and does not have time to focus on data collation and analysis. Academic and/or research institutions can be engaged for regular data collation, trend analysis, and any other analysis and intimate the monitoring committees to monitor the performance and progress of the action plan.
			Industries Associations, GPCB, and SMC should collaborate to explore the possibilities of enhancing resource consumption efficiency in the industries of the SMC area. However, while this need not be mandatory, the industries that are willing to take steps must be provided support and incentives.
2.	Household Cooking	Mr. Chirag Gajjar (WRI-India) Dr. Raj Lal (University of Michigan) Mr. Mehul Patel (IUC) Dr. Vimal Trivedi (CSS Surat VNSGU)	The analysis of policies and schemes on mitigating emissions from the sector should be done using a structured approach. Household cooking is a decentralized sector, with many centralized policies governing the distribution and pricing of the fuel.
			Strategies to incorporate behavior change should be included in the action plan. Policies for this sector have hitherto neglected the importance of behavior change. Such strategies will impact the mitigation options proposed for the medium term and eventually remove the subsidy for high-income households covered in the assessment.

Sr.No.	Chapter	Reviewing Agency/Individual	Feedback
3.	Open Burning of MSW	Dr. Raj Lal (University of Michigan) Dr. Vimal Trivedi (CSS Surat VNSGU) Ms. Swati Singh Sambyal (UN-Habitat India) Mr. Subrata Chakrobarty (WRI India)	While assessing, the focus should be placed on imperial formulae. Greater emphasis should be placed on the different emissions factors for different waste articles. The methodology for selecting these emission factors should be explained in detail.
			The sector operates under MSW management, which would control the emission mitigation policy framework. Thus, the difference or change can be brought in by targeting the application side of the suggested interventions. The MSW management principles, which are already monitoring issues related to waste in the SMC area, can be extended for the behavior change and waste collection efficiency aspects in the affected areas of open MSW burning.
			Principles such as circular economy should be applied in umbrella mitigation measures to reduce the practice of MSW burning.
			While managing the problem of open burning of MSW, the contribution of the transportation sector too must be considered. This is different from the waste collected from door to door. The allocation should be made for the road dust and transportation sector in the case of significant fugitive emissions from MSW burning.
			Having wage factors or incentives over the collection of waste is also important. If SMC is collecting coconut shells for their flagship project, contrary as perception prevails, the door-to-door vehicle does not collect waste such as used sugarcane shoots. Once end up in the open, these shoots would form the base for the people to burn them in the open, creating unnecessary emissions that could have been averted if the services collected the mentioned waste. But this latter point needs to verify from a valid source.
			Data suggests that only a small portion of waste gets recycled or composted in landfills. Waste such as household packaging material, carry bags, milk pouches, and industrial plastic waste contains dangerous chemicals for the environment and human health.
			Door-to-door waste collection coverage can be added as the fourth factor influencing people's perception of burning waste in the open. For instance, if the waste collection does not regularly occur in residential societies, households may decide to burn their waste in the open.
4.	Construction	Ms. Prerna Mehta (WRI India) Dr. Jignesh Patel (CREDAI Surat) Dr. Bhavna Vimawala (SCET Surat) Dr. Namrata Jariwala (SVNIT Surat)	The integration of mitigation policies for the construction sector with national-level programs, such as Smart Cities Mission and Climate Smart Cities, would help draw attention to the sector that lacks focus in urban agglomerations such as the SMC area.
			The development of a pilot site case control module has certain benefits. The sites can be developed into museums or demonstration sites where professionals can observe and learn through hands-on exercises. Institutions and engineering colleges should be encouraged to integrate air pollution management in bachelor's and master's civil engineering and architecture programs.
			As many construction agencies have an affinity to adopt sustainable norms, a promotion base is recommended wherein the central command center will award or recognize those companies who adopt clean construction practices on their sites. Such cases can be highlighted by performing evidence-based analysis as well.

Sr.No.	Chapter	Reviewing Agency/Individual	Feedback
5.	Eateries	Dr. Vimal Trivedi (CSS – VNSGU, Surat)	While the inventorization of food joints in the SMC area is a good strategy, integrating the inventory with the databases of the Food and Drug Department and that of Shop and Establishment Department is equally important to reduce duplicity. The list should be comprehensive, and the sources would need to be checked by the respective departments that should manage the databases.
		Mr. Shwetal Shah (Climate Change Dept, Government of Gujarat)	Provisions in the National Street Vendors (Protection of Livelihood and Regulations of Street Vending) Act, 2014, and access to schemes like UJWALA may be analyzed better when a third party implements the projects.
			It is necessary to have a food waste audit. Generally, food waste is broadly classified into two types – waste that accumulates during cooking, which includes peels, rinds, etc., and the waste from the leftovers.
			The proposed mitigation measures should be implemented in the wards or zones with the highest number of eateries. Data on fuel types and cooking methods in eateries should be collected. After proving the effectiveness of the mitigation measures against emissions from eateries where the cooking techniques and choice of fuel are causing harm to air quality, these can be applied to all the other wards in the SMC area.
6.	Transport	Dr. Robin Christian (SVNIT, Surat)	A thorough assessment of the vehicular population entering the SMC area should be made. To implement mitigation measures in this area, it is important to have a list of entry gates leading HCVs into the city, increasing the vehicular emissions load.
		Dr. Namrata Jariwala (SVNIT, Surat)	Mitigation measures related to transportation emissions should focus on managing VKT through public transportation and providing last-mile connectivity through NMT options and fuel-efficient motorized systems.
		Mr. Prashant Bachu, (Independent Consultant)	Non-exhaust emissions, too, are important in the planning of reductions in emissions from transportation. The mitigation measures must include a standalone assessment for the NEEs or modify the SMC area's physical development principles to accommodate measures that are highly decentralized and effective in controlling NEEs at the city's busiest junctions.
		Mr. Ravi Ponappureddy (WRI India)	Flagship projects such as BRT must be kept on vigil to develop innovative ways through which VKT can be managed and emissions can be reduced. In line with BRT, specialized corridors for freight movement can also be planned inwards/zones where business activity is higher.
			Measures such as fare rationalization should focus more on formulating an umbrella mitigation measure policy under which financial and administrative needs to implement physical changes proposed to the SMC area can be included.

