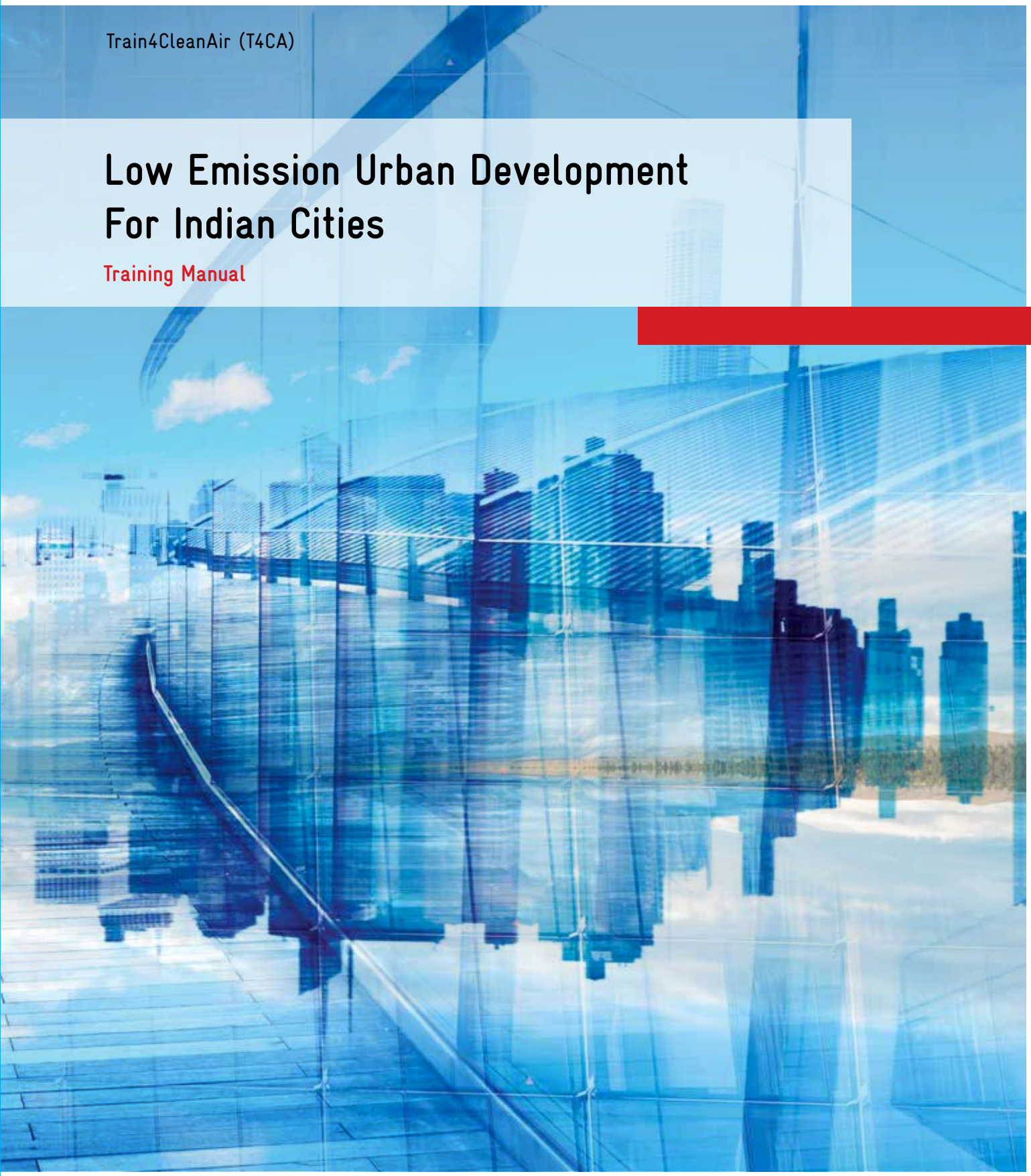
Train4CleanAir (T4CA)

Low Emission Urban Development For Indian Cities

Training Manual



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INTRODUCTION

National Clean Air Programme (NCAP), launched in 2019, is India's flagship program for better air quality. NCAP designated 122 cities as non-attainment from 21 states and 2 union territories (Chandigarh and Delhi) based on the ambient monitoring data from the network operated by Central Pollution Control Board (CPCB). As of August 2021, the number of non-attainment cities has increased to 132. NCAP in its first round of activities aims to increase the capacity of the Pollution Control Boards both CPCB and SPCBs to measure, evaluate and manage air pollution. This includes improving capacity in preparation of an information baseline for emissions and assessment of source contributions, communication strategies to maintain and disseminate information, clean technology assessments and review, management development on inspection monitoring, awareness generation and designing strategies for air pollution mitigation.

Train for Clean Air (T4CA) is a regional training approach that aims to assist cities to create and implement Clean Air Plans (CAPs) and make informed policies and decisions. It includes standardized modular training courses customized for different stakeholders – decision-makers, technical staff, researchers, NGOs, and the media. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in partnership with Clean Air Asia in 2008 developed T4CA modules for an international audience. Clean Air Asia has used these modules to conduct several trainings to build the capacity of officials and strengthening implementation and monitoring of clean air action plans of different cities of Asia.

Support to the National Clean Air Programme the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH under the Indo-German Development Cooperation and Bloomberg Philanthropies supported Clean Air Asia to develop five training manuals based on the T4CA manuals. Since the implementation of CAPs lies with the city, officials involved in the mitigation of air pollution in need of capacity development could benefit through these manuals.

This manual titled Low Emission Urban Development for Indian Cities is designed for a specific group of urban planners, architects, municipal commissioners, officials from urban management, smart cities and others whose functions encompass city planning who can facilitate air quality management in their domain and mainstream air quality in urban development.

The training manual shall support the decision-makers and strengthen their knowledge on air quality management and be able to make decisions on city development and help better air quality in India.

Table of Contents

Table of Abbreviations 6

List of Figures, Tables and Boxes 7

1 Air Pollution – Introduction And Key Concepts 9

1.1 Cities And Air Pollution 9

1.2 Defining Air Pollution 10

1.3 Types Of Air Pollution 11

1.4 Ambient Or Outdoor Air Pollution 11

1.5 Sources Of Outdoor/Ambient Air Pollution 13

1.6 Indoor Air Pollution – Sources And Cause 16

1.7 Interactions Between Outdoor And Indoor Air 17

1.8 Climate Change And Air Pollution 18

1.9 Key Messages 21

2 Mainstreaming Air Quality In Urban Development 22

2.1 Why Mainstream Air Quality In Urban Development? 22

2.2 Understanding Low Emissions Urban Development 23

2.2.1 The Green City and Low Emissions Urban Development 23

2.2.2 Important components of Green Cities 25

2.2.2.1 Urban Resilience 25

2.2.2.2 Liveability 25

2.2.2.3 Integrated Urban Development (IUD) 26

2.3 Investment Areas For Green/Low Emissions Urban Development 26

2.3.1 Green Urban Development 26

2.3.2 Investment Areas and Low Emissions Urban Development 27

2.3.2.1 Low-Emissions Mobility 27

2.3.2.2 Green and Clean Industry 27

2.3.2.3 Energy-Efficient Buildings 27

2.3.2.4 City Greening 27

2.3.2.5 Green, Resilient Infrastructure 27

2.3.2.6 Waste Management 27

2.3.2.7 Clean Cooking 28

2.3.2.8 Community Engagement 29

2.4 Need To Focus On Five Elements In Urban Operation Model In India 30

2.4.1 Funding 30

2.4.2 Planning 31

2.4.3 Sectoral Policies such as public transportation, affordable housing, and climate change mitigation 31

2.4.4 Shape 31

2.5 Key Messages 31

3 City Development And Clean Air Action Planning 32

3.1 Air Pollution And Asian Cities 32

3.2 Relevance Of Air Quality Management In Cities 33

3.3 Strategic Framework For Air Quality Management 34

3.4 Why Clean Air Action Planning? 36

3.5 What Is Clean Air Action Plan? 37

3.6 Developing A Clean Air Action Plan 38

3.6.1 Assessment 38

3.6.2 Action plan development 39

3.6.3 Implementation and enforcement 39

3.6.4 Review and improvement 39

3.7 Control Measures To Improve Air Quality 41

3.8 The Clean Air Action Planning Process 41

3.8.1 Stages of the CAAP process 41

3.8.2 Role of stakeholders 42

3.9 Sectoral Interventions In Clean Air Action Planning 43

3.9.1 Mobilizing resources 44

Table of Contents

3.9.2 Develop a communication plan 45
3.9.3 Formulate a monitoring and evaluation system 47
3.10 Integrating Clean Air Action Planning And Climate Change Mitigation Into City Development Planning 47
3.11 Clean Air Action Plans In City Development Plans 48
3.12 Key Messages 50

4 Relevance Of Air Pollution Data In Indian Cities 51
4.1 Introduction 51
4.1.1 Urban Air Pollution 51
4.2 Urban Air Data 53
4.2.1 Monitoring the pollution 55
4.2.2 Calculating/estimating air pollution 55
4.2.3 Use of mapping 55
4.2.4 Emissions inventories 56
4.3 Key Messages 56

5 Health Impacts Of Air Pollution 57
5.1 Introduction 57
5.1.1 What is air pollution and how does it occur? 58
5.2 Effects Of Air Pollution On Human Health And Ecosystems 59
5.2.1 Effects on human health 59
5.2.2 Estimates of burden of disease due to air pollution globally and in India 62
5.2.3 Emerging evidence linking poor air quality to COVID-19 64
5.2.4 Effects on the ecosystem 65
5.2.4.1 Greenhouse Effect 65
5.2.4.2 Ozone Depletion 66
5.3 Minimizing Exposure To Air Pollution – Outdoor And Indoor 67
5.3.1 Facemasks 68
5.3.2 Shift from motorized to active transport whenever possible 68
5.3.3 Monitor air pollution levels 68
5.3.4 Cleaner cooking fuels 69
5.3.5 Improved ventilation 69
5.3.6 Use portable air cleaners as an indoor environmental intervention 69
5.4 Key Messages 70

6 The Regulatory Framework For Air Pollution In Indian Cities 71
6.1 Need For Mainstreaming Air Quality 71
6.2 Policies And Standards For Air Pollution 72
6.3 Available Air Quality Measurement Data In India 73
6.3.1 Policy regulation framework for air quality monitoring system in India 73
6.3.1.1 National Clean Air Programme 76
6.3.1.2 National Ambient Air Quality Standard (NAAQS) 77
6.3.1.3 National Air Quality Index 79
6.3.1.4 National Air Monitoring Programme (NAMP) 80
6.4 Current Policies Towards Air Pollution 80
6.5 Involvement Of Stakeholders 80
6.6 Key Messages 82

7 Urban Governance And Its Relevance To Air Quality Management In India 83
7.1 Urban Governance 83
7.2 Urban Agglomeration 86
7.3 Urban Policy 86
7.3.1 Urban policy framework in India 88
7.3.2 Urban development policies: A review 88
7.4 Smart Cities And Air Quality Monitoring 91
7.5 Relevance Of Urban Governance From The Perspective Of AQM In India 92
7.6 Key Messages 93

Table of Abbreviations

AAP	Ambient Air Pollution
AQ	Air Quality
AQM	Air Quality Management
B(a)P	Benzo (a) Pyrene
CCAC	Climate and Clean Air Coalition
CAAQMS	Continuous Ambient Air Quality Monitoring
CEMS	Continuous Emission Monitoring System
CEQMS	Continuous Effluent Quality Monitoring System
CFCs	Chlorofluorocarbons
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
GBD	Global Burden of Disease
GHG	Green House Gases
HAP	Household Air Pollution
HCP	Health Care Provider
IAP	Indoor Air Pollution
IARC	International Agency for Research on Cancer
IEA	International Energy Agency
LEUD	Low Emission Urban Development
LPG	Liquid Petroleum Gas
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MSW	Municipal Solid Waste
MT	Metric Tonnes
Ni	Nickel
NO	Nitrous Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxide
O_3	Ozone
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PCC	Pollution Control Committee
PM	Particulate Matter
PPP	Public Private Partnership
SLCP	Short-lived Climate Pollutant
SO_2	Sulfur Dioxide
SO_X	Sulfur Oxide
SPCB	State Pollution Control Board
UK	United Kingdom
ULBs	Urban Local Bodies
UN	United Nations
UNEP	United Nation Environment Programme
USEPA	United States Environment Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization
WMO	World Meteorological Organisation

List of Tables, Figures and Boxes

Table 1:	Six (6) Criteria Pollutants	12
Table 2:	Recommended Components of Clean Air Action Plan	40
Table 3:	AQM stakeholders and recommended roles in Clean Air Action Planning Process	42
Table 4:	Recommended implementation timeline for each sector	44
Table 5:	Examples of measures to reduce emissions of air pollutants and GHGs	48
Table 6:	Sources, health, and welfare effect for criteria pollutants	61
Table 7:	Health impact of air pollutants	62
Table 8:	Different Air Quality Standards	78

Figure 1:	Air Pollution from emissions to exposure	11
Figure 2:	Sources of air pollutant emissions	14
Figure 3:	Link between air pollution and climate change	19
Figure 4:	Greenhouse Effect	20
Figure 5:	Short-Lived Climate Pollutants	20
Figure 6:	Components of Green Cities	26
Figure 7:	Combination options for cleaner cooking technologies and affordable cooking fuel	29
Figure 8:	Five Elements for India's operating model	30
Figure 9:	City Development and Air Pollution	33
Figure 10:	Air Quality Management Framework	35
Figure 11:	Simplified Framework for Clean Air Action Planning	36
Figure 12:	Venn diagram for air pollutants, GHGs, and SLCPs	47
Figure 13:	Overall Structure of the Clean Air Scorecard	53
Figure 14:	Layers of Atmosphere	58
Figure 15:	Sources of Air Pollution	58
Figure 16:	Air Pollution and Health	59
Figure 17:	Reduced Visibility (Image by Rahmad Gunawan)	60
Figure 18:	Greenhouse Effect	65
Figure 19:	Ozone hole over Antarctica	66
Figure 20:	Key elements in mitigating air pollution exposure and protecting respiratory health	67
Figure 21:	Solutions for reducing air pollution	70
Figure 22:	Policies Adopted for Air Mitigation (A)	74
Figure 23:	Policies adopted for Air Mitigation (B)	74
Figure 24:	Air Quality Regulations in India	75
Figure 25:	Overview of the National Clean Air Programme	76
Figure 26:	Air Quality Index	79
Figure 27:	Main characteristics of Urban Local Governments	85
Figure 28:	Number of UAs/Town and Out Growths (OGs)	86
Figure 29:	Climate Smart Cities Framework	90

Box 1:	AQM Toolbox, UN Habitat, UNEP	10
Box 2:	Tackling human-made Pollutants: Case Study of United Kingdom	16
Box 3:	Case study particulate matter – 'Ready to Burn'	18
Box 4:	Case Study: The Rio de Janeiro Low Carbon City Development Program	24
Box 5:	The economic and social benefits of low-emission cities	31
Box 6:	Beijing's Heightened Air Pollution Control Efforts	34
Box 7:	Roles and Responsibilities of Key Stakeholders in AQM	35
Box 8:	Air Quality Management in Thailand	36
Box 9:	Nepal combating its way through air pollution	38
Box 10:	National Clean Air Programme	39
Box 11:	Guidance Framework for Better Air Quality	42
Box 12:	Conformity between Transport and Air Quality Management Planning in the United States: A Case of Planning Coordination	44
Box 13:	Ahmedabad Heat Action Plan	46
Box 14:	Cleaner Air for Scotland: The Road to a Healthier Future	49
Box 15:	Air Quality Management in Oxford	50
Box 16:	Clean Air Scorecard Tool	52
Box 17:	Air Quality Model Classification	54
Box 18:	CAST Assessment of Air Quality in Indian Cities	54
Box 19:	National Action Plan on Climate Change (NAPCC)	77
Box 20:	Types of Stakeholders	81
Box 21:	Lessons for Improved Urban Management	87
Box 22:	What is 'Urban' in India?	87

Low Emission Urban Development For Indian Cities

Learning Objectives

Goal

This manual enables participants to develop their understanding of urban development, urban planning and co-relate the two areas with air quality. It outlines the key components required for a city planning that can promote low emissions development and help in reducing urban air pollution. By working through this manual, participants will achieve a higher level of understanding of impact of urban development on air pollution, need for urban planning to integrate clean air action and its intersection with urban development planning strategies.

Target Audience

The manual is aimed to improve understanding on air pollution control and air quality management of urban planners, city officials, architects, municipal commissioners, officials from urban management, smart city leaders and other key decision makers who are involved in city planning.

Contents of the Manual

In the manual, *Low Emission Urban Development for Indian Cities*, participants will examine the role of urban planning in reducing air pollution.

The manual contents include:
- Information on key air pollutants
- The need, methods and processes for data generation that can be integrated in urban development/planning strategies
- Basic air pollution monitoring methods
- Health impact of air pollution and the need for air pollution management in cities
- Opportunities and best practices for integrating air quality management in urban and city planning

Objectives of the Manual

The manual can be used to support training around Low Emission Urban Development for Indian Cities. *With the help of this manual participants can*
- Describe the impact of urban development on air pollution and co-relate city and urban planning with better air quality management needs
- Understand the current status of air quality in Indian cities and the contributions from different sectors
- Know about clean air action planning and co-relating it to city development planning
- Design and develop strategies for urban planning, design and policy that will mainstream clean air.

1. Air Pollution – Introduction And Key Concepts

1.1 Cities and Air Pollution

Air pollution is a serious, current and global concern. Before the rapid development pace set in, the main sources of air pollution were from natural processes such as ocean waves, volcanic eruptions and wildfires. Nowadays, the rising pollution levels are very much human made and a serious cause of concern. A study of 465 Asian cities was published by Clean Air Asia in 2013. Since then it has been revealed that air pollution in many of these cities has become worse compared to World Health Organization (WHO) standards and only 35 percent meet the interim AQ standards as put forward by the WHO.

Most of these cities are at a stage of swift development with increasing energy needs, rising transport requirements, with unplanned and rapid urban development. Air pollution today is of major concern due to its widespread nature, damage to our environment and major health risk to humans.[1]

Currently, in India, air pollution is the second largest risk factor contributing to the countries burden of disease[2]. Air pollution affects each citizen as it increases the mortality and morbidity rate of a country, with corresponding social and economic effects. It also contributes to climate change.

1 Dennis Y. Leung, Outdoor - Indoor Air Pollution in Urban Environment: Challenges and Opportunity, Frontiers in Environmental Sciences, January 2015 https://www.researchgate.net/publication/272390698_Outdoor and indoor_air_pollution_in_urban_environment_Challenges_and_opportunity

2 Aparna Roy, Tanushree Chandra and Aditi Ratho “Finding Solutions to Air Pollution in India: The Role of Policy, Finance, and Communities,” ORF Special Report No. 120, September 2020, Observer Research Foundation.

Box 1: AQM Toolbox, UN Habitat, UNEP

Air is an important environmental resource. Air is a part of Earth's atmosphere, and one of its most important natural resources. Air is shared and used by all – humans, animals, and plants - to sustain life. Near major industrial centres and in big cities, often the air is of unsatisfactory quality. Air quality degradation is not new – since the middle of the 19th century, the atmosphere of the major British cities was regularly polluted by coal smoke in winter, giving rise to an infamous mixture of fog and smoke known as smog. Today the emphasis has shifted from the pollution problems caused by industry to the ones associated with motor vehicle emissions. Also, some methods of waste disposal release air pollutants and greenhouse gases into the atmosphere. The deterioration of air quality caused by these different activity sectors is affecting human health and ecosystems. All contributors to pollution (i.e., industries, transport companies, companies involved in waste disposal or deforestation activities, individual motorists, individual tree felling, as well as individual burning of wastes) ought to coordinate efforts so that the resource 'air' is further available in good quality to all its users. Air quality management, therefore, is resource management.

1.2 Defining Air Pollution

Pristine air is a mixture of various gases such as oxygen, nitrogen, argon, carbon dioxide and small amounts of other gases in a fixed proportion. When the composition of these gases becomes altered through addition of non-natural components it becomes polluted. Therefore, in simple terms air pollution is the contamination of the air we breathe with harmful substances.

Air pollution is a mixture of chemical components, including fine particulate matter that is less than 2.5 micron in diameter ($PM_{2.5}$), coarse particulate matter that is less than 10 microns in diameter (PM_{10}), ozone (O_3), sulfur oxides (SO_X), nitrogen oxides (NO_X), and other chemicals. These chemicals are associated with a variety of deleterious health effects, and have been regulated over decades in India and elsewhere in the world.

The effects of air pollutants on humans depends on their toxicity, concentration and exposure time and may vary from person to person depending on their specific susceptibility. Typically, the young and old, and those with pre-existing medical conditions are most susceptible.

When emissions of these air pollutants exceed the capacity of natural processes to convert or disperse them, their concentrations build and they can cause damage to human health and the environment[3]. The combustion of fossil fuels (coal, oil, and gas), changes in land use and industrial activities all produce air pollutants.

3 EEA (2003) EEA Signals 2003. European Environment Agency, Copenhagen, Denmark

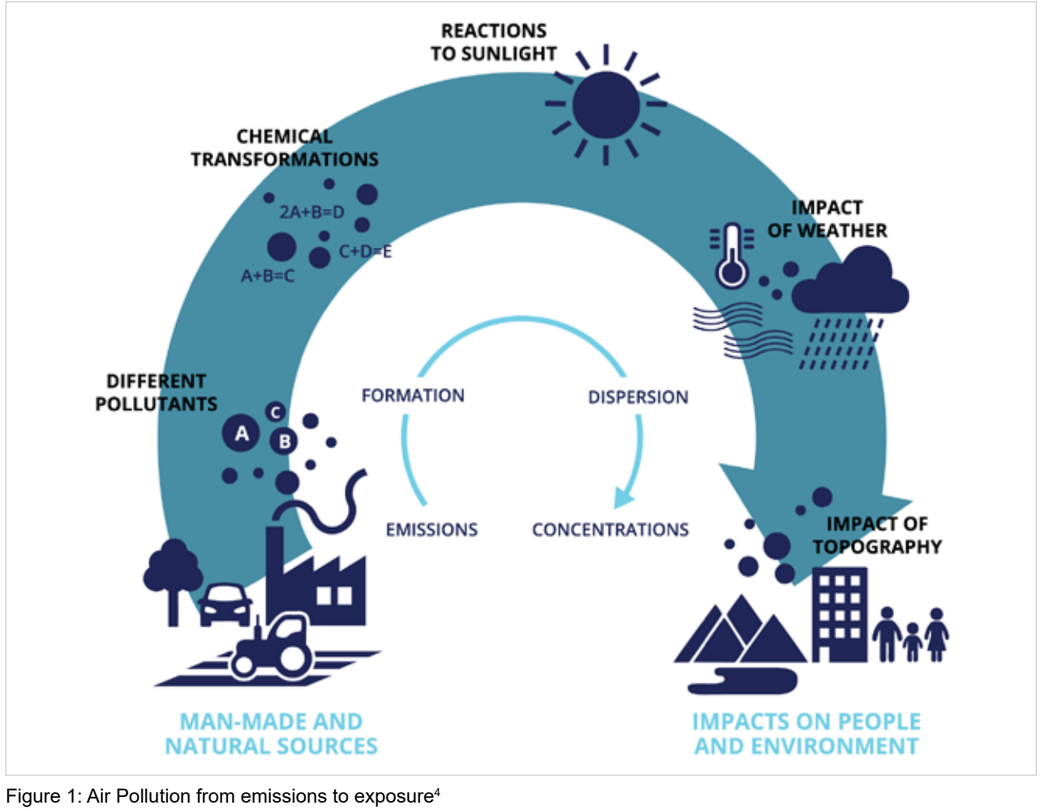

Figure 1: Air Pollution from emissions to exposure[4]

1.3 Types Of Air Pollution

Air pollution is typically discussed in terms of Household Air Pollution (HAP) or Indoor Air Pollution (IAP) that originates in the household (e.g., from cooking, heating, and lighting) and Ambient Air Pollution (AAP) that is external to buildings. AAP can result from both human-made sources (e.g., electricity generation, vehicles, agricultural fires) and natural processes (e.g., natural forest fires, wind-blown dust). HAP can also be a substantial contributor to ambient air pollution in places where burning of wood, garbage, solid fuels or kerosene use for household energy is widespread[5]. Likewise outdoor AAP can transfer indoors to become HAP.

1.4 Ambient Or Outdoor Air Pollution

Outdoor or Ambient air pollution is a complex mixture of pollutants that originate through natural and anthropogenic sources such as on road and off-road dust including transformation, power generation, industrial activities, biomass and crop burning and domestic heating and cooking. The mix of pollutants in outdoor air varies widely in space and time, reflecting the diversity of sources that influence the atmospheric process[6]. The commonly measured outdoor air pollutants are Particulate Matters ($PM_{2.5}$ and PM_{10}), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Lead (Pb), Ozone (O_3), volatile metals, and other volatile organic compounds (VOCs)[7].

4 EEA (2003) ibid

5 Dennis Y. Leung, Outdoor - Indoor Air Pollution in Urban Environment: Challenges and Opportunity, Frontiers in Environmental Sciences, January 2015 https://www.researchgate.net/publication/272390698_Outdoor and indoor_air_pollution_in_urban_environment_Challenges_and_opportunity

6 Global Burden of Disease (GBD) 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioral, environmental, and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018; 392:1923-1994.

7 Outdoor Air Pollution, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 109, International Agency for Research on Cancer, 2016

In 2017, 4.1 billion people were living in urban areas. This means over half of the world (55%) resides in cities or other urban areas[8]. Urban air quality is highly affected by city planning and design[9]. Poor urban design, for example, densely distributed and deep streets canyons, and narrow streets can block and weaken the approaching winds, thus reducing air dispersion capabilities. On the other hand, good urban design can disperse the air pollutant and alleviate the problem of air pollution accumulation[10].

It can also help reduce the requirement of pollutant generating activities, for example, more walkable cities require less motorization.

There are many air pollutants with some more common than others. Typically, the six most important air pollutants are referred to as criteria pollutants and are: O_3, PM, CO, NO_2, SO_2 and Pb. A detailed description of each of these criteria pollutants is provided in Table 1.

Table 1: Six (6) Criteria Pollutants[11]

Ozone (O_3)	• Created by chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in sunlight. It is the main component of the photochemical smog formed in the atmosphere. • Major sources of NO_x and VOC include: emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents. • Ground level ozone is a toxic air pollutant, different from stratospheric ozone, which protects the Earth from harmful ultraviolet radiation.
Particulate Matter (PM)	• Also known as particle pollution, it is made up of a mixture of solid particles and liquid droplets found in the air. • Common examples are: dust, dirt, soot, or smoke that are large or dark enough to be seen with the naked eye. Others, however, can only be detected through an electron microscope. • It is generated from a wide variety of natural processes, such as dust storms, oceans/seas (sea salt), fugitive dust erosion by the wind, forest fires, volcanic eruptions, and release of biogenic PM (e.g., plant wax) and anthropogenic sources: traffic, non-combustion and combustion industrial processes, power plants, construction activities, agricultural activities (including agricultural waste burning). • PM includes black carbon, metal oxides, sulfates, nitrates, and other chemicals.
Carbon Monoxide (CO)	• A colorless, odourless gas emitted from combustion processes. • Mobile sources are the main source of CO emissions in the urban areas; open fires are another source that may be more significant in local areas.
Nitrogen Dioxide (NO_2)	• One of a group of highly reactive gases known as nitrogen oxides (NO_x), which include nitrous acid and nitric acid. • Forms rapidly from emissions from cars, trucks and buses, power plants, and off-road equipment.
Sulfur Dioxide (SO_2)	• It is an acidic gaseous pollutant that can affect human health, associated with increased daily mortality and hospital admissions from respiratory and cardiovascular disease. • Fossil fuel combustion in power plants and other industrial facilities are the main sources of SO_2 emissions; other sources include: industrial processes such as extracting metal from ore, burning of high sulfur fuels by locomotives, large ships, and non-road equipment.
Lead (Pb)	• Motor vehicles have been known to be the major contributor of lead emissions in the air. A multi-stakeholder initiative, the Partnership for Clean Fuels and Vehicles (PCFV) at the global level was established 10 years ago to phase-out the use of lead-based additives in gasoline and to address its adverse health impacts. • Afghanistan, Myanmar, and North Korea are the three remaining countries that have yet to ban lead in gasoline (Rono and Fabian, 2014).

8 Hannah Ritchie and Max Roser, Urbanisation, Number of people living in urban areas, (last revised 2019), accessed on 24th May 2021, Our World in Data
9 Hewitt, C.N., Ashworth, K. & McKenzie, A.R. Using green infrastructure to improve urban air quality (GI4AQ). Ambio 49, 62–73 (2020).
10 Dennis Y. Leung, Outdoor - Indoor Air Pollution in Urban Environment: Challenges and Opportunity, Frontiers in Environmental Sciences, January 2015
11 USEPA, Criteria Air Pollutants, accessed on 25th May 2021; Stockholm Environment Institute, 2008.

1.5 Sources Of Outdoor / Ambient Air Pollution

We typically discuss air pollution emissions in terms of anthropogenic sources, but natural sources also play a significant role in generating air pollution. For example, wildland fires lead to emissions of CO, NO, toxic organic gases and Particulate Matter[12]. Volcanoes emit sulfur oxide (SO_x), mercury and other metals. Wind raises dust. Many plant species emit organic gases. Microbial activities lead to emission of NO_x and Ammonia as well as bio-aerosols. Biogenically emitted VOCs and NO_x react to form Ozone and organic PM.

Major sources of air pollution in India include coal fired power stations, industry, construction activity, brick kilns, transport vehicles, road dust, residential and commercial biomass burning, waste burning, agricultural stubble burning, and diesel generators. These sources of air pollution vary spatially throughout the country with differences between the urban and rural. Hence, the concentration of the outdoor air pollutants varies across India, depending on sources and meteorology.

Air pollution emissions can be identified based on their source:

- Stationary (point) sources such as major industrial sites
- Area (non-point) sources such as domestic emissions and emissions from light industry and commercial areas
- Mobile (line) sources such as motor vehicles
- Natural (biogenic) sources such as dust storms, forest fires, and volcanic eruptions

Stationary Sources

A stationary source is a fixed-site emitter of pollution which usually involves industrial combustion processes. Emissions may be from large or small sources or several single sources over a small area (e.g., several smokestacks in a copper smelter). Emissions may also be released from material transfers, equipment leaks, stacks, or vents. Point source emissions can be further divided into various sub-categories, depending on the industrial process such as fugitive emissions, process emissions, combustion emissions, various solvent usage emissions, and storage tank emissions.

In India, coal use is a key component of the energy system, accounting for two thirds of electricity generation and a quarter within industries. The efficiency and environmental performance of the coal sector is critical to reducing stationary air pollution emissions such as SO_x, PM, and NO_x[13].

12 Outdoor Air Pollution, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 109. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Lyon (FR): International Agency for Research on Cancer; 2016
13 International Energy Agency (IEA) (2020)) India's Energy Policy: key findings of the IEA in-depth Review 2020 Paris, France

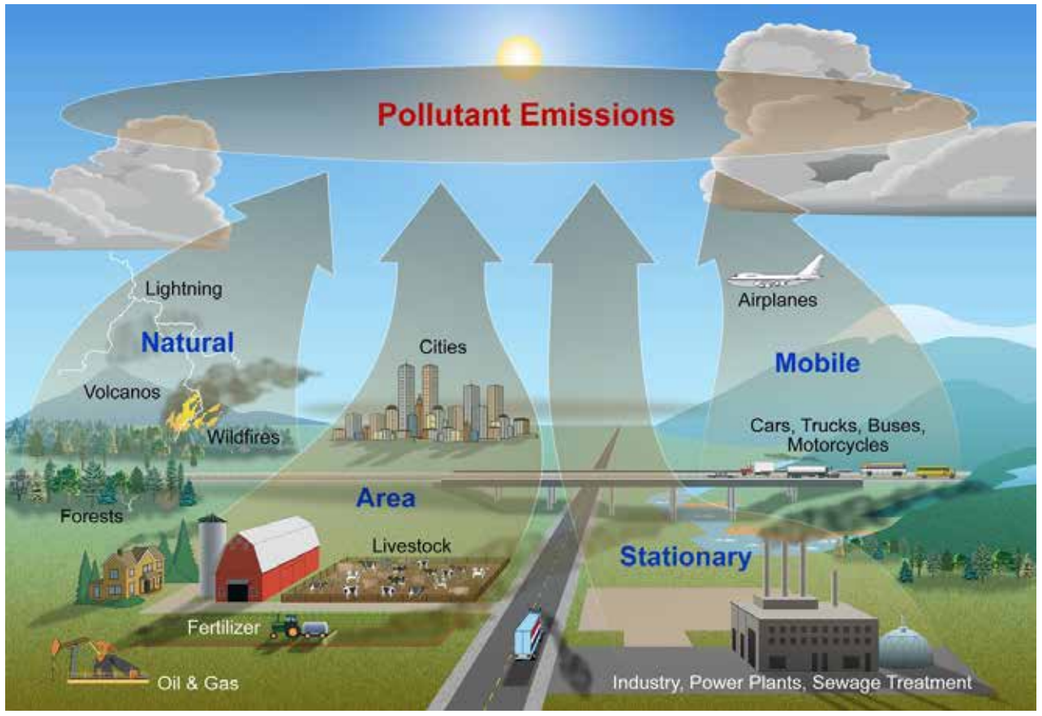

Figure 2: Sources of air pollutant emissions[14]

Area Sources
Area sources refer to any source of air pollution emitted over an area, which cannot be classified as a point source. Area sources can be a large number of similar small stack point sources (e.g., household emissions) which can be difficult to estimate individually. Area sources include emissions from household activities such as cooking, space- and water- heating, and kerosene used for lighting. Relatively small amounts of coal are used in households nationally in India and in recent years the use of kerosene for cooking has declined. This is mostly attributed to the Government of India's Ujjwala LPG distribution programme.

Other area sources include small business activities, agricultural residue burning, waste combustion, fugitive dust from deposits and roads, forest fires, small activities from gasoline service stations, small paint shops, consumer use of solvents and biogenic (natural) sources. Waste deposits can also be a large area source of emissions, rotting of food and other decaying organic waste allows methane and CO_2 to seep out of the ground and up into the air. Methane is a potent greenhouse gas and can itself be a danger because of its flammable nature. CO_2 is the most widely produced greenhouse gas. On its own, CO_2 is not considered harmful to human health, unless it is found in very high concentrations. But it does contribute to climate change by trapping heat in the atmosphere.[15]

In India, large cities are often surrounded by agricultural land. The open burning of agricultural waste contributes directly to urban air pollution. In poorer cities, backyard burning of refuse (garbage and biomass) is another source of air pollution. Open street cooking is also a source of air pollution in many urban areas. The absence of properly monitored urban waste management facilities in urban cities allows for unchecked activities like garbage burning which is being recognized as a significant source of air pollution.

14 Where does Air Pollution come from?
15 Maheep Kumar and Vijay Prakash (2020), "A review on Solid Waste: Its Impact on Air and Water Quality", journal of Pollution Effects and Control.

Diffuse sources are sources that are not clearly delimited such as open windows, gates, doors, tube connections and flanges in a plant. Emissions from diffuse sources also include evaporative emissions from motor vehicles and non-road mobile sources (e.g., hot soak emissions, running and diurnal losses) and emissions from areas with light industry, domestic and wood burning as well as emissions from natural sources. Diffuse pollution can be caused by a variety of activities that have no specific point of discharge. Agriculture is a key source of diffuse pollution, but urban land, forestry, and rural dwellings can also be important sources.[16]

The combined impact of area sources can be significant but difficult to quantify given the challenge of collecting data for each individual source. Since area sources can be difficult and time-intensive to inventories, various screening techniques are often used to estimate their emissions.

Mobile Sources
Mobile sources refer to road and non-road vehicles, ships, and aircraft. Emissions from vehicles can be distributed over a large urban area and are normally close to residential areas. In addition, the tail-pipe emissions are more likely to be close to the level of the individual (e.g., breathing zone of children); therefore, exposure and impact of vehicle source emissions on human health may be higher than from stationary sources with elevated emission outlets.

Mobile road sources include all vehicles which move on roads. On-road sources include passenger cars; light duty vehicles; heavy duty vehicles; urban buses and coaches; and two- and three-wheelers[17].

Non-road sources include a large number of different emission sources such as construction machines and equipment, tractors, lawn mowers, oil field equipment, boats, ships, aircraft, etc. Emissions from these sources are similar to those from road vehicles but difficult to estimate due to the fact that for most of the categories, no registration and activity rates are available.

Ships and aircraft Emissions are usually found in the vicinity of their functioning areas, like the harbors, shipping routes close to ports, airports and the runways (emissions are generated due to activities of landing, taxiing and taking off while on the runway).

The main pollutant categories associated with motorized vehicles are hydrocarbons[18] which contain a number of different HC species including carcinogenic substances such as benzene and PAH. Other pollutants emitted from motor vehicles include PM, NO_X, CO, and NH_3.

Natural Sources
Many pollutants are emitted into the atmosphere from naturally occurring sources, such as SO_2 from volcanic eruption. Volcanic eruptions generate gaseous, liquid, or solid products that also deteriorate air quality.

Other natural sources of air pollution include sand and dust storms, volcanic activity, and forest fires (e.g., caused by lightening). However, human activity can also contribute to these natural sources through activities like deforestation which removes the vegetation that holds the soil together and reduces suspension of the dust.

Sand and dust storms occur during dry periods. They are a meteorological hazard, which are related to the process of wind erosion of the surface soil and the mineral dust aerosol emission to the atmosphere.[19]

Although the contribution of natural sources to air pollution is widely recognized, a precise assessment is difficult, this is due to the uncertainties that exist in the emission, reactivity, transport, and deposition of biogenic compounds in the atmosphere, and the ability of mathematical models to describe these processes.

16 European Environment Agency (2020), Diffuse Sources, accessed on 24th May, 2021
17 Different vehicles have different emissions dependent on size, age and class of engine and type of fuel used
18 The major pollutants released as vehicle/fuel emissions are, carbon monoxide (CO), nitrogen oxides (NO_x), photochemical oxidants, air toxics, namely benzene (C_6H_6), aldehydes, 1,3 butadiene (C_4H_6), lead (Pb), particulate matter (PM), hydrocarbon (HC), oxides of sulphur (SO_2) and polycyclic aromatic hydrocarbons (PAHs). While the predominant pollutants in petrol/gasoline driven vehicles are hydrocarbons and carbon monoxide, the predominant pollutants from the diesel-based vehicles are Oxides of nitrogen and particulates
19 WMO (2019) WMO Airborne dust bulletin. World Meteorological Organization, Geneva, Switzerland

Box 2: Tackling human-made Pollutants: *Case Study of United Kingdom*

Human activity results in a range of pollution emissions to air and we are continuing to tackle these emissions as new evidence emerges. Heavy metals accumulate in the environment, especially in lake and marine sediments, and are toxic to many species at low concentrations. Airborne lead (Pb) emissions have decreased by 98% since 1990, achieved mainly by phasing out the widespread use of leaded petrol. Work is continuing to reduce other pollutants as well. Levels of airborne nickel (Ni) can exceed health-based standards in some parts of the UK, particularly in the vicinity of steel processing plants.