ANNEXURE 6: REPRESENTATIVE SAMPLE ASSESSMENT FOR INDUSTRIAL UNITS IN THE SMC AREA

The information shared by the regional office of GPCB focused on the following:

- Fuel used – Type, quantity, and different production and utility vessels being operated
- Size of industrial unit operations and their main product which determined their type
- Different vessels being used for achieving production for each industrial unit, the capacity of vessels, and raw material processing
- Combustion capacities – Vessels, production, and fuel type
- Air Pollution Control Devices installed – Types and numbers

Distribution of Industrial Units – Size/Type

As presented in **Table 63**, this assessment revealed that the textile industry comprises 67% of the total number of industries in the SMC area. The percentage of textile units is very high in the medium and small categories, at 11% and 47% of the total representative sample, respectively. Similarly, chemicals as main products and intermediates are another type of industry prevalent in the SMC area. These form a significant 17% of the total number of industries, with the majority of these being large industrial units, at 11%. Further distribution has been presented in **Figures 81-83**.

Table 63: Distribution of industries – Size and type - from sample data

Sr.No.	Size of Industry	Textile	Chemical	Engineering & Metal Works	Others	Total
1.	Large (10%)	42	48	6	18	114
2.	Medium (11%)	46	5	6	2	59
3.	Small (47%)	202	18	24	13	257
4.	Total (67%)	290	71	36	33	430

Figure 81: Small scale industries – Representative numbers

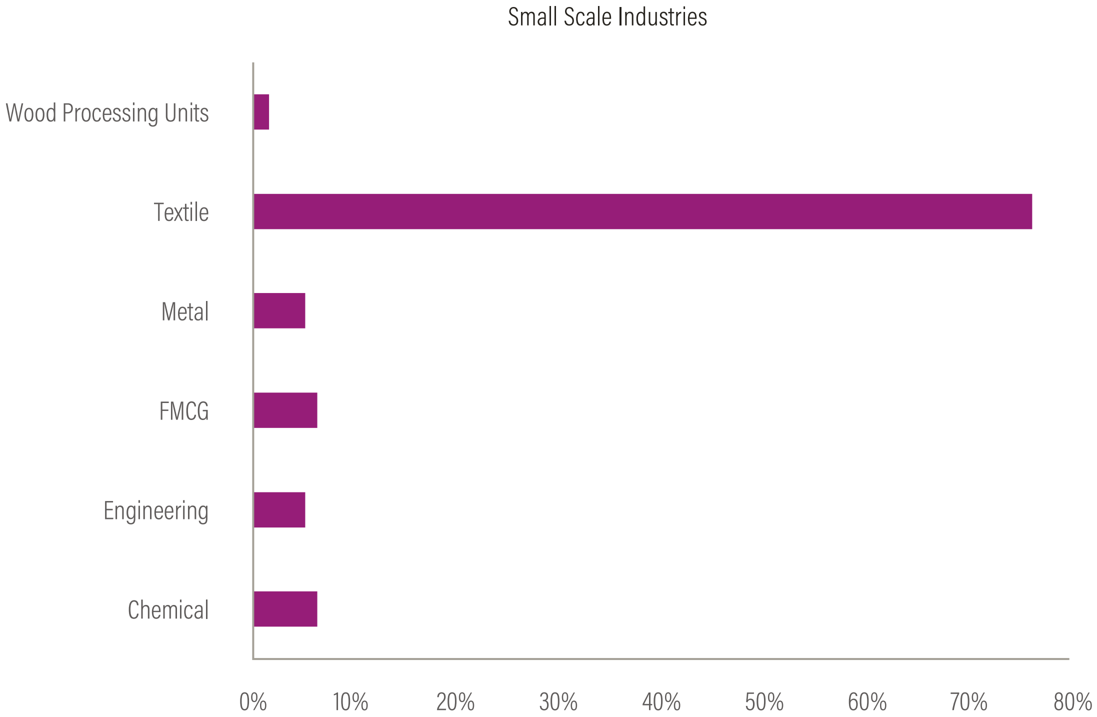


Figure 82: Medium scale industries – Representative sample

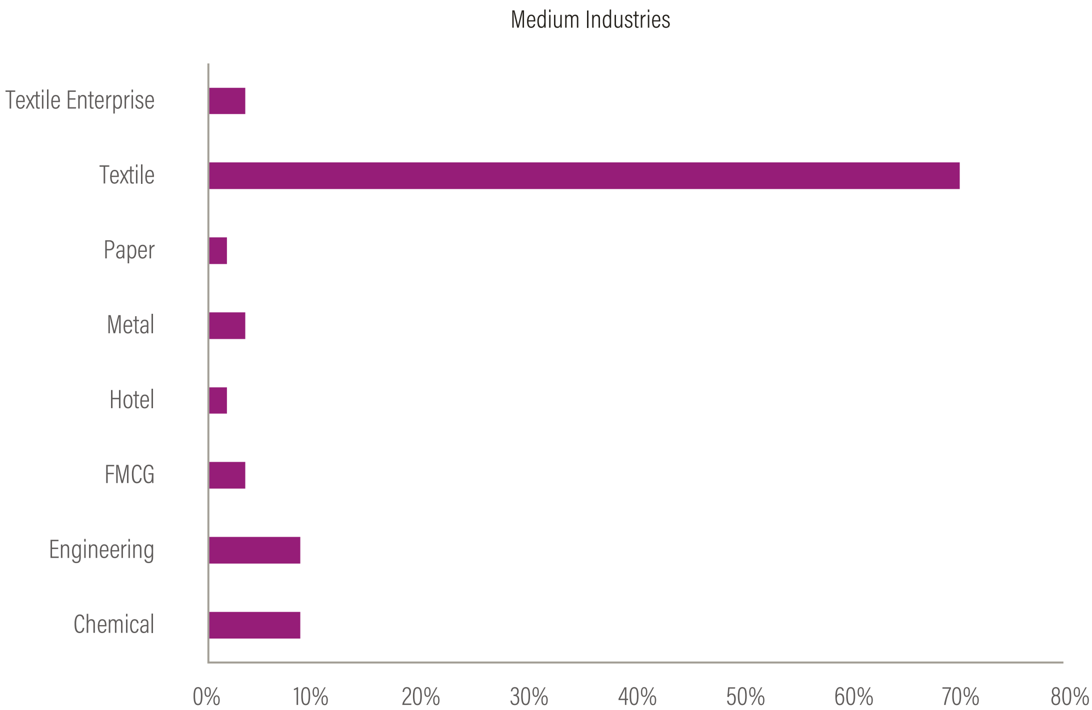
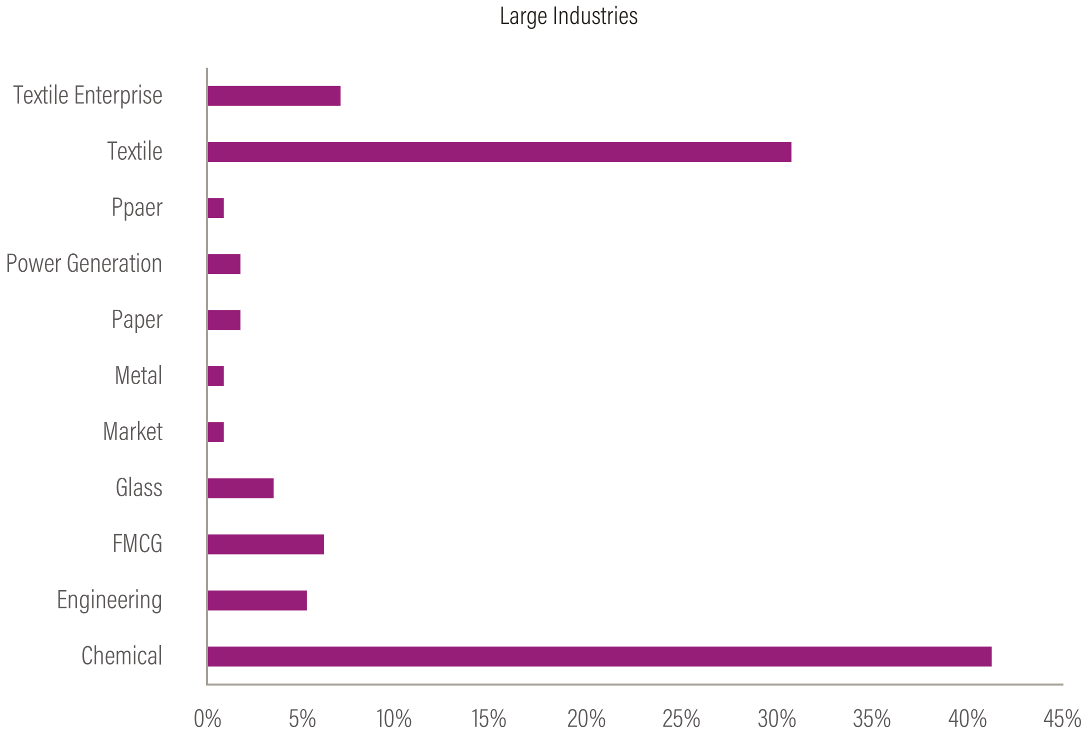


Figure 83: Large industries – Representative sample



Processing Vessels or Combustion Equipment Used

The quantity of this equipment installed in industries in the SMC area is indicated in **Table 64**. Boilers are the most widely used combustion equipment in industrial clusters of the SMC area, with 52% of all industries using these for processing. This is followed by the thermic fluid heater that has been installed in 30% of all industries in the SMC area. The assessment for capacities of boilers has been presented in **Table 64**. A majority of the boilers are less than 2 TPH in capacity (termed as '**baby boilers'**). This is an important aspect in the allocation of emissions since every unit increase in the industrial cluster would add to the emissions in the city's air.

Table 64: Different processing vessels – Size of the processing units

Equipment Type	Large	% Large	Medium	% Medium	Small	% Small	Total %
Boiler	82	18	34	7	129	28	52
Furnace	4	1	0	0	20	4	5
Incinerator	1	0	0	0	0	0	0
Thermic Fluid Heater	35	8	33	7	113	24	39
Hot Air Generator	0	0	0	0	1	0	0
Hot Batch Mixing Plant	0	0	0	0	4	1	1
Other	2	0	0	0	10	2	3

Boilers Capacity Category	Large	Medium	Small
Less than 2 TPH	16	9	65
2 to 5 TPH	45	7	19
5 to 10 TPH	11	10	19
More than 10 TPH	6	0	4

Fuel Consumption – Solid Fuels, Liquid Fuels and Gaseous Fuels

Fuel in the SMC area industries is mainly used for processing and heat-generating vessels, such as boilers for steam generation, furnaces for heating and melting purposes, thermal fluid heaters for heating purposes, or process applications. The major fuels used in industries are coal, lignite, wood, high-speed diesel (HSD), furnace oil (FO), natural gas, LPG, bagasse, and rice husk. This depends on the industry, application of technology, process requirement, availability, economic efficiency, and safety. **Table 65** presents the fuel usage pattern in a year for the representative sample provided by GPCB after calculating and compiling the fuel consumption by different air-polluting industries in the SMC area. **Table 65** also lists the different types of fuels as per the representative sample.