The UK Government is working with the regulators and industries to ensure emissions are lowered so that these standards are not exceeded. Polycyclic aromatic hydrocarbons (PAH) are toxic, persistent and accumulate through food chains, where they can affect animal reproduction, development and immune systems. PAHs are released into the air by the incomplete burning of fuels, particularly solid fuels such as wood and coal. One specific PAH, benzo[a]pyrene (BaP) is a common component of combustion products and is a known carcinogen. Regulation has helped to decrease emissions of PAHs by 98% since 1990. However, the use of wood as a domestic fuel has increased markedly over the last 20 years, and is calculated to produce 78% of total national BaP emissions.

Source: Department of Environment, Food and Rural Affairs (2019), Clean Air Strategy, Government of United Kingdom.

1.6 Indoor Air Pollution – Sources And Cause

A number of air pollutants have been recognized to have significant concentrations indoors including NO_X, SO_2, O_3, CO, PM and volatile organic compound (VOCs) and bio-aerosols[20]. Some of these pollutants e.g., NO_X, SO_2, O_3, and PM are common in both indoor and outdoor environment. Some indoor sources originate from outdoor sources, and vice-versa. The indoor sources can contribute to the outdoor sources through ventilation. These air pollutants can be inorganic, organic, or biological in composition.

Many studies conducted on the impact of Indoor Air Pollution (IAP) give strong evidence of their harmful human health effects.

Indoor air pollutants can be grouped into four categories:

1. Combustion contaminants comprising of a large group of gaseous and particulate pollutants that may be emitted from all types of combustion. The composition and magnitude of the combustion emissions depend on the combustion efficiency and the temperature of combustion. Smoke from combustion processes may contain thousands of substances, many of which can damage human health.

2. Volatile organic compounds (VOC) may be emitted to indoor air from many sources. These include building materials, household products and paints, or from contaminated soil.

3. Biological agents (bioaerosols) include mildew, molds, fungi, or bacteria. Furthermore, biological allergens such as dust mites may cause an allergic reaction in vulnerable people.

4. Other contaminants are specific groups of chemicals such as pesticides or asbestos.

On a global scale, indoor air pollution is responsible for the premature death of 3.8 million people due to exposure to household air pollution from inefficient cooking practices using polluting stoves together with solid fuels and kerosene.[21]

Within India, about 64% of the population still uses solid fuels, biomass, and coal[22]. This issue is predominant in the rural household for which the contributing factor is poverty, and due to this socio-economic gap, it stands as a barrier to shift from solid fuels, biomass and coal to a cleaner fuel.

20 EEA (2003) EEA Signals 2003. European Environment Agency, Copenhagen, Denmark
21 World Health Organisation (2018), Household air pollution and health, accessed on 24th May 2021
22 Beluah Sarah James, Ranjitha S. Shetty, Asha Kamath and Avinash Shetty, (2020) "Household cooking fuel use and its health effects among rural women in Southern India – A cross-sectional study", Plos One

Smoke from biomass fuels and coal contains a range of health-damaging pollutants including $PM_{2.5}$ that penetrate deep into the lungs. In poorly ventilated dwellings, indoor smoke can be a hundred times higher than acceptable levels for small particles, which are set for outdoor air. Exposure is particularly high among women and children in rural areas, who spend more time indoors[23].

Although household air pollution is common it is also preventable. Replacement of solid cooking fuels with clean fuels such as liquid petroleum gas (LPG) gas was exemplified by the Pradhan Mantri Ujjwala Yojana, which intended to provide 80 million who are 'below poverty level' households with LPG by 2019.

Many studies[24,25] indicate that indoor air pollution and air quality are highly related to indoor activities such as smoking, cleaning, and conducting combustion process such as cooking and the use of fireplaces. For example, it has been shown that cooking related activities could increase the PM during the process and elevate the indoor particle number concentration by 1.5 to 27 times[26].

1.7 Interactions Between Outdoor And Indoor Air

Indoor air contaminants can originate within buildings or can be drawn in from outdoors. Many studies including various WHO reports indicate that indoor air quality is affected by outdoor air. Some outdoor sources that have been shown to have an impact on indoor air quality are as follows[27]:

- Contaminated outdoor air – pollen, dust, fungal spores, industrial pollutants.
- Emissions from nearby sources – exhaust from vehicles on nearby roads, or in parking lots, or garages, loading docks, odors from dumpsters, re-entrained exhaust from the building itself or from neighboring buildings.
- Gas emitted from the ground – including Radon which is radioactive, and contaminants from previous uses of the sites, for example methane from landfills, and pesticides from farmland.
- Moisture or standing water promoting excess microbial growth – rooftops after rainfall, crawlspace.

An example of the interactions between outdoor and indoor air, was shown by the similarities in concentration profiles of $PM_{2.5}$ and PM_{10} in both indoor and outdoor air measured in Birmingham, UK. The interpretation for the relationship between indoor and outdoor environments was the extraction of outdoor air from their buildings' natural ventilation systems[28]. The observed similarities in the chemical composition of the indoor and outdoor PM, proved that outdoor sources such as sulfate particles penetrate from outdoors into indoor environments. Another example from Korea, suggested that majority of VOCs measured in both indoor and outdoor environments were derived from the outdoor sources[29].

23 Dennis Y. Leung, Outdoor - Indoor Air Pollution in Urban Environment: Challenges and Opportunity, Frontiers in Environmental Sciences, January 2015
24 Taisto Raunemaa, Markku Kulmala, Helena Saari, Markus Olin & Marita H. Kulmala (1989) Indoor Air Aerosol Model: Transport Indoors and Deposition of Fine and Coarse Particles, Aerosol Science and Technology, 11:1, 11-25
25 Li, Xian-Xiang & Liu, Chun-Ho & Leung, Dennis. (2009). Numerical investigation of pollutant transport characteristics inside deep urban street canyons. Atmospheric Environment. 43. 2410-2418. 10.1016/j.atmosenv.2009.02.022.
26 He Congrong, Lidia Moraswka, Jane Loveday and Dale Gilbert, Contribution Indoor Source to Particulate Number and Mass Concentration in Residential Houses, 2004 Atmospheric Environment Volume 38, Issue 21, 3405 – 3415
27 United States Environment Protection Agency, Factors affecting Indoor Air Quality, accessed on 24th May 2021
28 N. C. Jonas, C. A. Thornton, D. Mark, and Roy M. Harrison (2000) Indoor / outdoor relationship of particulate matters in domestic homes with roadside urban and rural location.
29 Baek, Sung-Ok, Kim, Yoon-Shin, Perry, Roger, Indoor air quality in homes, offices and restaurants in Korean urban areas—indoor/outdoor relationships, 1997, Atmospheric Environment, Volume 31, Issue 4, p. 529-544.

Box 3: Case study particulate matter - '*Ready to Burn'*

In United Kingdom the PM emissions have been the centre of debates, which has a significant impact on human health. It is widely recognised that domestic wood burning is the primary single contributor, accounting for 34% of $PM_{2.5}$ emissions in 2016. Defra held a meeting with fuel industry representatives in January 2017 to discuss and identify ways to reduce emissions from wood fuel. This led to the wood fuel industry launching the 'Ready to Burn' scheme in September 2017.

The aim of the scheme was to raise consumer awareness and educate wood-burning stove owners about the importance of burning clean, dry, quality logs to help reduce air pollution. The scheme sets a benchmark for logs and other wood fuels in the UK to help consumers to identify wood that has been carefully chosen and is 'Ready to Burn' for the benefit of their appliance and the environment.

The initiative is being led by Woodsure, UK's only wood fuel quality assurance scheme, and supported by Defra. Suppliers signing up to the scheme provide a guarantee that the fuel they sell as 'Ready to Burn' has a moisture content of 20% or less, meaning that it can be burned without the need for further drying out. To date, over 50 UK suppliers have signed up to the scheme including UK's largest suppliers of wood fuel alongside small and medium fuel producers.

Source: Department of Environment, Food and Rural Affairs (2019), Clean Air Strategy, Government of United Kingdom.

1.8 Climate Change And Air Pollution

Climate Change is one of the greatest global challenges we face today with its effects and consequences becoming ever more evident. Global warming is one consequence of climate change. Other consequences include increased variability in the weather with the likelihood of extreme weather events increasing. The Earth's surface temperature has increased by approximately 0.74°C since 1906.[30] Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052, if emissions continue to increase at the current rate.[31]

The earth's climate is fuelled by the sun. The absorption of a fraction of the sun's energy in the earth's atmosphere keeps our planet warm enough for life. This absorption of energy by the atmosphere by naturally emitted greenhouse gases (GHGs) is known as the natural 'greenhouse effect'. Without the natural greenhouse effect, the earth's average temperature would be much colder, and the planet would be uninhabitable.

However, as emissions of anthropogenic greenhouse gases increase, an imbalance in the gaseous composition on the air occurs with GHGs increasing in concentration. This has led to an increase in the temperature on the earth and this temperature increase is known as global warming. This has resulted in the melting of glaciers and an increase in sea level. The key GHGs are carbon dioxide, methane, nitrous oxide, fluorinated compounds, and ozone. The greenhouse effect is illustrated in Figure 4.

30 Intergovernmental Panel on Climate Change (2007), Climate Change 2007: Synthesis Report
31 Intergovernmental Panel on Climate Change (2019), Special Report: Global Warming of 1.5°C, Summary for Policymakers

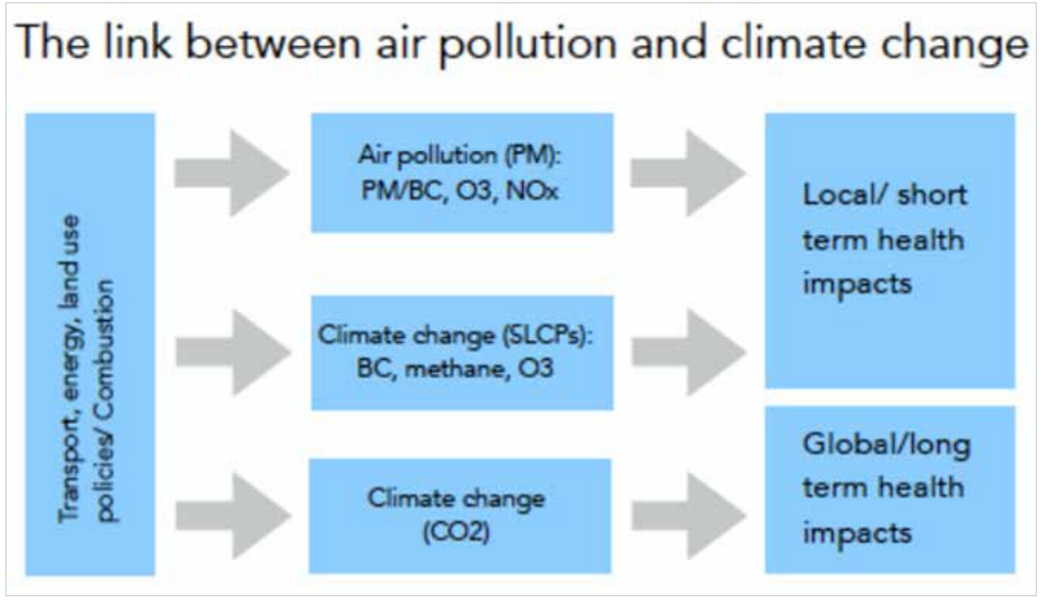

Figure 3: Link between air pollution and climate change[32]

Several air pollutants are also climate forcing agents. Tropospheric O_3 and PM are short lived air pollutants that also affect the climate. O_3 in the troposphere warms the climate, while the different components of PM can have either climate warming or cooling effects. Black carbon, a constituent of PM, is generated from combustion and contributes to global warming while other PM components such as Ammonium, Sulfate, and Nitrate have a cooling effect on the earth's atmospher[33].

Climate change can impact air pollution by changing the sources of air pollutants and by affecting meteorology that is involved in the generation and removal of air pollutants. Hence air pollution and climate change should be considered as two sides of the same coin. Therefore, air quality and climate change should be tackled together, by using policies and measures that have been developed through an integrated approach. These integrated policies would help avoid the negative impacts of climate on air quality, and vice versa. Examples of climate policies that have had a negative impact on air quality was the subsidization of diesel (with lower CO_2 but higher PM and NO_x emissions) and the increased use of biomass[34].

In addition to changing weather patterns, climate change may also change the transport, dispersion, deposition, and formation of the air pollution in the atmosphere. Increasing temperature will also increase the emissions of biogenic volatile organic compound (VOCs).

In 2012, the United Nations Environment Programme (UNEP), together with six countries[35], established the Climate and Clean Air Coalition (CCAC) to reduce Short-Lived Climate Pollutants (SLCPs) to harness collective resources and maximize co-benefits of mitigation measures. While the coalition is at the global level, initiatives undertaken help raise awareness on SLCPs and enhance and develop national and regional actions[36].

Policies at the national level and initiatives at the global and regional levels such as those cited above are by no means exhaustive. However, the relationship between air quality and climate change highlights the fact that addressing one or the other, entails a collective effort and involvement of a range of stakeholders to be effective and sustainable.

32 World Health Organisation, Breathe Life, Climate Change and Air Pollution: two sides of the same coin, accessed on 24th May 2021
33 EPA (2020) Air quality and climate change research
34 A. Gonzalez Ortiz, Cristina de Brito Beirao, Guerreiro Frank De Leeuw, Jan Horalek (2017) Air quality in Europe -2017 report guide.
35 Bangladesh, Ghana, Canada, Mexico, Sweden, and the United States
36 http://www.unep.org/ccac/About/History/tabid/130280/Default.aspx accessed on 21st May 2021; USEPA (no date). "Climate Change and Air Quality".

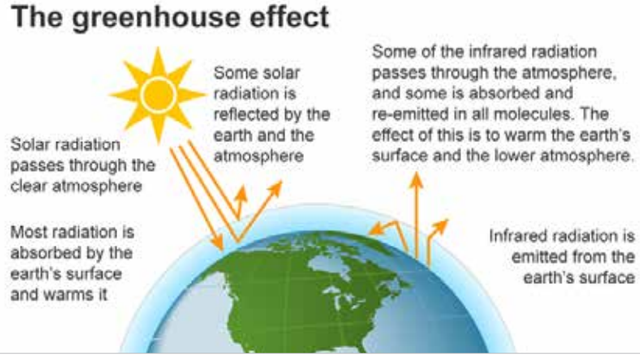

Figure 4: Greenhouse Effect[37]

Short-Lived Climate Pollutants[38]

Short-Lived Climate Pollutants (SLCPs) are powerful climate forcers that remain in the atmosphere for a much shorter period than carbon dioxide (CO_2), yet their potential to warm the atmosphere which can be many times greater than CO_2 on a molecule per molecule basis. Certain short-lived climate pollutants are also dangerous air pollutants that have harmful effects for people, ecosystems, and agricultural productivity.

The SLCPs black carbon, methane, tropospheric ozone, and hydrofluorocarbons[39] (Refer to Figure 5) are the most important contributors to the man-made global greenhouse effect after CO_2 which is responsible for up to 45% of current global warming. If no action to reduce emissions of these pollutants is taken in the coming decades, they are expected to account for as much as half of warming caused by human activity.

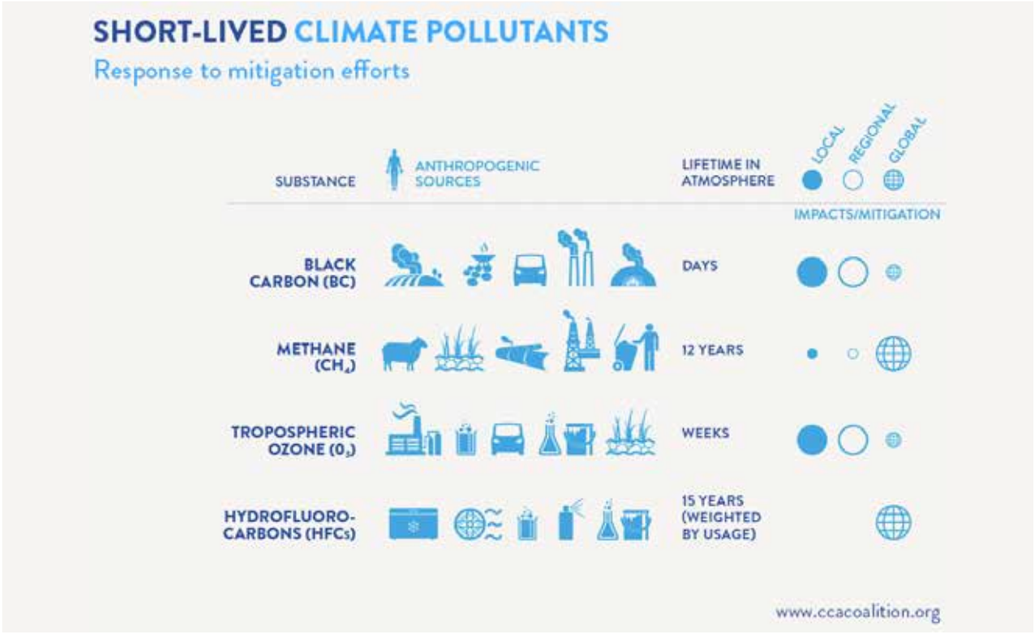

Figure 5: Short-Lived Climate Pollutants[40]

37 What is greenhouse effect?, ISRIC World Soil Museum accessed on 20th May, 2021
38 Climate and Clean Air Coalition, What are Short-Lived Climate Pollutants?
39 Hydrofluorocarbons are man-made greenhouse gases used in air conditioning, refrigeration, solvents, fire extinguishing systems, and aerosols. Though HFCs represent a small fraction of current greenhouse gas emissions, their potential to warm the atmosphere is hundreds to thousands of times greater than that of the same given mass of carbon dioxide.
40 Climate and Clean Air Coalition, What are Short-Lived Climate Pollutants?

Ozone Layer Depletion

The release of chlorofluorocarbons (CFCs), halons, and hydrochlorofluorocarbons (HCFCs) into the atmosphere is the major cause of the depletion of the stratospheric ozone layer. This ozone layer is a key component of the atmosphere which prevents harmful ultraviolet radiation from reaching the Earth. This ultraviolet radiation is responsible for many kinds of skin disease and eye problems among individuals[41].

1.9 Key Messages

Severe urban air pollution in India and elsewhere reflects the fast rate of urban development with its associated increases in energy needs, rising transport requirements, and booming populations. Cities produce a significant share of the countries air pollution and the air pollution within cities has a high cost to human life and economy in the cities.

This puts pressure on cities to be efficient in the urban development process and to make economic growth sustainable. Currently, cities are battling between economic growth and environmental protection.

It is critical for decision-makers and local governments to design policies and promote measures that address air pollution and mitigate climate change. Cities are therefore at an important juncture to address air pollution as an overall crosscutting issue, and to respond to climate change, a global issue which affects the local level.