Table 65: Fuel usage pattern in industries

Total Industrial Units (Numbers) - Sample by GPCB RO Surat		429
Solid fuel (MT/Y)		3.7x10^E+8
Liquid fuel (KLT/Y)		2.2x10^E+8
Gaseous fuel (n m3/Y) or m3		1.5x10^E+9
Solid Fuel	Liquid Fuel	Gaseous Fuel
Coal	Furnace Oil	Natural Gas
Bagasse	Diesel	LPG
Lignite coal	Light Diesel Oil	Methane
Wood	-	-
Petcock (or coke)	-	-
Solid Fuel	Liquid Fuel	Gaseous Fuel
Husk	-	-

The total consumption of coal by industry in the SMC area has been estimated to be around 5.75 million tons per year. However, further analysis shows that coal, furnace oil, wood, and HSD are the main fuel used in large industries. In the medium industries, coal, furnace oil, and wood are the major fuels used. In the small industries, coal, furnace oil, and wood, and, in some cases, bagasse are the main fuels used. The fuels are classified into solid, liquid, and gas for understanding and analysis. **Solid fuels** comprise coal, wood, lignite coal, and agricultural waste, such as rice husk, and bagasse, primarily used by industries in the SMC area.

Coal is the most widely used solid fuel in the SMC area's industry sector, followed by wood and lignite. **Liquid fuels** such as FO, HSD, and LDO are the next most consumed fuel by industries in the SMC area. FO is the most widely used fuel in the SMC area, primarily by the medium and small industry, followed by HSD used in negligible amounts compared with FO. In the case of **gaseous fuels,** natural gas is largely consumed more in a large industry. However, in the medium industries, besides natural gas, a small quantity of LPG is also used, and in the small-scale industries, the share of LPG is higher than that of natural gas.

Similarly, the major component has been seen in small and micro-level industries for the industries using de-oiled coke. In contrast, medium and large-scale industries use diesel or light diesel oil. Similarly, industries dependent on gaseous fuels for processing are basing their production on natural gas-based processing plants. This specific pattern can be linked to the availability, affordability, and accessibility of different fuels and the complexity of processing parameters.

Status of Air Pollution Control Devices (APCD)

More than 90% of industries in Surat have installed APCDs to check the stack emissions. The APCDs were also analyzed for their adequacy. This assessment was done based on the numbers of units provided against the capacities of processing or heating vessels along with the latter's numbers in that unit. The adequacy was not measured individually for the industrial unit by the GPCB. As per the evaluation guidelines, the pollution control board is authorized to check the availability of APCD equipment against the processing vessel's capacity. Small industrial units are doing better than medium and large-scale industries in terms of installing APCDs and are adequate in numbers as per the size of the processing vessel.

Techno-Economic Analysis Costs Considerations

Fuel

Energy accounts for a significant share of total input costs for MSMEs, ranging between 10% and 25% for energy-intensive industries. The industry uses thermal energy and electricity. Thermal energy is produced from the combustion of fuels such as coal, lignite, biomass, FO, natural gas, LPG, methane, HSD, etc. The costs[93] attributed here have been calculated following a review of relevant literature, news reports, and discussions with the industry sector experts.

- Coal: As per GPCB, coal of medium quality with calorific value in the range of 2500-5000 kcal/kg is used primarily by industries in India. The price of coal of medium calorific value ranges from INR 3500 to INR 5000 per ton.
- Lignite: Lignite is mined in Gujarat locally and is available through Gujarat Mineral Development Corporation, whose CMP ranges from INR 2000 to INR 4500 per ton based on its grade.
- Biomass (groundnut husk briquettes and wood): Wood and groundnut shell briquettes are available locally in the SMC area in the price range of INR 3000-5000 per ton with a calorific value in the range of 3000-3500 kcal/kg.
- Furnace Oil: It is a by-product of the process of oil refining and is available in large quantities due to the presence of oil refineries near the SMC area. Also, it can be imported freely. Its CMP ranges from INR 25,000 to INR 30,000 per kilo liter.

[93] *The costs have been derived from experts' opinions and secondary literature suggested by them*

- Natural Gas: It is available in abundance in the SMC area due to the presence of Hazira, Gujrat Gas, and several other players in the SMC area. It is available at INR 30-40 per SCM and a 9200 KCAL/SCM calorific value.
- HSD: HSD is also available in the SMC area and is marked through state companies. The market price in 2020 is INR 75-80 per liter.
- Methane: The gas is available at a price range of INR 300-500 per kg.
- LPG cylinders come in two sizes/capacities, 47.5 kg and 475 kg big cylinders at INR 450-550 per kg.
- Electricity is supplied at INR 3.7 per unit in industrial clusters in the SMC area.
- Natural gas is being supplied at the rate of INR 2.57 per SCM.

Workers and Health Cost

Last year, the government highlighted the need for introducing social security for the MSME sector workers. The SMC area is dominated by textile, diamond, and other supporting industries. The job in the textile industry does not require any specific skill or educational background. These are low-skill and low technology jobs. The workers joining this industry are trained on the job. This feature attracts many people to the SMC area from all over the country. The conditions for work are also challenging, with low wages and occupational health being areas of concern. As these workers are migrants, they are not offered any social security. The pace of upward mobility of workers in the labor market, too, is slow. Usually, as per the Labor Department statistics, in the SMC area, daily wagers are to be paid INR 332 per day and must be hired after completing all legal formalities, while unskilled workers are to be paid INR 150 per day and can be hired without any registration or paperwork.[94]

Raw Material Cost

Cotton accounts for 51% of the total raw material cost in the Indian textile industry and continues to remain at an elevated level, thereby pressurizing domestic industry margins, according to India Ratings and Research (Ind-Ra). The raw material is available in the SMC area owing to its proximity to the cotton-growing region and textile being a major industry. The spinning and weaving industry provides yarn to the textile processors and being in a cluster, one unit's finished products become the raw material for another unit. The average price of raw cotton is in the range of INR 100-125 per kg. Some types of yarn used as raw material are synthetic polyester filament yarn, nylon filament yarn, viscose filament yarn, and blended sun yarn. Its average cost based on assumption is in the range of INR 150-300 per kg.

Some of the feasible policy recommendations in the SCAP to mitigate the industrial air pollution in the SMC area are based on the GPCB data and the analysis by WRI India.

Air Pollution Control Devices Used in Industries of the SMC Area

Air pollution control devices are a series of devices that prevent various pollutants, primarily from industrial smokestacks, both gaseous and solid, from entering the atmosphere. These control devices can be separated into two broad categories - devices that control the amount of particulate matter escaping into the environment and devices that control acidic gas emissions. Although complex, these

[94] *Ajeevika Bureau AR 2019*

devices have shown to be effective in the past, with the overall emissions levels for many pollutants dropping with the implementation of these control devices.[95]

For particulate control, specific machinery is used to remove particulate matter from gases escaping at the stack. Much of this separation uses physical means of separation and not chemical separation techniques, simply because particulate matter is large enough to be ‘caught’ in this manner. The following are a few basic methods to extract particulate matter through APCDs:

Electrostatic Precipitators: An electrostatic precipitator is a type of filter that uses static electricity to remove soot and ash from exhaust fumes before they exit the smokestacks. Unburned carbon particles in smoke are pulled out of the smoke by using static electricity in the precipitators, leaving clean, hot air to escape the smokestacks. It is vital to remove this unreacted carbon from the smoke, as it can damage buildings and harm human health, especially respiratory health.

Cyclone Separators: A cyclone separator is a separation device that uses the principle of inertia to remove particulate matter from escaping stack gases. In these separators, polluted gas enters a chamber containing a vortex, like a tornado. Because of the difference in the inertia of gas particles and larger particulate matter, the gas particles move up the cylinder. In contrast, larger particles hit the inside wall and drop down. This separates the particulate matter from the gas, leaving cleaned gas to be released into the atmosphere.

Fabric/Bag Filters: Fabric filters are a simple method that can be used to remove dust from stack gases. In some cases, these can also remove acidic gases if they utilize basic compounds. In this method, some fabric is placed, so stack gases pass through it before exiting the Escape Towers. – When the gas passes through, dust particles are trapped in the cloth. Generally, felt is the cloth that is used.

More intense chemical separation methods are generally required to control gaseous pollutants to be released in an environment with stack gases. However, this extraction is important as many acidic gases in stack gas contribute to acid rain. A few basic methods to extract gases are the following:

Scrubbers: Scrubbers are a type of device used to remove harmful materials from industrial exhaust gases before they are released into the environment. These pollutants are generally gaseous, and when scrubbers are used to remove SOx specifically, it is referred to as stack gas desulfurization. There are two main types of scrubbers, wet scrubbers and dry scrubbers. The main difference is in the type of material used to remove the gases. By removing acidic gases from the exhaust before it is released into the sky, scrubbers help prevent the formation of acid rain, which is harmful to humans on contact and buildings, as it has been reported that acid rain damages building surfaces.

Carbon Capture: Theoretically, carbon dioxide can be captured and stored below the ground or in forests and oceans to prevent it from entering the atmosphere. Carbon capture and storage refers to capturing carbon dioxide and storing it below the ground, pumping it into geologic layers. This process is rarely used but is extensively discussed to limit greenhouse gas emissions that are causing climate change.

---

[95] *Air pollution control devices. (n.d.). Energy Education. https://energyeducation.ca/encyclopedia/Air_pollution_control_devices#cite_note-RE1-2*

ANNEXURE 7: EATERIES SECTOR COST FACTORS

Costing of Eateries

Table 66: Cost estimations for eateries

Items	Numbers (for 2021)	Numbers (for 2026)
1. Survey Cost		
One volunteer survey (No. of eateries per day - No.)[96]	20	20
Total no. of eateries to be covered (No.)[97]	9642	12102.4
Total no. of volunteers/surveyors required for the survey (Consider)	20	20
No. of eateries covered in one day (No.) – (eateries covered per day (20)* Total surveyor (20))	400	400
No. of days required to do the survey (Total no. of eateries covered*No. of eateries covered in one day)	24	30
Remuneration of surveyor/ volunteer per surveyor/ day each (INR)	220	253
Local travel allowances and food cost (person/day)	110	127
Total cost bear on one volunteer/surveyor (remuneration, travel and food cost * No. of days (24))	7955	11482
Total Cost of Survey	159097	229643
2. Awareness Drive Cost		
IEC material Cost		
a. Per small brochure cost (INR)	5	7
b. Required brochure (INR)	10000	12000
Total cost of brochure (a*b)	50000	84000
Sub-total (1+2)	209097	313643
After rounding off (INR crore)	0.021	0.032

*Note: Expenditure for software for analytics etc. are not included (Assuming it will be done by SMC***)**

[96] *Ministry of Rural Development, Department of Rural Development, Government of India. (2019). Concept Note and Guidelines on Ease of Living Survey (PMAY-G/IAY,PMGSY, MGNREGS, DAY-NRLM, PMUY, Jan Dhan Yojana).*

[97] *Estimated based data of Economic Survey of India 2014*

ANNEXURE 8: INDIVIDUAL PROJECTS INDICATING MITIGATION MEASURES FOR DIFFERENT SECTORS

Construction Sector

Option 1 – Creating Prototype Case-Control Best Practices Site at the SMC Area

The fluid nature of construction sites makes them difficult to apply a thumb rule, and all construction sites are monitored differently. However, it is a fact that there are heavy emissions from these sites, which can be curbed if small changes are brought in through capacity building and handholding. The DREAM city project in SMC is in progress and promises to consolidate the diamond market. The complex would have the best construction practices on display. However, before displaying these practices to the public, it is important to have evidence that clean construction practices reduce particulate emissions from the sector. With this objective, a pilot best practices site can be executed at an actual ongoing construction site by the collaborative effort of CREDAI Surat, SMC, and GPCB. This pilot site can implement all the measures covered in various rules and regulations to reduce particulate matter, and that have been collated in the Handbook of Clean Construction Practices Guidelines Surat 2020. Two components could be displayed and worked upon further. All the proposed engineering and administrative controls should be strictly implemented at the prototype site during execution. After the execution of these best practices, the monitoring module can be initiated. In the monitoring module, gradual monitoring of the particulate matter can be executed. The best practices prototype and adjoining construction sites should be monitored for particulate matter emissions every three months. A progress monitoring statement should be released in which the activities of the Central Command Centre and the Dust Control Group should be described.