41 Byju's (2020) air pollution and its control.

2. Mainstreaming Air Quality In Urban Development

2.1 Why Mainstream Air Quality In Urban Development?

Mainstreaming air quality in urban development involves the active promotion of better air in the identification, planning, designing, and implementing of urban development strategies and policies. Mainstreaming in this context, refers to addressing air quality issues strategically as a cross-cutting aspect of urban development and goes beyond just air pollution mitigation to a more holistic and strategic approach to achieving low emissions urban development.

Mainstreaming requires considering the impact of air quality in the earliest stages of the decision-making process when urban development challenges and proposed city implementation plans are being designed. Taking into consideration air quality as an integral part of urban development planning can play a major part in achieving broader development objectives. It can also define how initiatives outside the traditional environment sector, where environment is associated more with conservation and only recently with restoration, can be designed to support environmentally sustainable urban development.

Mainstreaming air quality within a city's priorities means identifying interventions that create co-benefits for both long term urban development and better air. City planning that takes into consideration many different sectors. For example, how people get around from one place to another and reduces the need for private vehicle use means taking into consideration air quality impact right from the beginning. Another example can be waste disposal systems integrated within the urban planning process to prevent dumping and burning.

While the benefits of mainstreaming air quality exist, its practical and effective application requires the understanding of some basic considerations. In the development community, attention to an issue like air quality is characteristically understood as an exercise in recognizing and mitigating adverse environmental impacts of projects. This traditional understanding is a result of the emphasis that development agencies give to the implementation of policies laid out for reducing adverse impact on the environment. The approach focuses on compliance with a given set of procedural standards.

We need to go beyond this traditional approach of looking at projects from a perspective of conservation and think about benefits. So instead of emphasising on cleaning up we need to talk about clean approaches that take into consideration externalities and highlight economic benefits. Mainstreaming air quality requires consideration of air quality in the earliest stages of the decision-making cycle when urban development challenges as well as proposed city interventions are framed. Mainstreaming prompts consideration of how interventions targeted at better air quality can play an integral part in achieving environmental standards as a condition to the achievement of other objectives. It thus requires a focus on proactive investment in policies and projects that promote integration of air quality into urban development strategies themselves, rather than as a separate compliance component of policy/projects.[42]

2.2 Understanding Low Emissions Urban Development

Cities are complex and dynamic entities. Asia is urbanizing rapidly, increasing pressure on resources and infrastructure, and simultaneously influencing the living conditions and quality of life conditions for inhabitants.[43] A study published by Clean Air Asia in 2018 of 889 Asian cities, revealed that 98 percent of these cities have unhealthy air pollution levels and only 32 cities meet the PM_{10} annual average as set by WHO Guidelines.[44]

There is no universal solution that can be applied to every city in any country. Cities in Asia vary in terms of their stages of development. Energy needs, rising traffic and unplanned growth characterise many Asian cities that are growing fast with rising populations. Innovative solutions that are adaptive and responsive will differ from one place to another, thus, enabling the Low Emissions Urban Development (LEUD) city to emerge.

By adopting a LEUD approach to development in Indian cities we can encourage development of urban spaces that can deliver benefits to both residents and the natural environment. The concepts of cities in nature, cities with forests and green cities are gaining much popularity recently and emphasizes the need for integrating a balanced approach in city development that take into consideration the principles of nature. While there is still more focus on the issue of "low carbon", and the green city has a primary focus on reducing GHG emissions/ climate resilience, the concept of the low emissions city is an effort to integrate the importance of air quality in city development.

2.2.1 The Green City and Low Emissions Urban Development

According to Lehmann[45], ultimately, the aim for cities adopting a Green City approach is that, through integrated planning and investments, urban environments will:

- Respond well to their climate, location, orientation, and context, optimizing natural assets such as sunlight and wind flow.
- Are quiet(er), clean, and effective, with a healthy microclimate.
- Have reduced or have no carbon dioxide emissions, as they are self-sufficient energy producers, powered by renewable energy sources.; and
- Reduce the concept of waste, as they are based on a closed-loop ecosystem with significant recycling, reusing, remanufacturing, and composting.

Many of the green city concepts automatically flow into the concept of the LEUD. However, the LEUD goes slightly beyond taking into perspective air pollutants and addressing these at source through a "planning" approach. While the green city focuses on climate and related mechanisms for achieving it; it is more on reducing GHG emissions through clean energy, reducing waste and designing a city based on nature. LEUD concept is an attempt to build a city/space by reducing air pollution through proper waste management, mobility engagement, reducing emissions from road dust, construction dust, industry, and other miscellaneous sources. It also takes into consideration the immediate health impact of poor air quality on citizens and the focus is on improving human health by supporting interventions that reduce air pollution.

Similarly, the concept of low carbon city development can build into Low Emission Urban Development (LEUD). Low Carbon City Development is a

42 Prarthana Borah (2019), Addressing air pollution with development policy: how mainstreaming air quality in India's existing policies beyond environment can help address pollution, The Journal of Governance, Ministry of Environment, Forest, and Climate Change: 251-258
43 Asian Development Bank (2015) Green City Development Toolkit, Mandaluyong City, Philippines (adapted)
44 Clean Air Asia (2018), Air Quality in Asia: Status and Trends, Manila, Philippines
45 Steffen Lehmann and Gaëll Mainguy (2010), Green Urbanism: Formulating a Series of Holistic Principles, SAIPENS (online) accessed on 7th June 2021.

pioneering model for low carbon and green growth in cities that demonstrates leadership, despite uncertainty in the current international climate policy debate.[46] It defines a pathway to transition of a city to low emission, green and inclusive urban economy. Such strategies are integrated into ongoing city development plans and processes.[47] Again, both concepts of low carbon city development as well as green city development tilt towards reducing carbon emissions and the focus is on long term impacts of climate change. Low emissions urban development proposes a more focussed approach to reducing air pollution and increasing co-benefits by integrating climate and clean air planning.

Emissions in cities come mainly from fossil fuel combustion for power generation, transport, industrial activities, municipal waste, and water and sewage treatment. In addition, if urban expansion is not appropriately planned, land-use change and deforestation can lead to the release of carbon dioxide (CO_2) from natural carbon stocks, such as forest cover. Thus, green cities/ low carbon cities will have to consider both mitigation measures that lower their carbon emissions, as well as adaptation measures that improve their resilience to climate impacts. In the context of the LEUD city the focus is more to consider air pollution mitigation measures with reduced focus on the adaptation aspects. This is because reducing air pollution is slightly less complex then reducing climate change and with decisive air pollution mitigation action, it is likely that reduced air pollution targets set are more likely to be acheived.

The implication of an 'urban carbon footprint' stretch far beyond city boundaries as locally emitted GHGs freely mix in the atmosphere and contribute to global climate change. While climate change is global problem largely affected by local action, a variety of local contexts, interests and priorities explain the difficulties in reaching an international agreement to reduce carbon emission. Air Pollution too has similar implications in terms of locally emitted air pollutants mixing in the atmosphere and contributing to local areas in and around the city. Addressing GHG emissions and air pollution requires to similar efforts for mitigation. While the concept of green city as well as the low carbon city focuses on reducing GHG emissions, the concept of low emissions urban development in cities promotes an integrated approach for reducing both air pollution and greenhouse gas emissions. As pointed out earlier, the mitigation strategies are similar. Cities can invest in green economic sectors, such as transport, buildings, waste management and clean energy, which can benefit the residents. Additionally, the LEUD model goes a step forward to emphasise public involvement. As major actors in the flow of goods and services, urban residents can be leaders in creating demand for environmentally friendly products and sustainable consumption.[48] Hence the emphasis is not just on policy and interventions to create low emissions models but to drive behaviour change that creates a demand for this intervention. This is where the need for clean air that is a basic human right needs to be a part of city development plans.

Box 4: Case Study: *The Rio de Janeiro Low Carbon City Development Program*

The Rio de Janeiro Low Carbon City Development Program (Rio LCCDP) was implemented with technical assistance from the World Bank and was tailored to the city's unique circumstances.

The Rio LCCDP is an ambitious, cross-sectoral climate change program implemented by the Municipality of Rio. Several economic and social growth plans and initiatives are being undertaken, particularly in preparation for the 2014 FIFA World Cup and the 2016 Summer Olympic Games. The Rio LCCDP acts as a channel to help distil the carbon reduction potential from these various initiatives and allows the City of Rio de Janeiro to demonstrate the achievement of self-set mitigation goals through bottom-up mitigation accounting in a transparent manner. As such, the Rio LCCDP helps to create a low carbon lens through which future municipal investments are evaluated, and ensures investments contribute to a legacy of urban sustainability.

The Rio LCCDP was independently certified by DNV KEMA Energy & Sustainability in accordance with the newly developed LCCDP Assessment Protocol (shown in full in the Annex). The certification process ensured that the Program complied with international standards for GHG accounting and environmental management systems. Programs that comply with the LCCDP Assessment Protocol are also certified according to the following standards:

- ISO 14064-2: the standard for quantification, monitoring, and reporting of GHG emission reductions or removal enhancements.
- ISO 14001: the standard for certification of environmental management systems; and
- The GHG Protocol (Project Accounting Protocol and Guidelines; WRI and WBCSD, 2005).

Through compliance with these standards, the Rio Program prepares the city to participate in climate finance at both sub-national and international levels. In this sense, the LCCDP builds upon previous examples of enhancing climate finance opportunities for cities, including the City-wide Approach to Carbon Finance (World Bank, 2010). The Rio LCCDP learned from the latter approach and was designed specifically for cities, based on the underlying standard behind the Clean Development Mechanism (CDM) and Verified Carbon Standard (VCS), which is ISO 14064-2. As a result, the LCCDP has set a new precedent in the accreditation of city-level climate change programs and has created an accreditation pathway specifically designed for cities, which can also be adopted by future carbon finance programs.

Source: The World Bank (2014), The Low Carbon City Development Program (LCCDP) Guidebook: A systems approach to low carbon development in cities, Washington DC, USA

2.2.2 Important components of Green Cities

Some basic concepts in the context of the Green city need to be understood to help us better understand the LEUD model. Correspondingly to achieve LEUD, green city concepts need to be reflected in LEUD strategies, project, and programs.

2.2.2.1 Urban Resilience:

The capacity of cities to respond, adapt, function, and evolve to changing climate patterns and related disaster events, shocks and stresses is called climate resilience. Climate resilience considers both the built form and human elements of a city. It describes the ability of people — especially the poor and vulnerable — to survive and recover.[49] Following from climate resilience, urban resilience takes into consideration climate change adaptation, mitigation actions, disaster risk reduction initiatives within the complex urban system, taking into consideration the uncertainty of climate change.

This means that building resilience is founded on the importance of understanding how a city functions, the boundaries of control and influence of different actors within the city, and how the city can evolve and adapt so that urban populations and especially the urban poor can survive when faced with a wide range of shocks and stresses. Building long term urban resilience will also contribute to reducing the impact of air pollution in the short term. Cities that plan infrastructure which is climate mitigation imbibed, automatically support better air quality.

2.2.2.2 Liveability:[50]

Considered a more people centric approach, liveability emerged as an important concept in the field of planning. Liveability is a term that outlines conditions of a decent life for all inhabitants of cities, regions and communities including their physical and mental wellbeing. Liveability is based on the principle of sustainability and hence promotes sensitivity to nature and protection of natural resources. Increasingly, policy and community planning efforts at all levels of governance use the term "liveability," often in describing long range goals.

Liveability is used in a wide array of contexts within the field of city urban planning, particularly when planning involves transportation, community development and community resilience. Clean air and good health are an integral part of making cities more liveable and this is more relevant when contextualised for children, the elderly and other vulnerable communities. Liveable cities drive citizen health,

46 The World Bank (2014), The Low Carbon City Development Program (LCCDP) Guidebook: A systems approach to low carbon development in cities, Washington DC, USA
47 UN-Habitat and ICLEI (2014), Promoting Low Emission Urban Development Strategies in Emerging Economies, Urban -LEDS Project
48 The World Bank (2014), The Low Carbon City Development Program (LCCDP) Guidebook: A systems approach to low carbon development in cities, Washington DC, USA
49 Asian Development Bank (2015) Green City Development Toolkit, Mandaluyong City, Philippines
50 Tyce Herrman and Rebecca Lewis, What is Livability? Sustainable Cities Initiative, accessed on 7th June, 2021

wellbeing and quality of life. The way these cities are planned, designed, built and managed can improve or deviate from the concept of liveability. The physical characteristics that play a role in liveability of cities include land use, buildings, efficiency of transport networks, quality of public spaces, conservation of natural environments, accessibility to work, education, health and community services and recreational opportunities.

2.2.2.3 Integrated Urban Development (IUD):

It is used to describe the consideration of multiple sectors and objectives within a planning and development process and often, needing to reconcile conflicting development objectives. IUD is relevant to LEUD as it enables the planning and development process to consider how an urban area will develop with green and sustainable principles in mind and regarding how the interplay between sectors helps to achieve such outcomes.[51]

2.3 Investment Areas For Green/Low Emissions Urban Development

2.3.1 Green Urban Development[52]

A Green City or Green Development is best understood within the frame of a city's actions and how these actions contribute to a city or urban area advancing as green and sustainable. Green Development considers how to improve and manage the overall quality and health of water, air, and land in urban spaces; its correlation with hinterlands and wider systems; and the resultant benefits derived by both the environment and residents.

Thematic Investment areas for Green Urban Development

Identifying strategic investments and developing a project pipeline is a crucial step in city planning. Strategic Investments are those investments that have the potential to provide catalytic impacts or provide a critical enabling link to support green development within a city. More than that, strategic investments recognize the importance of sequencing to ensure maximum impact and effective delivery of services. Investment planning is the process of prioritizing actions over multiple time horizons that considers budgets and access to finance.[53] It prepares a project pipeline to ensure that actions and development are undertaken in a coordinated manner to support green and sustainable outcomes.

Figure 2.4: Components of Green City Investments

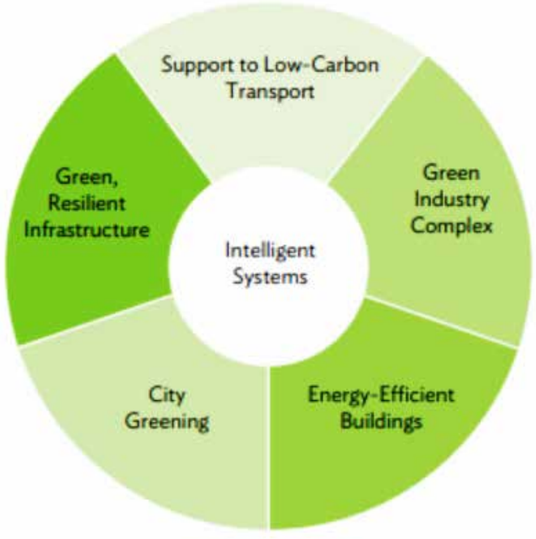

Figure 6: Components of Green Cities[54]

51 Asian Development Bank (2015) Green City Development Toolkit, Mandaluyong City, Philippines (adapted)
52 Asian Development Bank (2015) Green City Development Toolkit, Mandaluyong City, Philippines (adapted)
53 J. Eichler, A. Wegener, and U. Zimmermann (2012). Financing Local Infrastructure – Linking Local Governments and Financial Markets. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
54 Asian Development Bank (2015) Green City Development Toolkit, Mandaluyong City, Philippines

2.3.2 Investment Areas and Low Emissions Urban Development

The thematic investment areas for LEUD may slightly differ from those of green urban development primarily. However overall, they remain similar because the mitigation activities housed within the city for reducing GHGs and leading to the green city are similar to those that are required for reducing air pollution by low emissions urban development are:

2.3.2.1 Low-Emissions Mobility

Transport systems that are accessible, safe, environment-friendly, and affordable. India's rapid growth of cities and reliance on fossil fuels/ petroleum-based modes of transport has direct links to air quality and greenhouse gas (GHG) emissions, climate change, and related health exposure leading to decreased quality of life. Low emissions mobility support reducing reliance on petroleum-based modes of transport and increased emphasis and encouragement of non-motorized transport.

For the same reason for the LEUD model to succeed there is a need for Transit Oriented Development (TOD). Well-integrated transit and land development facilitates urban forms that reduce the need for travel by private motorized modes. Enhancing urban areas through good design that create spaces that are accessible, walkable, and serviced by efficient public transport help reduce air pollution and improve living conditions.

2.3.2.2 Green and Clean Industry

The concept of Green and Clean Industry takes into consideration the multiple life cycles of various products and by-products. The by-product on one industry becomes the inputs for another one. This is the concept of the circular economy, an approach where implementation requires both government involvement and effective institutional arrangements to enable regulation, coordination, and incentives for adoption. Additionally, clean industry depends on energy choices in the production process as well as technology used. While the circular economy concept focusses on resources, by product and reduced waste generation, in order to promote the concept of the green and clean industry, there is a need to look into energy and technology use.

2.3.2.3 Energy-Efficient Buildings

Buildings that consider both the energy required to extract, process, transport and install building materials as well as the energy to operate services such as heating, cooling, and powering equipment are those considered energy efficient. The source of this energy is also important when discussed in the context of LEUD.

Building design standards support the design and construction of energy-efficient buildings. Such buildings are expected to consider solar access; water capture, treatment, and reuse; improving operating efficiency; reliance on clean energy sources; and the use of alternative energy sources.

2.3.2.4 City Greening

The provision for green and open space is called city greening. Increased green areas within the city extent help reduce the impact of heat island effect, improve air quality, improve quality of water runoff through filtration, function as natural buffers to natural hazards, and increase urban biodiversity. City greening also provides the opportunity to increase food security in urban areas through urban farming and simultaneously increasing public open space for recreation.

2.3.2.5 Green, Resilient Infrastructure

A network of multifunctional natural and seminatural areas, features, and green spaces can be considered green infrastructure. Resilient infrastructure on the other hand refers to the ability of infrastructure to withstand extreme weather events or natural disasters and the impact of climate change.

Green infrastructure in urban areas includes addressing issues (like drainage) that traditionally have been addressed through hard engineering solutions, green infrastructure considers natural processes like, sustainable drainage systems. This response may be integrated into open space networks including walkways and bikeways. Responding to climate change and reducing vulnerability of communities are key considerations for provision of resilient infrastructure.

2.3.2.6 Waste Management

Cities with efficient recycling systems can reuse up to 75% of household waste. Manufacturing and construction generate four times as much waste as households do[55].

In 2016, the world's cities collectively generated 2.01 billion tonnes of Municipal Solid Waste (MSW), with

55 Herbert Girardet, (1996) The Gaia Atlas of Cities: New Direction for sustainable urban living, Page 152-154 accessed on 7th June 2021

a per capita volume of 0.74 kilograms per day.[56] "With rapid population growth and urbanisation, annual waste generation is expected to increase by 70 percent from 2016 levels to 3.40 billion tonnes in 2050."[57]

In India, the volume of waste generation has been increasing rapidly over the last few years. According to the "Swachhata Sandesh Newsletter" by the MoHUA, as of January 2020, 147,613 metric tonnes (MT) of solid waste is generated per day, from 84,475 wards. The 2014 report by the "Task Force on Waste to Energy," under the Planning Commission[58], estimates that urban India will generate 2,76,342 tonnes per day (TPD) of waste by 2021; 4,50,132 TPD by 2031; and 11,95,000 TPD by 2050.