Option 2 – Using the Best Practices Case-Control Site for the Purpose of Capacity Building

When a clear reduction in the particulate matter is observed at the end of the year, the prototype pilot site will be used as a capacity-building center for engineers and students for awareness generation. This option will form activities such as monthly induction training, bi-monthly engineers' training, quarterly students training, and annual exposure tours of bilateral partners. Perception noting and collaboration with other flagship projects, such as SGPPL, will be explored to cover the complete sustainable supply chain of the construction and demolition processes.

Household Cooking Sector

Option 1 – Creating Strengthened Decision-Making Process by Filling in the Data Gaps

Any air quality management plan requires primary and secondary data for estimating emissions and proposing interventions. In proposing interventions for the SMC area, a significant challenge was lacking area-specific data for all the sectors. Such data is required to formulate policies and assess the outcomes after the policies are implemented. An open data portal can help reduce uncertainties, where all information and primary surveys carried out by any organization (private and public) related to the SMC area are available. Data availability would help at multiple levels, such as formulating policies and studying their impacts at local and regional scales. The numbers of PMUY beneficiaries and LPG cylinder refills ordered should be available ward-wise and village-wise to assess the implications accurately. This will help the government identify the areas where the percentage of consumers returning for LPG cylinder refill is less so that awareness programs can be implemented there.

Similarly, wards inhabited by low-income groups and lacking facilities need more attention. Such issues can be solved only when accurate data is available. The following data can help fill these gaps effectively:

- City-specific PNG coverage and extension map
- The number of LPG connections for the city can be compiled in one place with the help of LPG distributors.
- Timely update of data for understanding the outcome of implemented policies

Option 2 – Creating Niche Space for Cleaner Fuel Use in the SMC Area

- The fuel use pattern of Indian households is continuously changing as per the various government policies and programs that aim to reduce the use of traditional fuels and increase access to cleaner fuels for cooking and other energy needs in urban and rural areas. A complete transition towards clean cooking fuels in India can reduce premature mortality by 13% and bring the average ambient $PM_{2.5}$ concentrations below the levels prescribed for national $PM_{2.5}$ standards[98]. The long-term health hazards, time-consuming effort, and safety risk in procuring firewood and that of air pollution and environmental degradation are some of the reasons for the Government to strategize the provision of cleaner fuel to all households. When people do not use clean fuel despite having access to these, the subsidy becomes a liability and an additional burden on the government. Hence, there is a need to conduct a detailed survey to understand household fuel usage patterns. This survey would help understand consumer behavior and various barriers to the usage of cleaner fuels. The survey would also guide the policymakers in developing strategies and interventions to improve cleaner fuels for cooking and heating at the household level.
- Carry out a detailed survey for six months, targeting 25% of the total migrant population of the SMC area before starting the pilot project, which is anticipated to last for one year. This will provide an insight into the living conditions, energy needs, type of fuel used, and power supply in the area. SMC will implement this pilot project.
- There is a need to explore electricity use for cooking in urban areas having a continuous power supply. LPG connections could be provided to underprivileged consumers with subsidies. Although the middle and high-income groups in urban areas use cleaner fuels, including LPG, PNG, and induction stoves, the BPL households continue to use solid fuels. This survey would also provide an insight into strategizing policies for BPL households, including the migrant population.

Open MSW Burning Sector

Option 1 – Mass Awareness Program

To create awareness among residents belonging to all categories of socio-economic status that MSW burning has adverse consequences on health and leads to economic loss and to create awareness in industries to not mix and burn solid waste and non-hazardous industrial waste and dispose of separately, it is important to establish a protocol to engage citizens. Mass awareness campaigns are considered an important element of strategic planning. Information on the health and economic impacts of MSW burning can be disseminated among large sections of the population. These involve using

[98] *Chowdhury, S., Chafe, Z. A., Pillarisetti, A., Lelieveld, J., Guttikunda, S., & Dey, S. (2018). The Contribution of Household Fuels to Ambient Air Pollution in India. Collaborative Clean Air Policy Centre*

various mass media to disseminate messages on eliminating the practice of MSW burning in the city. Despite several initiatives on MSW management taken by SMC, the practice of MSW burning has not ceased in the city. It is hoped that the proposed mass awareness protocol would result in increased involvement of communities in curbing the practice of MSW burning.

In addition, large sections of society would become aware of the consequences of MSW burning, which would lead to a decrease in the practice. This would also result in attitudinal and behavior change, thus reducing the practice of MSW burning in the city to a very large extent. The project period is anticipated to spread over a time span of three years, starting 2021, while approximately INR 4 crore will be spent on the implementation.

Option 2 – Construction of MRF

SMC started the MRF center at all the Secondary Refusal Transfer Stations with an average daily waste of 360 MT[99]. Under Swachh Bharat Mission DPR 2016, MRF construction with a capacity of 600 TPD has been proposed; thus, an additional capacity of 240 MT is required. Instead of installing a 100-200 TPD plant, the recovery facility was proposed to be installed in a more decentralized way for maximum recovery of recyclable materials. The main functions of this facility would be to segregate all forms of dry waste, such as paper, plastic, and glass, at the proposed MRF sites, ensure sorting and segregation of recyclable and non-recyclable waste, and recover recyclable material used as functional products. It is expected that in the initial phase, the burning of recyclable or dry waste would reduce as a result of this measure.