The Urban Ministry launched a new multi-media campaign on waste-to-compost, titled "Compost Banao, Compost Apnao" under Swachh Bharat Mission -(Urban). The aim is to encourage people to convert their kitchen waste into compost for use as fertiliser and to reduce the amount of waste going to landfill sites. This campaign is an attempt to encourage citizens to contribute towards making their city clean.[59]

2.3.2.7 Clean Cooking

Clean cooking is an essential part of Sustainable Development Goal (SDG) 7: ensuring access to affordable, reliable, sustainable, and modern energy for all (SDG 7.1.2 specifically identifies increasing clean fuel use).[60]

Urban India has witnessed greater access to clean cooking energy than its rural counterpart, with a significantly higher proportion of urban households primarily using liquified petroleum gas (LPG). The Government of India has made efforts to enhance access to clean cooking energy by promoting biogas, improved cookstoves (ICS), and LPG through various policies and programmes. It has also envisioned new solutions—including electricity and piped natural gas (PNG)—for meeting the demand for cooking energy in urban India.[61]

Solid fuel combustion is a major cause of household air pollution, a leading environmental health risk factor globally. In India, over 750 million people continue to rely on firewood and other solid fuels for daily cooking.[62] Census of India (2011) reported firewood as the primary cooking fuel among 63% of the rural households while another 23% used crop residues and cow dung cakes as cooking fuels. Only 11% rural households were using LPG as primary cooking fuel.[63]

There have been several initiatives and programmes which have been introduced by the government to promote clean fuel, these programmes need to focus on more than one (about two to three) cooking fuel and technology combinations One among the technology must resemble the existing cooking practices and the other must be the cleaner cooking technology.

For example, a programme can introduce a natural draft improved cookstove along with LPG. The combinations may be introduced based on the cooking technologies used in the area, economic status of the households, affordability of the clean cooking fuel, availability of solid fuels, connectivity to the LPG refilling stations, and electricity access scenario of the area. Figure 7 provides the combination options for cleaner cooking technologies and affordable fuels. The matrix also includes Renewable Energy (RE) based induction cooking option though the technology is at very nascent stage.[64]

56 Silpa Kaza et al., (2018) What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 , World Bank Publications
57 Ibid
58 Ministry of Housing and Urban Affairs (2020), Swachhata Sandesh, January 2020 ed., Swachh Bharat Mission Urban
59 Satpal Singh, (2020) "Solid Waste Management in Urban India: Imperatives for Improvement," ORF Occasional Paper No. 283, Observer Research Foundation.
60 United Nations Statistics Division (2019) E-handbook on sustainable development goal indicators, United Nations Statistics Wiki
61 Patnaik, Sasmita, Saurabh Tripathi, and Abhishek Jain. 2019. Roadmap for Access to Clean Cooking Energy in India, New Delhi: Council on Energy, Environment and Water
62 Carlos F Gould et al (2020), Jointly modeling the adoption and use of clean cooking fuels in rural India, Environment Research Communication
63 Manjushree Banerjee (2019), Increasing the share of cleaner cooking among rural households of India, Observers Research Foundation
64 Ibid

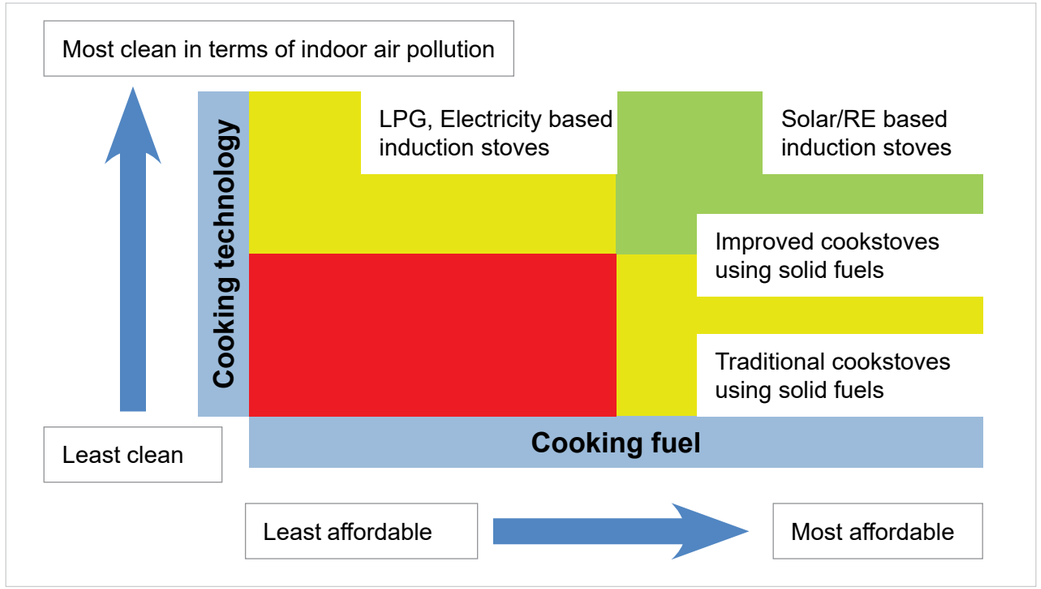

Figure 7: Combination options for cleaner cooking technologies and affordable cooking fuel[65]

2.3.2.8 Community Engagement

Community Engagement means active engagement of public in the process of achieving low emissions urban development. This can be facilitated by making information on data and services public. The role of information and communication technologies (ICTs) helps improve the provision of data and service delivery; encourages citizen participation; and assists in making government more accountable, transparent, and effective by supporting enforcement of regulation.

When data across numerous sectors are integrated, it enables cities to operate more effectively, support decision making, and facilitate more responsive government and provision of services. Similarly, when people have access to information, they are more likely to support initiatives in all the above sectors mentioned and make things work.

65 Manjushree Banerjee (2019) Increasing the share of cleaner cooking among rural households of India, Observers Research Foundation.

2.4 Need To Focus On Five Elements In Urban Operation Model In India[66]

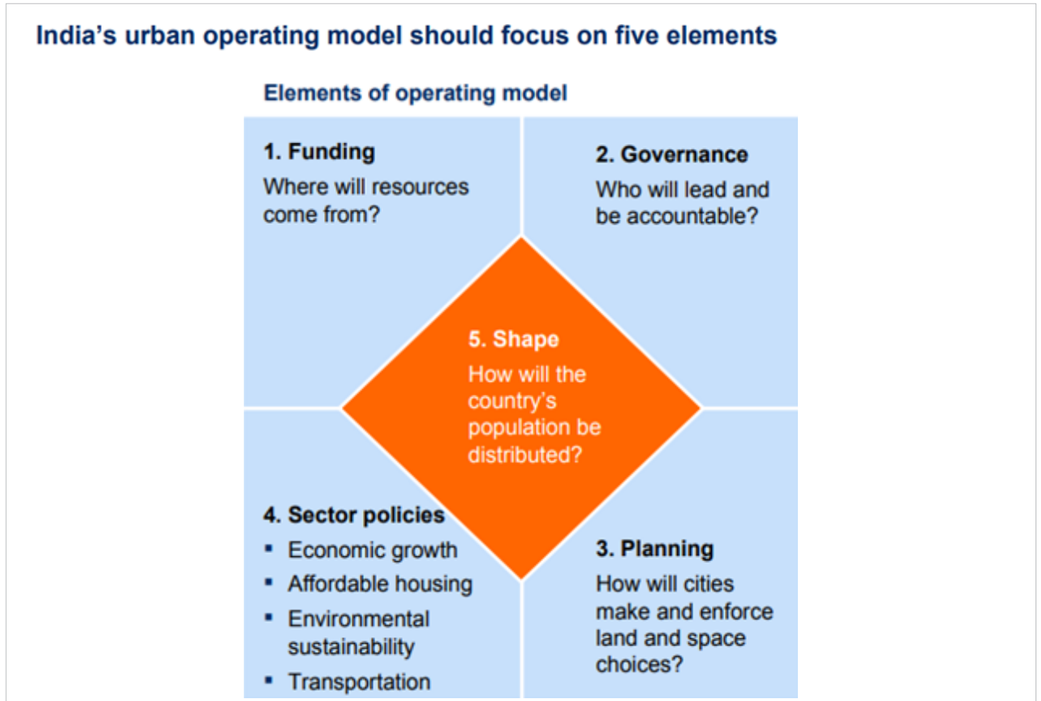

Figure 8: Five Elements for India's operating model[67] Source: McKinsey Global Institute Analysis

2.4.1 Funding

In countries around the world, the government have devised mechanisms to ensure that the cities have reliable access to funds. In developed countries, the government has created transparent, formula-based mechanism. to fund their cities. The developing countries have used land monetarization and debt quite extensively to fund its urban infrastructure. For example, China has given its cities the freedom to raise the substantial investment resources by monetarizing land assets and retaining a 35% share of value added taxes. China has also converted many of its big cities into special purpose vehicles to access the debt market. China's major cities have powerful political appointees as mayor's and use focused special provision vehicles (SPVs) as in the case of Shanghai's water supply or to build and run the urban infrastructure. With some exceptions, India has barely utilized these sources of funding[68].

One of the main reasons behind inadequate financial resources for air pollution prevention and control. Most countries in Asia allocate financial resources for environmental management as part of annual nationally appropriated funds and environmental planning is part of national planning. One way to boost those outlays is to ensure that urban planning prioritizes air pollution control measures – and hence the allocation of funds for the enforcement of such measures at the local level. Private-public partnerships can help support cleaner technology and ground level work to reduce air pollution. Special funds to finance air pollution control projects may also be established by governments.

Empowering local and city government to plan and finance low-emission, resilient infrastructure is an essential part of achieving climate, clean air and development goals.

66 Mckinsey Global Institute (2010), India's urban awakening: Building inclusive cities. Sustainable economic growth, McKinsey and Company
67 Ibid
68 McKinsey Global Institute (2010), India's urban awakening: Building inclusive cities. Sustainable economic growth, McKinsey and Company

Box 5: The economic and social benefits of low-emission cities

A study by the Coalition for Urban Transition finds that the transition to low-emission cities is good for the local economy and well-being:

- Directing investment towards clean public transport and greater vehicle efficiency could create up to 23 million additional jobs a year and tackle congestion, cutting the wasted hours spent sitting in traffic by up to 30%. It could further promote a reduction by over 80% in the 1.3 million transport-related deaths and 78 million transport-related injuries worldwide each year.
- Investing in city cycling infrastructure could save five times the cost of this investment by improving public health and reducing traffic congestion. Extrapolating across Europe, the health benefits from cycling could be worth USD 35-136 billion annually.
- Investing in energy efficiency for new and existing buildings could create up to 16 million additional jobs a year worldwide. Improved working and home environments would lower rates of illness, saving on health bills and making workers up to 16% more productive.

Importantly, these initiatives benefit the poor the most. Low-income groups are more likely to live in poorly insulated buildings and neighbourhoods with chronic air pollution, and depend on public transport, cycling and walking over private car use. An ambitious program to reduce greenhouse gas emissions would especially improve the living conditions of the poor, and therefore help to achieve more equitable cities.

Source: Andy Gouldson et al. (2018), The Economic and Social Benefits of Low-Carbon Cities: A Systematic Review of the Evidence, Coalition for Urban Transitions, London and Washington, DC.

2.4.2 Planning

Effective and systematic urban planning has been part of a fabric of successful cities for decades. Planning is important to cities to make informed decisions on the use of scarce resources such as land. A metropolitan master plan sets out the overall strategies for the economy, mass transit, and affordable housing for instance which is then applied in detail at borough level. For example, London plans 20 years in advance on how to deal with peak morning traffic. China too has a master urban planning regime that emphasizes the systematic redevelopment of run- down areas in a way that is consistent with long- range plans for land use transportation. In all these cities, the head of urban planning is a coveted and high-level position generally directly reporting to the mayor.

2.4.3 Sectoral policies such as public transportation, affordable housing, and climate change mitigation

Many cities invest effort in designing of policies for the most important sectors and that influence the city's economy and quality of life. For example, affordable housing and now the climate change mitigation policies for all, are the important consideration in all the cities. The planning mandates in the United Kingdom have generated 20 to 25 % of all affordable units built over the last decades. South Africa provided free land for housing for its poorest income group. Singapore provided the public housing for more than 80% of its population through a dedicated housing board by using land monetization and interest rate subsidies to make the affordability work. A good city also invests in facilitating community networks that foster innovation and drive the ethos and soul of the cities.

2.4.4 Shape

Most of the countries in the world have had the luxury of urbanizing organically through history and ended up with different portfolios and distribution of cities. In Germany, for instance many small and medium sized cities have grown up parallelly and reflects the Germany's federal governing structure. We have seen the same in India. China is exceptional in this as it consciously fostered a concentrated pattern of urban expansion initially with the development of its dynamic coastal cities. India can proactively shape the overall portfolio of cities in a way that optimizes their economic contribution, investment and land requirement and the objective of regional equity.

2.5 Key Messages

This chapter highlights concepts that lead to the idea of an LEUD city. Drawing instances from development strategies like Green City Development and Low Carbon City Development, that enable the planning and development process to consider green and sustainable principles that support climate friendly and clean air strategies for improving health of the city dwellers.

3. City Development And Clean Air Action Planning

3.1 Air Pollution And Asian Cities

Megacities are cities with a population of greater than 1 crore (10 million) people. 17 of the 25 most densely populated megacities of the world are in Asia; by 2025 projections show that 21 of the world's 37 megacities will be in Asia[69]. This indicates a continuous upward trajectory of economic growth that is rapidly taking place and forecasted for the Asian region.

As urban population grows, so does the rise in the demand for road transport and energy consumption. By 2025, the Asian region is projected to account for 40% of the total increase in world energy consumption. Increased emissions in terms of air pollution and global greenhouse gases (GHGs) are therefore going to be a significant feature of growing Asian cities. Air pollution remains one of the biggest environmental health risks especially in developing countries and in particular in the cities of Asia. Out of the 7 million premature deaths estimated to be related to air pollution globally, one-third occur in the Asia-Pacific region[70].

It is estimated that 98% of the cities in Asia are currently at risk from the health impacts of exposure to $PM_{2.5}$[71]. When annual levels of PM_{10} were measured, it was found that 7 out of 10 cities in developing Asian countries have unhealthy levels of air pollution[72]. There is a severe need within countries and cities to drastically reduce air pollution. With a major proportion of the total Asian population residing in cities, and more people projected to migrate to cities in the coming years through increasing urbanization, addressing air pollution in the context of urban development is imperative to ensure sustainability.

69 Improving Air Quality Monitoring in Asia: A Good Practice Guidance Mandaluyong City, Philippines: Asian Development Bank, 2014, Clean Air Asia Cross reference: Key Indicators for Asia and the Pacific 2012: Green Urbanization in Asia, special chapter. Mandaluyong City, Philippines: Asian Development Bank, 2012,

70 World Health Organization Western Pacific Regional Office, One third of global air pollution deaths in Asia Pacific, 2018.

71 Analysis of Ambient Air Quality in Asia, Clean Air Asia, 2018

72 Improving Air Quality Monitoring in Asia: A Good Practice Guidance Mandaluyong City, Philippines: Asian Development Bank, 2014, Clean Air Asia Cross reference: Clean Air Asia (2011). Status and Trends in Air Quality Management. Pasig City, Philippines.

3.2 Relevance Of Air Quality Management In Cities

The process of Air Quality Management (AQM) in cities helps to ensure clean air and protect human health and the environment. The process involves setting air quality goals, estimating emission sources, assessing air quality status, looking at air quality impacts and developing and implementing solutions to reduce emissions.

AQM priorities vary within the context of local public health and the local environment. Decision-makers need to make an effort to balance air pollution prevention and control with economic, environmental and health policy priorities, taking into consideration issues of intergenerational justice, equity across sectors, and environmental justice during the planning process. Allocation of resources for prevention of air pollution, needs to be considered within the context of the other environmental factors such as unsafe water, poor sanitation, and vector-borne diseases (i.e., malaria and dengue fever) as well as co-benefits associated with climate change mitigation. Most importantly air quality policies must run across sectors and need to be interconnected and compatible with policies for health, energy, transport, and climate[73].

Consistent economic growth is currently fuelled by increased use of fossil fuel-derived energy and is a major source of air pollution. Economic activities that do not take into consideration environmental factors can create adverse effects for the environment and public health. This makes it essential for cities to be in the forefront of addressing air quality. The factors that relate city development with air pollution are illustrated in Figure 9.

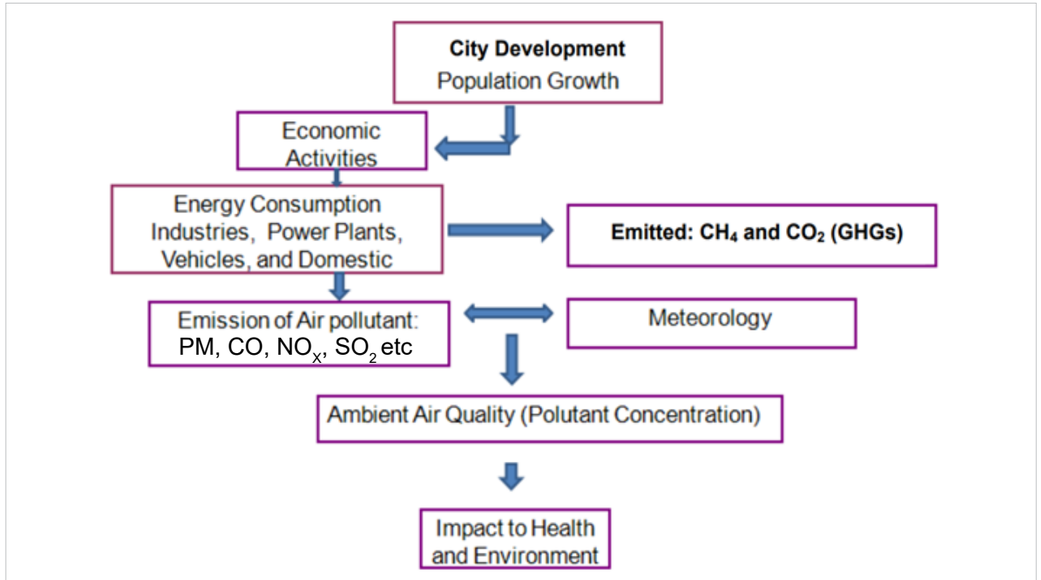

Figure 9: City Development and Air Pollution

Figure 9 shows that a city's development leads to population growth (due to migration from less urban locations and other natural factors), which leads to increased economic activities (industries, power plants, number of vehicles and so on) that encourage energy consumption leading to emissions. These emissions affect ambient air quality and impact health and the environment.

The combination of the increasing emission levels with the high density of people living and working in urban areas increases the population exposure to air pollution. This leads to more people being exposed to unhealthy levels of air pollution on a daily basis.

73 WHO, Guidelines for Air Quality: Chapter 6: Air Quality Management (105-130), 2000, Geneva;
UNDP China, Climate Change Newsletter, March 2015; USEPA, EPA Air Pollution Control Cost Manual: 6th Edition, 2002; Kuylenstierna, J.; Hicks, K. (2008). Benefits of integrating air pollution and climate change policy; Schmale, Julia; von Schneidemesser, Erika, (2013) Needs, Potentials and Challenges of Integrating Air Quality and Climate Change Policies

Box 6: Beijing's Heightened Air Pollution Control Efforts

In recent years, one of the more infamous cities in terms of alarming air pollution episodes is the city of Beijing, the capital of China. To strategically address the city's severe smog, Beijing launched its five-year plan (2013-2017) to improve air quality through key measures, which include: reduction of coal consumption, promotion of clean energy use, and lessening heavily polluting production activities. One of the key actions identified is to cut cement production capacity to 4 million tons in 2017, from 10 million tons indicated in the city's 12th five-year development plan for 2011-2015.