In addition, within a time span of five years, the burning of recyclable materials, such as paper, plastic, metal, textile, glass, rubber, and leather, would occur in a controlled manner. This will ensure that the load on landfill sites reduces and the move towards zero landfill sites begins. This facility will also help other sectoral interventions such as AFR as fuel for industrial productions and fuel alterations propositions under the sustainable energy access policy of the Gujarat state in the residential cooking sector.

Option 3 – Gasification Plant for Heat Generation for Shredded Textile, Thread, and their Packaging Material

With objectives such as preventing the burning of textile waste shreds, cartons, plastics, and packaging materials and improving collection efficiencies by allowing ‘zero’ mixing of industrial and MSW waste articles, the setting up of a 150-TPD gasification plant could be proposed. Such a proposal would benefit the current DPR of SMC under the Swachh Bharat Mission. The anticipated outcomes from this project would be a reduction in the prevalence of shredded textile waste in industrial, residential low SES areas, and commercial areas, as it would be used as fuel for the gasification plant. The application of gasification technology has advantages such as reduced auxiliary fuel consumption and fewer emissions than incineration. The project is anticipated to be completed by 2025. A capacity of 50 TPD will be added after that for the prolonged use of the facility, depending upon the success of the operations.

[99] *https://www.suratmunicipal.gov.in/CleanSurat/Home/PastEventsAndInitiatives accessed on 21/04/2021*

Option 4 – Decentralized Compost Manure Production (organic waste converter) at Residential Unit Level or Community Level and Waste to Compost Plant

To promote decentralized OWCs, SMC has initiated installing 100 OWC units with a capacity of 1 ton each. A 1-TPD organic waste processing plant has begun functioning at the Anjana transfer station. Around 25 OWCs were installed at different vegetable and non-vegetables municipal markets and slaughterhouses. Additionally, waste to compost plants of 10 TPD at four locations is proposed. It is hoped that these steps would lead to a decentralized approach for smaller residential units and ease waste collection and segregation. It is important to engage residential welfare associations in this project. This focuses on the direct involvement of citizens in waste management and prevention of MSW burning. Involving the informal sector, including ragpickers, NGOs, and SHGs, would mean opening up a source of income. The proposal will cover five years in temporal scope. A chain of decentralized processing compost units would be set up in various residential societies (100 TPD of OWC and 40 TPD of waste to compost). After this is done successfully, by 2030, it would be replicated throughout the city (more than 55 TPD of OWC and 40 TPD of waste to compost will be installed).

Option 5 – Closure of Old Dumping Site, Bhatar

The MSW collected from the SMC boundary is dumped into the Khajod landfill of the SMC area. Previously, MSW collected from the SMC area used to be dumped in an open space in the Bhatar area of SMC. During the primary survey, continuous burning of MSW was observed in the old MSW dumping ground in Bhatar. This dumping area is about 0.23 sq.km in size, and the waste dumped there is estimated to be 35,45,040 MT[100]. The scientific closure of this dumping site and reclamation of this land would be necessary. The project would cover three years, with anticipated outcomes of reducing emissions from continuous landfill fires and preventing the harmful odor that affects the environment.

Eateries Sector

Option 1 – Developing Inventories of Formal and Informal Eateries for the SMC Area

There is no formal data currently available about the characteristics of formal and informal eateries in the SMC area. There is a need to develop a formal inventory of all the available eateries of the SMC area with their detailed characteristics. The proposed project creates an objectified requirement for enlisting all street vendors wherein the defined area should be wide enough to allow vendor mobility within the city. This survey will cover all eateries, including small and large/informal and formal/unorganized and organized sectors in the surveyed region. The anticipation with this project is that a list of eateries with their contact details, vending place, type of vending activities, time of engagement in their shop, belongingness to BPL/APL, and cooking technique (barbeque, grilling, frying) along with fuel type and fuel consumption would be inventorized. The detailed list will help implement and manage welfare schemes, subsidies or aid, and assistance from local authorities while serving as a knowledge base for the specific fuel usage in the SMC area specific to all eateries. The main output of the inventorization would be the regulation of the activities specific to eateries and the emissions from the sector. In the implementation part, the project will be completed within 6-12 months; SMC may engage an agency through the request for proposal or alternate survey methods, such as community participation, or with support of NGOs or govt research organizations.

---

[100] *Kulkarni, T. (n.d.). GHG Accounting and Planning approach to Solid Waste Management from the landfills in Surat City, Gujarat. https://www.researchgate.net/publication/282642291_GHG_Accounting_and_Planning_approach_to_Solid_Waste_Management_from_the_landfills_in_Surat_City_Gujarat.*

Industrial sector

Option 1 – Carrying Capacity Assessment of SMC Area's Air Shed

To effectively utilize the city boundary's natural resources, a research study could be carried out to understand the city's carrying capacity and the threshold number of industrial units in SMC area boundaries with respect to their contribution to the city's air pollution. The carrying capacity assessment will help understand how the city can accommodate different industries since an operational limit can expand industrial clusters within the city or urban development limits. The energy efficiency, circular economy, and reduction of air pollution principles will be core pillars for this assessment that will be conducted every five years in the purview of environmental impact assessment norms. The analysis can be done as a five-year project in three phases, including baseline, midterm, and end line impact assessments, wherein action research-based assessment and updates in monitoring mechanisms by the SMC and GPCB would be carried out. The final assessment at the end of the fifth year, starting from 2021, will have recommendations on updating policies and programs affecting the growth of industries within the city limits. In addition, the Gujarat Forest Department's district office can be involved in developing green patches in newly developed areas or suggesting cost-effective adaptation measures.