Moreover, in an unprecedented move to address the city's severe smog, the municipal legislature of Beijing in January 2014, passed a regulation that features more stringent emission controls and harsher penalties. Previous initiatives of the government only monitored growth of emissions; the new regulation will target sources of emissions more aggressively. This translated to the government imposing yearly quotas on emissions of major air pollutants to gradually lower total emissions. Targets include: cutting coal consumption by 2.6 million tons, ban heavily polluting vehicles, cut new car registrations, and promote new energy vehicles.

Source: UN Environment 2019, A review of 20 years' Air Pollution Control in Beijing, United Nations Environment Programme, Nairobi, Kenya.

3.3 Strategic Framework For Air Quality Management

Air Quality Management (AQM) is the strategic framework for addressing and improving air quality. AQM is a process that helps cities maintain and improve air quality to protect public health and general welfare, ecosystems, materials, and structures. It is a tool, which enables governments to set objectives to achieve and preserve clean air and reduce adverse impacts on human health and the environment[74].

Governments and decision-makers are responsible for creating, developing, and implementing the AQM framework. Within the AQM framework, government authorities with the support of relevant stakeholders can do the following:

- Identify major sources of air pollution
- Establish appropriate policies on air quality that include co-benefits of climate change
- Prepare the institutional structure and program to implement these policies
- Develop legislative and regulatory requirements
- Set goals, objectives and targets for health and priorities to achieve these
- Facilitate activities, such as emissions inventory, air quality monitoring, and other scientific research required to facilitate the AQM process
- Establish systems for compliance with emissions and ambient air quality standards.

74 SEI, et. Al. (2004), A Strategic Framework for Air Quality Management in Asia.

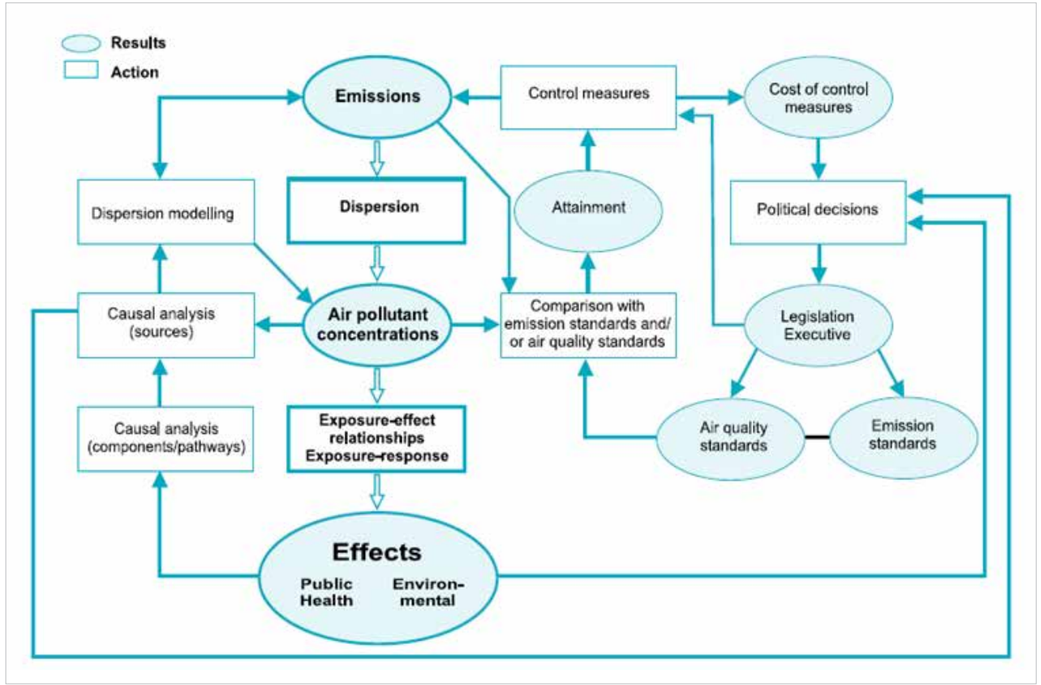

Figure 10: Air Quality Management Framework[75]

As illustrated above in Figure 10, AQM processes depend on emissions inventory, air quality monitoring networks, air quality modelling, exposure and damage assessments, and health and environment-based standards. These are coupled with a range of cost-effective pollution control measures, legislative instruments, and resources to implement and enforce them.

Box 7: Roles and Responsibilities of Key Stakeholders in AQM

- National government - establishes policies, and standards
- State government - regulates policies to meet standards; establishes state/ plans
- Local government (cities/municipalities) - develops and implements action plans and makes investments
- NGOs and the media - promote public participation, debate and raise awareness.

The purpose and benefits of establishing an AQM system are important in the sustainability of development in cities in the region. However, the process is not as easy as simply fulfilling the necessary data requirements and convening concerned groups and stakeholders. It is not without its challenges. Lack of political will, inadequate resources, limited infrastructure and capacity, unavailability of data such as emission factors and emission inventories can be major challenges to the process of AQM. Steps like national government support, multilateral development organization input and conducting cost-benefit analyses and health impact studies can help in overcoming challenges[76].

75 SEI, et. Al. (2004), A Strategic Framework for Air Quality Management in Asia.
76 SEI, et. Al. (2004), A Strategic Framework for Air Quality Management in Asia.

Box 8: Air Quality Management in Thailand

Thailand developed several good practices in AQM, including emissions standards set for industries, power plants, and refineries. It has specified ambient air quality standards for CO, NO_2, SO_2, Pb, PM_{10} and TSP. Thailand has progressively imposed European vehicle emissions standards. Since 2012, Euro IV emissions standards have been imposed for new and imported light-duty vehicles and fuel specifications have been continually tightened. Lead was successfully phased out in 1996, and sulfur content in diesel fuel was reduced to 50 parts per million (ppm) since 2012.

Thailand also developed a policy of encouraging the use of natural gas and ethanol in transport. Both command-and control (standard) and economic instrument (tax on leaded gasoline) were applied which mobilized key stakeholders (refinery industry, vehicle owners, public) to act. The country also implemented a policy to subsidize liquefied petroleum gas (LPG) for cooking to promote its wider use. Several EIs were conducted and databases updated for key man-made and natural air pollution sources.

An integrated emissions reduction approach for the Mae Moh coal-fired power plant, a huge source of SO_2 and PM, included the enforcement of emission standards, fuel quality improvement, and use of alternative fuels. Since the 1980s, the automatic ambient air quality monitoring network has been successfully operated with almost 70 stations at present. Equipment calibration and data QA/QC procedure are well documented and implemented. Data is shared with, and disseminated to, key stakeholders online, on display boards, and on a mobile application.

A strong collaboration between government offices and the academe has been implemented. Providing real-time information on the state of air quality is important for mobilizing citizens and protecting their health. Cloud and mobile applications and utilizing satellite data could be used. For example, the Thailand PCD established the Air4Thai application, which reports hourly data on Thai AQI to disseminate information to the general public.

Source: Asian Development Bank (2018), Mainstreaming Air Quality in Urban Development in Asia, Philippines.

3.4 Why Clean Air Action Planning?[77]

Cities require a strategy to deal with the continuously changing issues and needs concerning Air Quality Management (AQM). The challenges of the AQM process are highlighted in the section above. The clean air action planning process can be considered as the core of AQM, which helps overcome challenges by including stakeholders in the AQM process right from the development stage.

The clean air action planning process helps to give a comprehensive understanding of the AQM of a city with scientific information on the levels of air pollution, emission sources as well as local health and environmental impacts of pollution. This can be a guide for government and other stakeholders to select measures that will reduce emissions from transport, industries, waste deposits, residential burning, and other sources during the planning process.

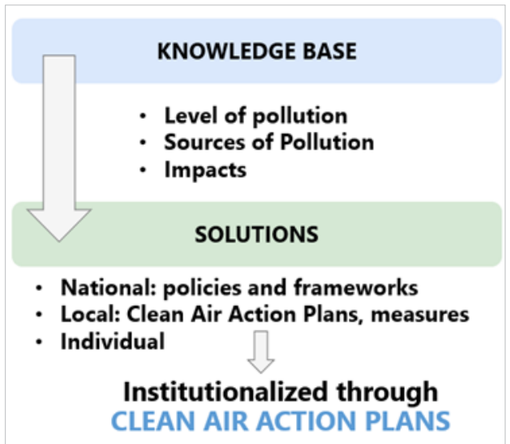

Figure 11: Simplified Framework for Clean Air Action Planning

77 Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines

3.5 What Is Clean Air Action Plan?[78]

A Clean Air Action Plan (CAAP) is developed to improve air quality and public health by identifying cost-effective measures to reduce emissions. It is a collection of regulations, policies, and programs for improving air quality. The CAAP development process is led by the government and involves stakeholders.

Approaches to CAAP, vary depending on local contexts of cities and countries. The CAAP development and implementation process is also dependent on the needs and capacities of cities and countries.

The following are the key features of CAAP:

- Instruments and strategies for compliance with air quality and emission standards
- Adoption and implementation of control measures
- Continuous improvement, and
- Forecasting of future trends including national policies and international goals

For the development of an effective CAAP, the following processes are recommended:

- Assessment – The baseline assessment prior to CAAP should include air pollution sources and emissions, ambient air pollution levels, air quality standards or target values, source apportionment and exposure assessment, health impacts assessment.
- Evaluation- There should be necessary information on air pollution drivers, future growth projections, and future air pollution scenarios.
- Consultation- CAAP needs to be a consultative process with defined roles and responsibilities for all major stakeholders.
- Preparation of control options – This requires consideration of cost-benefit or cost-effectiveness, technical feasibility, and ease of implementation.
- Setting targets and timelines for implementation.
- Institutional arrangements and partnerships, infrastructure, and financial resources need identification and clarity.
- Considering technological change.
- Defining the monitoring and evaluation process.
- Defining timeframe for reviews.

The experience of developed countries demonstrates that the CAAP is an efficient instrument of air pollution control. It enables effective and efficient resource mobilization in identifying and planning for operationalization of reduction measures. With the CAAP, multi-year efforts to reduce emissions have been made through various control measures and clear frameworks for implementation and enforcement of the control strategies. As a result, emissions from anthropogenic sources have been substantially reduced, and most developed countries reported improvement in their nation's urban air quality.[79]

78 Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines
79 Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines

Box 9: Nepal combating its way through air pollution

Air pollution in the Kathmandu Valley is high – about 5 times higher than the WHO Air Quality Guideline – and transport is the main source of air pollution in the Valley. The growing pollution has attracted significant media attention, and advocacy groups have also raised their voices against the pollution. The government has responded with a few measures, but these are often scattered and insufficient. The multi-sectoral nature of the air pollution problem there requires coordination across sectors, and yet no central agency is responsible for air quality management.

The Mayors of the 18 municipalities in Kathmandu Valley have created a Forum to further coordinate and share experiences among the city governments. As city governments are responsible for overall urban development and management of basic urban services such as waste management, they can play an important role in providing solutions to urban pollution. It was suggested that the 2017elected Kathmandu city officials – local elections were held in 2017 after 20 years – can take on this responsibility if their capacity is enhanced and they are provided with the full support and cooperation of other agencies.

There are many entry points to reducing air pollution in Kathmandu. In the case of urban mobility, cities can adopt the Avoid-Shift-Improve strategy to reduce air pollution by reducing travel, shifting to environment friendly modes of transport, and improving the energy efficiency of vehicles. Cities can promote compact settlements with streets that promote walking, cycling and public transport to reduce the use of polluting vehicles and shift to environmentally friendly modes of transport.

In this context, the Global Street Design Guide, prepared by National Association of City Transportation Officials (NACTO) in the US and Global Designing Cities Initiatives based on experiences from 72 cities in 42 countries, can be a useful resource for city governments and is already used in Mumbai and Addis Ababa.

In the long-term, managing air pollution in an integrated manner is essential. Actions such as designing compact cities with streets that prioritize walking, cycling and public transport, promoting electric vehicles, particularly for public transport, and managing waste effectively are key solutions to air pollution.

Source: USAID, BreatheLife, accessed on 9th July, 2021

3.6 Developing A Clean Air Action Plan

The process of developing a CAAP includes four steps. Stakeholder participation and communication are an integral part of the process:

1. Assessment
2. Action plan development
3. Implementation and enforcement
4. Review and improvement

Table 2 provides the **Recommended Components of Clean Air Action Plan.**

3.6.1 Assessment

The starting point of CAAP development is the assessment of current and projected scenarios. This includes collection and interpretation of data of status and trends of air quality, impact on health, information on key pollutants and sources of pollutant emissions. Additional information like indicators of economic growth, energy use and population growth and their projections in future are also useful for the assessment. In addition, baseline emissions inventory (EI) for targeted pollutants; and projected levels of emissions, source apportionment (SA) information may be used to prioritize the source types and key pollutants that need to be dealt with.

3.6.2 Action plan development

The action plan development encompasses identification of different types of control measures, estimation of effect of the control measures on pollutant emission reduction, cost-effectiveness of the control measures, and co-benefits.

3.6.3 Implementation and enforcement

Implementation and enforcement are key to reducing air pollutant emissions and achieving air quality objectives. A successful and implementable CAAP needs clear institutional framework and responsibilities, stakeholder coordination and communication, political support, allocation of financial resources, technical capabilities, and review and improvement[80].

Three factors determine the success of a city or country in providing better air quality:

1. The existence of policies and action plans, and their implementation details (mechanism, timeline, assignment of responsibility).
2. Provision of enough resources to implement the policies and action plans.
3. Actual implementation of the policies and action plans.

3.6.4 Review and improvement

Review and improvement are essential in the CAAP process. It helps to track and report on implementation of measures and overall changes in emissions. It is important to identify mechanisms and responsibilities for monitoring/tracking progress to enable review of the effectiveness of available control measures. This also helps if changes are needed to achieve greater reductions, address excessive costs, or amend measures, as appropriate.

Box 10: National Clean Air Programme

In India, the Ministry of Environment, Forest, and Climate Change released the National Clean Air Programme (NCAP) to control air pollution. The plan aims to be the basis for performing comprehensive mitigation actions for the prevention, control, and abatement of air pollution; improvement of data collection, management, and analysis; and strengthening of institutional capacity and stakeholder engagement.

At the national-level, the NCAP will be implemented by institutionalization of respective ministries which will be organized through inter-sectoral groups. The Plan also calls for formulation of city-specific clean air action plans for the 102 non-attainment cities in the country in order to localize implementation (Ministry of Environment, Forest, and Climate Change, 2019). Within this context, CAAPs at the city-level are a way of localizing national regulations and operationalizing their implementation by local authorities.

80 Clean Air Initiative for Asian Cities (CAI-Asia) Center, 2012. “Clean Air Action Planning in Chinese Cities: Hangzhou and Jinan Cases”. Pasig City, Philippines

Table 2: Recommended Components of Clean Air Action Plan[81]

Heading	Details
Executive Summary	
Introduction and Background	City overview: Geography and meteorology Population and urbanization Economic and industrial development Energy and transport
Legal Framework/Legislative and Policy Context	
Roles and Responsibilities (National/Provincial/ Municipal)	
Current status and challenges of air quality Baseline assessment	
• Current status, Air Pollution Index (API) and comparisons to objective/standard	
• Emissions inventory and key pollutants	
• Causal analysis of effects and attribution to individual sources	
• Air pollution trends and tendencies analysis	Trends in air pollutant concentration
• Impact on public health and the environment	Evaluation of health effects, exposure to pollution investigation Environmental and economic impacts
Target and goals	Air quality objectives Emission reduction targets Long-term environmental/development planning
Development of the Action Plan	
• Process of development	
• Focus areas and main tasks	Specific planning linked with/refer to other government departments plan
• Expected impacts	Probability of success and risk factors for control measures and possible economic and social impacts
Implementation of the Action Plan	
• Analysis of costs and feasibility	Cost and impact on air quality
• Institutional arrangements (enforcement procedures, coordination, roles, and responsibilities)	
• Steps, working periods, timeline	
Supporting Policies	Specific planning linked with/refer to other government departments plan
• Monitoring and evaluation	Annual self-review Mid-term evaluation by independent party

81 Clean Air Initiative for Asian Cities (CAI-Asia) Center, 2012. "Clean Air Action Planning in Chinese Cities: Hangzhou and Jinan Cases". Pasig City, Philippines

Heading	Details
• Resource commitment (Institution, financing, policy, technology, social)	
Key Projects	Key projects and their relevance to control measures Specific sources of funding, how to guarantee the investment
• Analysis of costs and feasibility	
• Expected impacts	

3.7 Control Measures To Improve Air Quality

The CAAP encompasses short-term, medium-term, and long-term mitigation and control measures to reduce emissions from mobile (transport), stationary (industry), and area sources.

Several different types of measures for improving air quality can be broadly identified and categorized as follows:

- **Conservation:** reducing the use of resources through energy preservation
- **Efficiency:** carrying out the same activity, but doing so more proficiently, thus reducing resource use and emissions of air pollutants
- **Abatement:** applying a technological approach to reduce emissions[82]
- **Fuel switching:** substituting a lower emission fuel for a higher emission fuel
- **Demand management:** implementation of policies or measures which serve to control or influence the demand for a product or service
- **Behavioural change:** changing the habits of individuals or organizations in such a way as to reduce emissions.

3.8 The Clean Air Action Planning Process

3.8.1 Stages of the CAAP process

In a fully developed CAAP, like that of the United States, the development follows four key steps[83], with similar components also found in the CAAP developed for Chinese cities:

- **Step 1. Define the goal.**
  This includes establishing National Ambient Air Quality Standards (NAAQS) to limit levels of criteria pollutants; establish national emission standards to control hazardous air pollutants (HAPs).
- **Step 2. Elaborate policy.**
  This involves proposed regulations to achieve and maintain outdoor concentrations of major pollutants at levels considered "safe" for human health and welfare.
- **Step 3. Formulate strategies.**
  This is the actual process of devising interventions like emission taxation and incentives.
- **Step 4. Employing action items.**
  This is the process of outlining options for city interventions across sectors and communities like switching to ultralow sulfur diesel fuel; removing highly polluting vehicles from the road.

82 Such as Flue Gas Desulphurization for Thermal Power Plants, Control of SO_2 emissions by using high efficiency Sulphur Recovery Unit (SRU), adequate stack height & low sulphur fuels, shift from bull-trench brick kilns and vertical shaft brick kilns to zig-zag brick kilns

83 USEPA, Basic Information about Air Quality SIPs, accessed on 26th May, 2021

Box 11: Guidance Framework for Better Air Quality

The Guidance Framework for Better Air Quality developed by Clean Air Asia in 2015, provides an overview of key concepts and highlights challenges for each guidance area, AQ Monitoring, Emissions Inventory, Health Impact Assessment, Clean Air Action Planning, Communication and Governance. It also provides recommended steps to guide cities (and countries) to progressively move towards each stage of AQM development – underdeveloped, developing, emerging, maturing, or fully developed based on where a city is with respect to air pollution levels, data and scientific information availability and policy regulation. These recommended steps offer cities (and countries) with the means with which to assess current capacities and limitations to enable them to attain the fully developed stage, thereby contributing to the achievement of the Long-Term Vision on Urban Air Quality in Asia.

For each Guidance Area, a self-assessment tool was developed so cities can assess their capacity in terms of the AQM development stages described in the Guidance Framework (underdeveloped, developing, emerging, maturing, or fully developed). Once cities determine what stage they are in using the tool's checklist, they can identify the corresponding steps recommended for progressing towards the next stage.

Source: Guidance Framework for Better Air Quality (2015), Clean Air Asia.

3.8.2 Role of stakeholders

Table 3 shows which stakeholders need to be engaged in the clean air action planning process. It also highlights recommended roles in clean air action planning. While it is not necessary to have all stakeholders involved in the manner highlighted here, it is important to establish a team that has the mandate, competence, and authority to develop the CAAP and implement its measures and have an effective monitoring set up that can review and evaluate implementation on a regular basis.

Table 3: AQM stakeholders and recommended roles in Clean Air Action Planning Process[84]

Institution	Roles and responsibilities
National government	• Establish or update national air quality policies, standards, and guidelines, as needed • Provide inter-agency administrative orders to facilitate data sharing, as needed • Provide financial support to the local government in implementing the CAAP and help seek funding from international donors • Ensure CAAP development process and activities comply with national policies and regulations
Local government	• Formulate policies for implementation within their jurisdiction • Monitor local air quality and emissions to verify compliance with national standards and CAAP targets • Enforce existing and newly established air quality regulations • Formulate roadmap, allocate funding, and set timelines for the different steps involved in developing the CAAP
Academia	• Establish emission inventories (EI) through scientifically valid and internationally accepted protocols, from data collection to analysis and reporting • Conduct modelling for further analysis of air quality monitoring data or EI results or for predicting future air quality trends in the city based on EI results • Provide technical support throughout the CAAP development process
Private sector	• Establish environmental management systems and adopt technologies to lower environmental impacts of business operations • Assist in funding CAAP development activities such as training workshops and emission inventory
Non-governmental organizations and foundations	• Monitor CAAP development process • Coordinate with national or local government in hiring local consultants and technical experts • Assist in funding CAAP development activities such as training workshops and emission inventory
Mass media	• Publicize important events related to CAAP development • Effectively communicate air quality data and related information (e.g., policies and regulations) to city residents and businesses
Civil society, sectoral groups (e.g., public transport associations) and private citizens	• Participate in group discussions and stakeholder consultations. Consultations will effectively highlight the realities of how air pollution is affecting everyday lives of the population and the environment.

3.9 Sectoral Interventions In Clean Air Action Planning

Clean Air Action Planning requires strategic interventions and control measures for identified sources at a city level. Once the goals and targets of CAAP are set and the priority pollutants and pollution sources identified, the first step in selecting control measures that need to be included in the CAAP. In order to identify priority pollutants, one needs to look at those that exceed national air quality standards and those that are major health risks. WHO guidelines and future trends are other issues that can be taken into consideration while identifying which pollutants to address. Along with pollutants, dominant pollution sources, possibly identified through an emissions inventory, need to also be considered.

The CAAP needs to put in place control measures for transport, industry, small-medium enterprise, open burning (of municipal solid waste and agricultural residues) and household air pollution (from cooking and heating). For each of these sectoral categories, there are recommendations on the implementation time scale from short term (3-5 years), medium-term (6-10 years) and long-term (11-20 years).

84 German International Cooperation [GIZ] and Clean Air Asia. (2015). Handbook for Clean Air Management in Smaller Cities. Pasig City, Philippines: Clean Air Asia

Table 4: Recommended implementation timeline for each sector

Sector	Short Term	Medium Term	Long term
Transport	• Phase-out of high emitter vehicles • Vehicle Inspection and Maintenance Programs • Non-Motorized Transport (NMT) • Model switch • Alternative working scheme (telecommuting) • Eco-driving • Fuel quality standard	• Traffic Management • Public transport engine standards	• Land use planning
Industry	• Tightening emission standards from stationary sources • Promoting/ enforcement of emission reduction in industry	• Land use planning and zoning,	
Small-Medium Enterprises	• Clean fuel for generator sets	• Renewable energy	
Open Burning	• Policy implementation/ enforcement of bans on open burning-awareness raising	• Shifting mindsets in Agricultural practices	
Household Air Pollution	• Cookstove Replacement • Water-based paints		

3.9.1 Mobilizing resources

Once steps for developing a CAAP are in place, there is the need to identify what kind of resources and the number of resources required for implementation. A clear commitment to securing resources will mean sustained support for air quality management efforts.

Box 12: Conformity between Transport and Air Quality Management Planning in the United States: A Case of Planning Coordination

The US government introduced the policy of transport conformity where air quality planning and transport planning are integrated. The air quality plan seeks to minimize emissions while transport planning seeks to increase mobility. Transport activities are not funded or approved unless they conform to the purpose of the air quality plan. In this conformity, transport activities should not result in:

- New violations of air quality standards
- Worsening of existing violations
- Any delay in the planned improvement of air quality

The transport plan funds transportation control measures in the air quality plan, calculates motor vehicle pollution inventory, and matches the air quality budget. This involves shared data and identical assumptions between the transport and air quality plans to generate realistic measures.

Source: UNEP-UNHSP, Urban Air Quality Management Toolbook, accessed on 9th July,2021.

One way is to form a CAAP Working Group who determine funding sources, whether through the local or national government, or through donors and other international agencies. Partnering with universities or businesses can reduce costs required from the city or allow for in-kind donations of time or other resources[85]. A number of good practices are recommended towards resource mobilization.

During CAAP development, maximize available resources by pooling different funding sources together and/or integrating projects or activities under different government programmes but with similar goals or outputs. A relevant example would be to align the city clean air plan with the city climate plan where cities are required to develop both. It is more beneficial for the city to combine efforts and resources for these two plans.

3.9.2 Develop a communication plan[86]

Air quality communication involves the use of data to inform the general public and key stakeholders about air pollution issues. Communication for clean air aims to raise awareness, change attitudes, and foster behaviour change. A CAAP is relevant if the pollution control measures identified in the plan are adopted by policymakers and stakeholders. Communication promotes cooperation and collaboration by conveying the relevance and benefits of the measures to stakeholders. An effective air quality communication strategy considers the intended outcomes of the communication activities, target audience, key messagess, and communication channels to be utilized[87]. Communication materials such as report briefs, posters, flyers, online infographics, videos, and many other types of media can be developed once a communication strategy is in place. It is important to make sure the communication material is suitable and tailored towards the target audience.

Communication and outreach strategies are critical. Key stakeholders should be considered from the initial planning stages.

The public, who are affected by poor air quality, can be one of the most powerful motivators of political will, yet many low-income country residents do not fully understand the linkages between air quality and health outcomes and/or the sources that are the most important contributors to local air pollution. Investment efforts can focus on public information campaigns, education programs for public health and medical providers, and in many locations religious institutions and traditional leaders. Communication strategies often include analyses for:

- Who does the public listen to?
- Where do they get information, whom do they trust?

Raising awareness about elevated levels of air pollution is critical to building interest and concern in the public domain. Making air pollution more visible could play an important role in advocacy.

Communicating about the health risks of air pollution can also be effective and can engage a broader audience including the health sector. Several countries have devised Air Quality Indexes, which relate concentrations to a color scale with recommendations about which population sub-groups should take action to limit exposure.

Beyond local communication, high profile global events (e.g., a special session at the United Nations General Assembly on air pollution) provide a special opportunity to link global engagement around air pollution with country engagement around key issues. With some advance planning, high burden countries in Africa and South Asia could play a major leadership and convening role. If multisectoral engagement is extrapolated across the continuum of the air quality issues, then long range transboundary issues for air also become important for global discussion. Existing resources can be tailored to the local context for more effective communication with the public and decision-makers in specific locations.

Since emission sources often produce both air pollution and greenhouse gases, leveraging public awareness of one can have benefits for mitigating both issues.

The necessarily multisectoral approach includes a wide variety of stakeholders to support and influence air pollution initiatives through funding, advocacy, convening power, creative solutions, and more.

To be able to tackle pollution effectively, governments need an informed citizenry that has easy access to justice. Citizens must also be able to participate in decision-making and in protecting human health and environment from pollution. All citizens, including

85 German International Cooperation (GIZ) and Clean Air Asia (2015). Handbook on Clean Air Management in Smaller Cities. Pasig City. Philippines: Clean Air Asia
86 USAID (2019), LMIC Urban Air Pollution Solutions, BreatheLife2030
87 Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines

children, have the right to know, engage, and participate.[88]

Governments can ensure public access to information and protect fundamental freedoms in accordance with national legislation and international agreements and in line with Principle 10[89] of the Rio Declaration and the Bali Guidelines for the Development of National Legislation on Access to Information, Public Participation and Access to Justice in Environmental Matters.

Effective public participation can only be ensured through transparent and effective environmental information systems and disclosure based on data gathering, monitoring and open access to information on emissions to air, land, and water and in products known to the public through portals on pollutants being discharged, publishing standards, air and water monitoring systems, and permit systems of discharging wastewater or effluent, noise pollution permissible levels and so on. Open data and citizen science, such as in the role of water and air quality monitoring or the measurement of biological indicators such as bird or frog counts, also have a promising role to play.

Local authorities must also publish relevant information, such as in the case of air pollution, to all areas that are affected, so that the affected public can take the necessary measures to protect themselves. Information disclosure from the regulatory community is also needed for public supervision of compliance by industries and public institutions.[90]

Box 13: Ahmedabad Heat Action Plan

The Ahmedabad's Heat Action Plan is a comprehensive early warning system and preparedness plan for extreme heat events in Ahmedabad.

The main objective of this plan is to spread awareness amongst the public about how they can take immediate and long-term actions as precautionary measures against the extreme heat of Ahmedabad. The objectives also include increased preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations.

The communication is affected through the dissemination of public messages on how to protect people against extreme heat. This is done by making use of numerous media channels, for example distribution of informational materials such as pamphlets, print advertisements as well as television commercials addressing heat stress prevention and the use of social media. Online platforms like Facebook, Instagram and Twitter can be used, in addition to traditional media such as television and radio to reach people with information about risk prevention from extreme heat. Efforts also include sending text messages, emails and WhatsApp messages for communication of alerts.

Special efforts are made to reach vulnerable people through inter-personal communication as well as other outreach methods. The Ahmedabad Municipal Corporation has created formal communication channels to relay news about the forecasted extreme temperatures and alert governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups, and media outlets.

Source: Ahmedabad Municipal Corporation (2019), Ahmedabad Heat Action Plan, National Resources Defense Council and Indian Institute of Public Health, Gandhinagar.

88 United Nations Environment Programme (2017), Towards a Pollution-Free Planet – Background Report, United Nations Environment Programme, Nairobi, Kenya

89 Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

90 United Nations Environment Programme (2017), Towards a Pollution-Free Planet – Background Report, United Nations Environment Programme, Nairobi, Kenya

3.9.3 Formulate a monitoring and evaluation system

A monitoring and evaluation (M&E) system enables policy makers, stakeholders, and the public to take stock of the progress towards the CAAP's vision as well as their city's AQM goals[91].

Monitoring and evaluation provide a means for learning from the experience of implementing a plan or project as well as demonstrating results as part of accountability to stakeholders. The objective of the monitoring is to support the implementation of the measures proposed in the CAAP. The monitoring system is a summary of the main activities that need to be undertaken to implement the measures proposed. As the work plan is further detailed for each measure, the monitoring system should be further developed.

3.10 Integrating Clean Air Action Planning And Climate Change Mitigation Into City Development Planning

Air pollution and climate change are closely interconnected. Air pollutants and GHGs are produced by many of the same sources including fuel combustion in transport, power generation, household activities, industry, crop, and municipal waste burning[92]. There is however a clear difference in the spatial scales between air pollution and GHGs. Ambient air pollutants generally stay in the atmosphere for a short period (e.g., days or weeks), while GHGs such as CO_2 and CH_4 have lifetimes approximately 150 years and 12 years respectively.

Air pollutants and GHG emissions interact in the atmosphere, resulting in a variety of direct and indirect health and environmental impacts at the local, regional, and global level. Air pollutants cause direct impacts while GHGs lead to climate change with indirect effects on human health and the environment. Aside from the traditional definitions of air pollutants and GHGs, there are also short-lived climate pollutants (SLCPs) that are powerful climate forcers that remain in the atmosphere for a much shorter period of time than carbon dioxide (CO_2), but are known to warm the atmosphere many times more. Certain SLCPs are also air pollutants.[93]

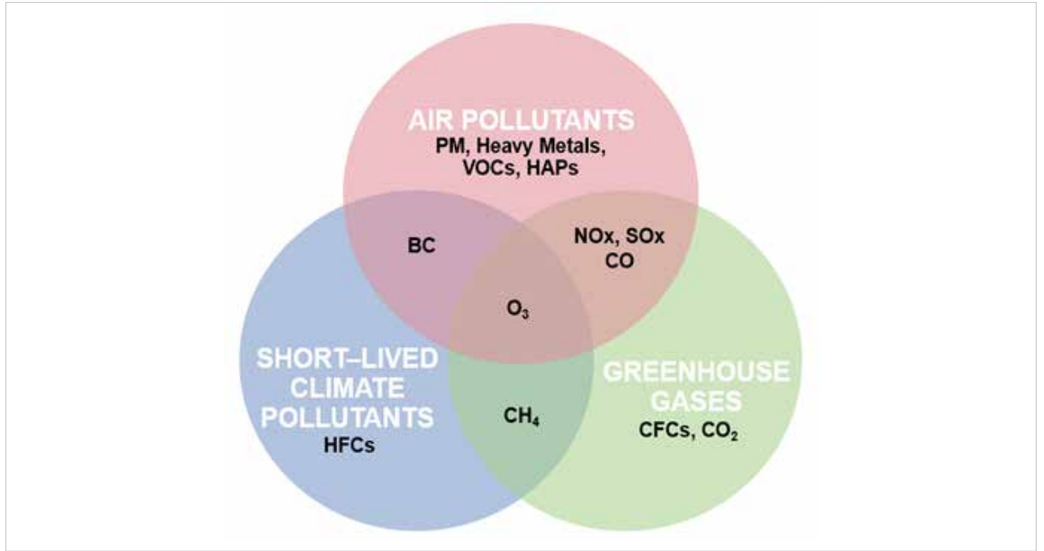

Figure 12: Venn diagram for air pollutants, GHGs, and SLCPs[94]

91 German International Cooperation [GIZ] and Clean Air Asia. (2015). Handbook for Clean Air Management in Smaller Cities. Pasig City, Philippines: Clean Air Asia

92 German International Cooperation [GIZ] and Clean Air Asia. (2015). Handbook for Clean Air Management in Smaller Cities. Pasig City, Philippines: Clean Air Asia

93 German International Cooperation [GIZ] and Clean Air Asia. (2015). Handbook for Clean Air Management in Smaller Cities. Pasig City, Philippines: Clean Air Asia

94 German International Cooperation [GIZ] and Clean Air Asia. (2015). Hndbook for Clean Air Management in Smaller Cities. Pasig City, Philippines: Clean Air Asia

Looking at air quality and climate change from an integrated perspective and addressing these issues simultaneously offers potential for large cost-reductions in public health and minimizing risks to ecosystems. Aside from maximizing resources, this approach allows for a more realistic accounting of potential impacts of a proposed policy or measure.

Co-controlling air pollution and GHGs will be more effective than targeting each one individually, particularly for developing countries in Asia where economic and social development is a higher priority than climate change mitigation (Clean Air Asia, 2015). However, it is important to note that measures targeting air pollution and GHG emission reduction can also contribute to economic and social development, such as cost savings on health care, reduction in deaths and diseases attributed to air pollution, improvement in food security and overall environmental sustainability.

Table 5: Examples of measures to reduce emissions of air pollutants and GHGs[95]

Measure	Effect on air pollutants	Effect on GHGs
Switching from coal to natural gas for power generation	Emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are reduced	Reduces carbon dioxide (CO_2) emissions for each kilowatt generated
Efficiency improvements in domestic appliances and industrial processes	Reduces emissions of both types of pollutant, but efficiency measures sometimes result in increased demand, which must be avoided	
Energy conservation (use less energy)	Reduces emissions of both types of pollutant.	
Use of new technologies in road transport, e.g. • hybrid vehicles • hydrogen from natural gas or from renewable energy sources • lean burn petrol vehicles fitted with nitrogen oxide traps	Reduces emissions of NO_x and particulate matter	Reduces CO_2 emissions for each kilometre travelled It is essential that the whole fuel/ vehicle cycle is analysed (e.g., the emissions associated with hydrogen generation)
Demand management/ behavioural change: improved public transport coupled with disincentives for private car usage.	Reduces emissions of both types of pollutant	

3.11 Clean Air Action Plans In City Development Plans

Considering that many cities have a master plan for urban development the plan would often incorporate, land use plans, zoning, infrastructure development plans, transport plans etc. As city circumstances differ from city to city, pollution sources and priorities, will vary accordingly. It will be important to incorporate the CAAP and align it with the city's master plans to avoid any policy and implementation conflicts. One way of doing this is by incorporating specific air quality objectives into city development plans. Ultimately this plan is important in ensuring the sustainability of finance mechanisms necessary to fund ongoing air quality action planning and implementation.

95 Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines

Box 14: Cleaner Air for Scotland: The Road to a Healthier Future

The Scottish Government in November 2015 released Cleaner Air Scotland – The Road to a Healthier future (CAFS), which provided a national framework that set out how the Government and its partner organisation propose to achieve reduction in air pollution. CAFS outlined the contribution that better air quality can make sustainable development whilst improving health and the natural environment and reducing inequalities.

A series of actions across a range of policy areas were outlined, and there were a number of important new initiatives:

- A National Modelling Framework
- A National Low Emission Framework
- Adoption of World Health Organization guideline values for particulate matter in Scottish legislation
- Proposals for a national air quality awareness campaign

The national framework was formulated for the period of 5 years from 2015-2020. They adopted a multisectoral as well as a multi stakeholder approach. They focused on health, legislations and policy, transport, climate change and most importantly communication. They Government ensured that every stakeholder in represented, and involved trade associations, institutions, industrial association, academia and all the key players who could assist and support in mitigating air pollution.

Source: The Scottish Government (2015), Cleaner Air for Scotland: The Road to a Healthier Future, Edinburgh.

Box 15: Air Quality Management in Oxford

This Air Quality Action Plan (AQAP), Oxford, United Kingdom, outlines the actions that will be taken to improve air quality in Oxford City from 2021 to 2025, this replaces the action plan which was earlier implemented in the year 2013.

The key objective of this AQAP is to bring NO_2 emissions into legal compliance as soon as possible. However, the Government also wants to reach beyond legal compliance for the whole city. Oxford City Council is committing to becoming the first UK Local Authority to set a local annual mean NO_2 target in a citywide AQAP. The overall objective of this AQAP for the whole of the Oxford City area is to:

Achieve a local annual mean NO_2 target of 30 $\mu g/m^3$ by 2025 - "**30 by 25**"

To be able to meet this target, we have developed a set of 30 actions and measures that we will deliver together with our partners and which sit within four priority areas of intervention:

- Developing partnerships and public education
- Support for the uptake of Low and Zero emission vehicles
- Reducing emissions from domestic heating, industry and services
- Reduce the need to travel, explore opportunities for mode shift and increase the uptake of sustainable transport

Source: Oxford City Council (2021), Air Quality Action Plan (AQAP) 2021 – 2025, United Kingdom.