Option 2 – Exploring Industrial Clusters Co-Generation Potential

Setting up a flagship project such as Steamhouse Pvt Ltd has opened many gates for exploring the potential for co-generation in the SMC area. The project was established with an investment of INR 10 crore in the initial phase, and 30 industries now serve tenfold in the Sachin GIDC of SMC area. This project can create a positive impact since it is based on the circular economy principle wherein the major stakeholders would not incur losses due to venturing into the sustainable production of goods through their standard industrial processes. The co-generation plan will use the combined cycle steam for industrial production and provide a cost-effective solution wherein the industrial units' non-utilized resources can be channeled into achieving further energy efficiency and air pollution neutral targets. The proposed project will be set up as part of Padensara GIDC or Palsana GIDC, where the scope of its success is very high. The advocacy work and baseline research for involving alternative fuel options for this plant can take about five years, and from the seventh year, it will be operational. It is anticipated that the plant can be run on segregated biofuel produced from the waste processing units owned by the SMC to become a success.

ACKNOWLEDGEMENTS

We thank Ms. Hemali Boghawala (Hon. Mayor Surat City), Mr. Banchhanidhi Pani, IAS, Commissioner, Surat Municipal Corporation, Dr. Jadgdishbhai Patel (Former Mayor Surat City), and Mr. P U Dave from Gujarat Pollution Control Board Regional Office Surat for their wholehearted support to the preparation of the Surat Clean Air Action Plan.

WRI India would like to acknowledge Bloomberg Philanthropies and Shakti Sustainable Energy Foundation for supporting the Surat Clean Air Action Plan by collaborating with us in implementation and monitoring. We thank Gujarat Pollution Control Board Regional Office (Surat) and Surat Municipal Corporation for their collaboration as part of the Surat Clean Air Action Plan.

We thank South Gujarat Textiles Processors Association (SGTPA), CREDAI Surat, Surat Collectorate, Surat RTO, Surat Traffic Police, South Gujarat Industrial Association, SCET, Centre for Social Studies – VNSGU, Facile Maven Pvt Ltd, J B EcoTex Pvt Ltd, Geostone Corporation Pvt Ltd, Navsarjan Trust, Ajeevika Bureau, SVNIT, CEPT University, IUT local chapter, Surat Resilient Society, UHCRCE Surat, UHC society, and other organizations who supported the study through their valuable inputs.

We acknowledge the support and inputs of individual external experts, including Mr. R J Pandya, Dr. Ashish K Naik, Mr. E H Pathan, Mr. Jwalant Naik, Mr. Maulik Rao, Mr. Mehul Patel, Mr. Mustafa Sonasath, Ms. Aparna Choubey, Mr. Unnat Shah, Dr. Jignasa Oza, Mr. Jitendra Vakharia, Mr. Vishal Budhia, Dr. Jignesh Patel, Ms. Bhavna Vimawala, Dr. Vikas K Desai, Mr. James Regina Dabhi, Dr. Vimal Trivedi, Mr. Sandeep Narang, Ms. Rejeet Mathews, Dr. Nitika Bhakuni, Dr. Ashwani Kumar. The stakeholder consultations and other thematic reviews could not have been possible without their participation.

We also thank the participants who attended the Surat-based stakeholder consultations, namely, the Opportunity Framing Workshop in July 2019, the Construction Sector workshop in November 2019, the Municipal Solid Waste workshop in February 2020, and the Industry sector workshop in November 2020.

We also thank the internal team of WRI India, who helped in preparing this plan.

We also acknowledge the inputs of external and internal reviewers from WRI India (refer to annexure) of this plan.

This report is a part of Surat Clean Air Action Plan (SCAP) developed by WRI India, in collaboration with Gujarat Pollution Control Board (GPCB) and Surat Municipal Corporation (SMC), supported by Bloomberg Philanthropies and Shakti Sustainable Energy Foundation (SSEF).

WRI INDIA TEAM

PRINCIPAL AUTHOR AND PROJECT LEAD:

Dr. Ajay Singh Nagpure*

PROJECT TEAM:

Air Quality Team:

Dr. Vijay Anadkat, Mr. Bhavay Sharma, Mr. Zahir Shaikh, Ms. Vandana Tyagi, Mr. Sanjar Ali, Dr. Kishore Wankhade, Mr. Ritesh Patidar

Transport Team:

Mr. Vishal Ramprasad, Ms. Krithi Venkat, Mr. Chintan Daftardar

Industry Team:

Ms. Kajol, Mr. Deepak Krishnan

Project Guide:

Mr. Madhav Pai, Executive Director, Sustainable Cities, WRI India

**Corresponding author*

IMAGE CREDITS:

Front cover page: Surat Municipal Corporation
Chapter-1 title page: Surat Municipal Corporation
Chapter-1 end page: Sujan Desai (via Flickr)
Chapter-2 title page: Surat Municipal Corporation
Chapter-3 title page: Surat Municipal Corporation
Chapter-4 title page: Ricky Singh (via unsplash)
Chapter-5 title page: Surat Municipal Corporation
Chapter-5 end page: Surat Municipal Corporation
Chapter-6 title page: Kailash Giri (via Flickr)
Chapter-7 title page: Akshar Choksi (via Flickr)
Chapter-8 title page: Tina P. (via Flickr)
Chapter-9 title page: Indian Boy Ankit (via Flickr)
Chapter-9 end page: Indian Boy Ankit (via Flickr)
Chapter-10 title page: Surat Municipal Corporation
Chapter-11 title page: Nishant Deshpande (via Flickr)
Back cover page: Keku192 (via Flickr)

WRI INDIA
ROSS CENTER

MUMBAI
1st Floor, Godrej & Boyce Premises,
Gasworks Lane, Lalbaug,
Parel, Mumbai 400012
+91 22 24713591

NEW DELHI
LGF, AADI 2, Balbir Saxena Marg,
Hauz Khas, New Delhi 110016
+91 11 40550776

BENGALURU
93/2 G Towers, South End Road,
Basavanagudi, Bengaluru 560004
+91 80 26560027

www.wricitiesindia.org