3.12 Key Messages

This chapter provides an overview of Clean Air Action Planning (CAAP) and its use in cities, with a focus on India. It shows how a CAAP is a key feature of air quality management. The stages involved in the design and implementation of a CAAP are provided in detail. The initial stages involve assessing the requirements and hence the goals of the CAAP. The next stage is the development of the CAAP, which takes into account the control measures that will be undertaken and the implications of these measures upon efficacy of the intervention in addition to its cost-effectiveness and co-benefits. It is highlighted that CAAPs should be iterative processes and review and improvement should be hardwired into the CAAP. The importance of stakeholder engagement is highlighted, because a CAAP will only be effective if it widely understood and endorsed by the stakeholders. The role of the stakeholders is defined at the governmental, state and local levels of governance. The role of media and NGOs is also discussed. To engage stakeholders, an effective communication plan is required and details are provided on how to do this. A successful CAAP needs effective monitoring and evaluation systems. Throughout the chapter, there are multiple international examples provided of best practise in the design and implementation of a CAAP.

4. Relevance Of Air Pollution Data In Indian Cities

4.1 Introduction

Air pollution and its impact have become one of the most important challenges for public authorities. The quantification of emissions as well as their spatial distribution are essential for any air quality program.[96,97]

Air Quality Monitoring Network is an essential element within environmental management, in special emphasis to air quality management.[98] An air quality monitoring network (AQMN) is a basic piece of environmental management which satisfies the major role in monitoring of environment emissions, with special relevance to target air pollutants. An adequate installation would lead to support high efficiency of the network.[99]

Human well-being is a factor tied to the presence of clean air. According to the 68th World Health Assembly[100], each year, a total of 4.3 and 3.7 million deaths, result from exposure to indoor and outdoor air pollutants, respectively.

4.1.1 Urban air pollution

From smog in cities to smoke in the home, air pollution poses a threat to human health and the environment. Around 91% of the world's population at present live-in areas with unhealthy outdoor air, causing 4.2 million premature deaths each year.[101] In India, air pollution is responsible for an estimated 1.2 million premature deaths each year and is costing the economy an estimated 3% of Gross Domestic Product (GDP).[102]

96 Mauro Rotatori, Rosamaria Salvatori and Roberto Salzano, Planning Air Pollution Monitoring Netwroks in Industrial Areas by means of remote sensed images and GIS Techniques, IntechOpen, July 2011
97 V. Aleksandropoulou and M. Lazaridis, Spatial Distribution of gaseous and particulate matter in Greece, Water, Air and Soil Pollution, March 2004
98 David Galán Madruga, May (2020) Importance of Air Quality Networks in Controlling Air Pollution, IntechOpen
99 ibid
100 World Health Organization. Sixty-eighth World Health Assembly. A68/18. In: Health and the Environment: Addressing the Health Impact of Air Pollution. World Health Organization (WHO); 2015
101 WHO (2020) Air Pollution
102 State of Global Air (2019) India, Health Effects Institute, USA

Urban air pollution affects the health, wellbeing, and life chances of hundreds of millions of men, women, and children every day. Exposure to fine particulate matter ($PM_{2.5}$) pollution has been identified as the largest risk to human health.[103] This is due to their small size (less than 2.5 micrometres (μm)), which enables $PM_{2.5}$ particles to penetrate deep into the lungs where they can cause serious negative health impacts.

Indian cities have high annual mean concentrations of $PM_{2.5}$ which typically exceed the 40 $\mu g/m^3$ limit set by the National Air Quality Standards (NAAQS). In 2015, an estimated 670 million people in India were exposed to $PM_{2.5}$ concentrations that did not comply with the NAAQS.[104]

The state of air quality in cities is closely connected to the earth's global climate and ecosystems. Many of the causes of air pollution (i.e., combustion of fossil fuels) are also sources of greenhouse gas (GHG) emissions. Air pollution can affect the regional climate. Black carbon is among the pollutants that deposit on snow and ice, darkening the surfaces.

This causes greater absorption of sunlight and faster melting, threatening future water availability and ecosystem productivity.[105] Black carbon, a PM created through the burning of fossil fuels (such as diesel) and biomass, not only affects human health but is also responsible for glacial melting[106].

Policies that reduce air pollution can be beneficial for the global climate and human health; lowering the burden of disease attributable to air pollution while contributing to the near- and long-term mitigation of climate change.

Box 16: Clean Air Scorecard Tool

The Clean Air Scorecard Tool (CAST) is an Excel-based tool incorporating three indices:

1. Air Pollution and Health
2. Clean Air Management Capacity
3. Clean Air Policies and Actions.

It was developed with support from Asian Development Bank (ADB) and the Swedish International Development Cooperation Agency (SIDA) to help cities have a comprehensive understanding of the status of their AQM.

For a city to be considered as having a 'developed' AQM status, there is a need to have a high level of information and dissemination of air quality and health data. In terms of assessment, this involves the availability of data and information for estimating health impacts of air pollution, processes for estimating health impacts of air pollution, capacity for estimating impacts in relation to health data, and the results of health impacts assessment communicated to stakeholders, including policy makers for awareness raising and policy development purposes. Planning and implementation require developing short-, mid- and long-term targets, aligning health impact assessment planning with city/regional environmental, development or other sectoral plans, ensuring multi-stakeholder participation and allocating financial resources. In addition, it includes institutional arrangements for conducting health impact assessment and developed capacity for conducting such assessments.

103 Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., AlMazroa, M.A., Amann, M., Anderson, H.R., Andrews, K.G., Aryee, M., Atkinson, et al, 2012, The Lancet 380, 2224–2260.
A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010.

104 International Institute for Applied Systems Analysis/Council on Energy, Environment and Water, New Delhi, India., 2019
Pathways to achieve national ambient air quality standards in India.

105 Lacombe, G., Chinnasamy, P., and Nicol, A. (2019) Climate risk and solutions: adaptation frameworks for water resource planning, development and management in South Asia. International Water Management Institute, Colombo, Sri Lanka.

106 Li, C. et al. (2016) Sources of black carbon to the Himalayan–Tibetan Plateau glaciers. Nature Communications, 7: 12574.

Figure 13: Overall Structure of the Clean Air Scorecard

4.2 Urban Air Data

The deterioration of air quality in urban areas is often closely related to urban development, public facilities, and traffic patterns.[107] As urbanization has resulted in rapid population growth and increased economic activities, this has led to changes in land use and transportation modes, which have also led to a significant increase in energy consumption and the massive emission of air pollutants, thereby exacerbating the current state of air pollution[108]. The main factor is the different patterns of urban planning or development, which can affect building height, spacing between adjacent buildings, and building layout in cities, thereby influencing the dispersion and accumulation of different air pollution sources in different ventilation environments. On the other hand, urban spatial patterns and land use types can also have a relatively significant impact. Therefore, by adopting reasonable planning methods, it should be possible to create the appropriate urban wind environment and microclimate, which will improve the air quality of urban areas.[109]

Monitoring data on air pollution (by type), location of specific air quality problems and main polluting sources, concentration of respiratory diseases, distribution of citizens' complaints, etc are all relevant information that can be plotted.

107 Chia-An Ku, 2020. "Exploring the Spatial and Temporal Relationship between Air Quality and Urban Land-Use Patterns Based on an Integrated Method," Sustainability, MDPI, Open Access Journal, vol. 12(7), pages 1-16, April.

108 Fang, C.; Liu, H.; Li, G.; Sun, D.; Miao, Z (2015) Estimating the impact of urbanization on air quality in China using spatial regression models. Sustainability, 7, 15570–15592

109 Chia-An Ku, 2020. "Exploring the Spatial and Temporal Relationship between Air Quality and Urban Land-Use Patterns Based on an Integrated Method," Sustainability, MDPI, Open Access Journal, vol. 12(7), pages 1-16, April.

Box 17: Air Quality Model Classification

Air quality models cover (either separately or together) atmospheric phenomena at various temporal and spatial scales. Urban air models generally focus from local to regional scale. Models can be broadly divided into two types namely physical and mathematical.

Physical models involve reproducing urban area in the wind tunnel. Scale reduction in the replica and producing scaling down actual flows of atmospheric motion result in limited utility of such models. Moreover, these are economically undesirable.

Mathematical models use either statistics to analyse the available data or mathematical representation of all the process of concern. The second type of mathematical models is constrained by the ability to represent physical and chemical processes in equations without assumptions.

Statistical model is simple but they do not explicitly describe causal relationships and they cannot be extrapolated beyond limits of data used in their derivation. Thus, dependence on past data becomes their major weakness. These cannot be used for planning as they cannot predict effect of changes in emissions.

Source: Anjali Srivastava and B.Padma S. Rao (2011), Urban Air Pollution Modelling, IntechOpen.

Box 18: CAST Assessment of Air Quality in Indian Cities

An assessment by Clean Air Asia (in 2017) of twenty Indian cities (Agra, Amritsar, Bengaluru, Bhopal, Bhubaneswar, Chandigarh, Chennai, Coimbatore, Dehradun, Indore, Jaipur, Kanpur, Kochi, Ludhiana, Nagpur, Patna, Pune, Raipur, Ranchi, and Varanasi) found that all cities exceed the annual PM_{10} standard (60 µg/m). Major sources of PM_{10} include combustion of coal, kerosene, petrol, diesel, biomass, cow dung, waste as well as dust. Coimbatore reported numbers just above the standard.

Six cities (Agra, Bengaluru, Jaipur, Kanpur, Ludhiana, and Raipur), recorded 4–6 times higher levels than the annual standard. These are among the fastest growing Indian cities, traditionally known to be dusty due to a lot of construction activities and dust on the roads which is resuspended when vehicles pass by these areas.

All cities comply with the annual SO_2 standard (50 µg/m). Major sources of SO_2 include combustion of coal. The three most populated cities (Bengaluru, Chennai, and Pune) recorded the highest SO_2 concentrations.

Nine out of the twenty cities exceed the annual NO_2 standard (40 µg/m). Major sources of NO_2 include combustion of petrol, diesel, and gas (i.e., transport related emissions) and large industries. Bengaluru, Chennai, Jaipur, Nagpur, Kanpur, and Pune recorded the highest concentrations of NO_2.

The study made several recommendations to control pollution and develop management skills:
Kochi and Chennai lie on the coast and host large commercial ports. Freight movement (i.e. ships and on roads heavy duty trucks) is a major source of $PM_{2.5}$ and SO_2 pollution. This sector can benefit from a freight management programme. For example, movement of freight on rail, restrictions on vehicle types entering the port area, restrictions on the fuel quality used by ships anchored at the ports. The decision makers and other key officials can develop professional knowledge and skills by learning about how these measures operationalized and different measures taken to reduce the air pollution emissions through freight management programme in Kochi and Chennai.

- All the cities need to promote public transport systems and non-motorized transport (walking and cycling) to reduce vehicle use and associated emissions including on-road dust. By 2030, the vehicle exhaust emissions are expected to remain constant or tend lower, if Bharat VI (equivalent of Euro-VI) fuel standards are introduced nationally by 2020, as recommended by the Auto Fuel Policy. The decision makers can develop professional knowledge on the subject of public transport system and utilize these skills in air quality management.
- All the 20 cities lack a comprehensive waste management system. The practice of open waste burning which contributes to air pollution is hard to regulate and monitor. The decision makers and other key officials need to develop their professional knowledge on how to reduce waste generation, to collect waste more efficiently, and manage collected waste. This can be done by understanding the norms given in Solid Waste Management Rules, 2016.
- Coal-fired power plants and large industries with captive power plants should meet stricter national emission standards for all the criteria pollutants to reduce their contribution to urban air quality. The professional knowledge can be enhanced by decision makers by the strengthening of legal frameworks such as tightening of coal-fired power emission standards and recommendation to improve professional skills through strengthened capacity to implement the standards and related regulations. The study stated that air monitoring capacity and data fall very short of expectations, in all the cities. Chennai, Bengaluru, Kanpur, Agra and Nagpur monitor at 25-30% of the recommended capacity. The regulatory authorities can build on their core skills to improve addressing the air pollution problem. This can be done by enhancing the capacity building on data management.

Source: Clean Air Asia (2018), Air Quality Management in India: Status of 30 Cities

Air Pollution data can be generated in multiple ways and for different purposes. The following methods are discussed below[110]:

4.2.1 Monitoring the pollution

Monitoring air quality provides the necessary baseline information to identify which pollutants are of major concern and are principal sources of pollution. Continuous monitoring is necessary to clarify air quality issues in greater depth and certainty. The reliability of the monitoring is critical. The methodology used for monitoring must be sound. Actual monitoring must be well documented. Both low-tech and high-tech methods of monitoring are readily available and each one has its advantages and disadvantages. Whichever technology is chosen must be appropriate in terms of the technical capability of the users and the availability of the resources to operate and maintain the technology.

There are basically four ways to measure urban air quality:

1. Passive Samplers
2. Active Samplers
3. Continuous Analyzers
4. Remote sensors

Many cities measure the quality of the city's air through monitoring stations. These stations measure the concentration of pollutants in the air, usually including SO_2, NO_x, PM_{10} or SPM, VOCs, etc. The measurements of these air pollutants can be done continuously or on a regular (e.g., weekly) basis. The different sampling stations can either work independently or can have direct connections to a central station. This information can be displayed in a time series, showing the change in concentration of the pollutant over time.

4.2.2 Calculating/estimating air pollution

Measuring air pollution can be very expensive. Not all cities have extensive monitoring networks and/or mobile monitoring equipment. Models and calculations are increasingly being used in many cases as this kind of equipment is scarce or the capacities to appropriately analyse samples is weak. Computer models are a relatively fast and inexpensive way of providing air quality information. Because models can be used to evaluate air quality management options, they are also suitable for planning and strategy development.

4.2.3 Use of mapping

Mapping is also a very useful tool to display information and clarify queries. Thematic maps will be useful in analysing the extent of the pollution problem from each activity sector.

110 UNEP-UNHSP, Urban Air Quality Management Toolkit, accessed on 17th June,2021

4.2.4 Emissions inventories

Preparing an Emission Inventory is a compilation of all air polluting activities in an area. It has two main components:

1. The pollutants (e.g., NO_X, SO_2) and
2. The sources (e.g., industry, traffic, and domestic)

It specifies the location of each source (point source or mobile source) and the time variations in the emissions. Emission inventories can be of great assistance in clarifying air quality issues because they, among other things, assist in the evaluation of emission trends, which in turn assist in formulating air quality management policies.

Utilizing air monitors with Internet of Things (IoT) technology, smart cities can efficiently gather and analyse localized air pollution data across their communities to make better decisions for citizens. For example, studies[111] link traffic pollution to poor academic performance. Urban planners utilizing a network of air quality monitors can obtain insights into the best placement for a new school to minimize student exposure to harmful air.[112]

4.3 Key Messages

Air quality monitoring is that part of an AQMS, that relates to areas in which air quality is required to comply with air quality standards or guidelines and/or population exposure or exposure of the environment to air pollution has to be estimated.

The technical aspects of urban air pollution are well understood while the necessary technologies for improving air quality are available on a larger scale. Compared to earlier times, today's citizens are generally better informed about the kind of air pollution they are exposed to and are increasingly unwilling to let the problem continue, let alone worsen. A growing political commitment to improve air quality can be observed in many cities. In order to convert these new attitudes into action, decision makers require a systematic approach to managing a city's air quality that also deals with the complex and difficult issues connected to the problem. Monitoring air quality provides the necessary baseline information to identify which pollutants are of major concern and are principal sources of pollution. Continuous monitoring is necessary to clarify air quality issues in greater depth and certainty. The reliability of the monitoring is critical. The methodology used for monitoring must be sound. Actual monitoring must be well documented. Both low-tech and high-tech methods of monitoring are readily available and each one has its advantages and disadvantages. Whichever technology is chosen must be appropriate in terms of the technical capability of the users and the availability of the resources to operate and maintain the technology.

111 Jennifer Heissel, Claudia Persico and David Simon (2019), Does Pollution Drive Achievement? The Effect of Traffic Pollution on Academic Performance, NBER Working Paper Series.
112 SmartCitiesDive (2020), Growing Cities to Monitor Air Quality for Urban Planning.

5. Health Impacts Of Air Pollution

5.1 Introduction

Stewardship of planet Earth is perhaps the biggest responsibility that humans hold. Humans live in the thin layer of atmosphere that covers the Earth, which reaches approximately 300 km high above the Earth's surface, but most of the air we breathe is held within the lowest 10 km of the atmosphere. To provide comparison, the diameter of the Earth is 12,742 km. Hence, every effort must be made to make this essential planetary resourceful is not polluted to the disadvantage of humans and ecosystems.

So, what is the air that is being referred to as being polluted? Earth's atmosphere is made up of a clear mixture of gases with no color or smell. It is predominantly composed of two gases: nitrogen (78 percent) and oxygen (21 percent), with lesser amounts of argon, carbon dioxide, hydrogen, neon, helium and other gases. Air has weight, and creates atmosphere pressure.

The atmosphere is a complex dynamic system that is essential for life on planet Earth.[113] It can be viewed as a giant safety blanket for Earth that keeps the temperature on Earth's surface within safe operating limits for human and ecosystems. It stops the surface temperatures from dipping to extreme icy temperatures that would freeze everything solid, or from soaring to blazing heat that would burn up all life.

The atmosphere is divided into several layers of air namely: troposphere, stratosphere, mesosphere, thermosphere, and exosphere. In the study of air pollution control, the layers of the air that are most important are the troposphere and the stratosphere.[114] The troposphere is important because that is where humans reside and it is tropospheric air that we breathe. (See Figure 14)

113 Air Pollution, Science Daily
114 Air Pollution Sources and Effects, Prabha Prabhat, 2009

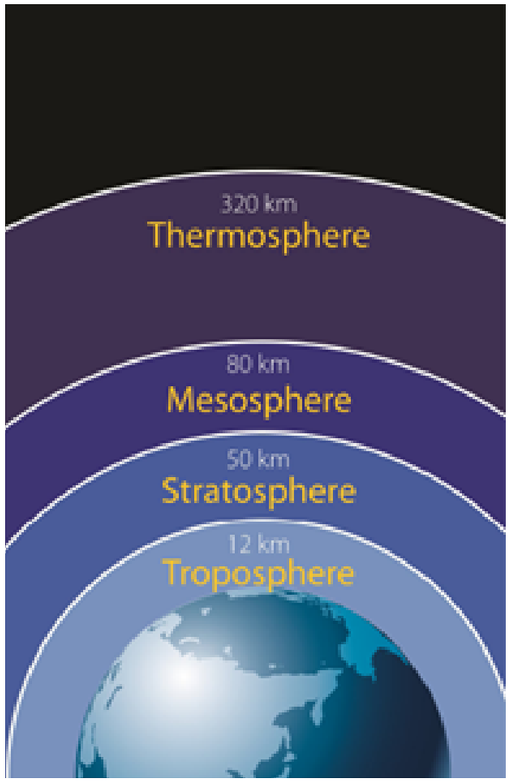

Figure 14: Layers of Atmosphere

Within the stratosphere, there is the ozone layer. Ozone (O_3) is a special form of oxygen, and the ozone layer is critical for life on Earth. The ozone layer blocks large amounts of damaging solar ultraviolet radiation, which can cause skin cancer and other ailments, from entering the troposphere. Too much solar radiation can harm living things, including people. It is damage to these two atmospheric layers, the troposphere and stratosphere, that puts life on earth at risk.[115]

5.1.1 What is air pollution and how does it occur?

Air pollution is the introduction of chemicals, particulate matter, or biological materials into the atmosphere that cause harm or discomfort to humans and other living organisms, or damages the natural environment.[116]

In theory, air has always been polluted to some degree. Natural phenomena such as volcanoes, windstorms, decomposition of plants and animals, and even the aerosols emitted by the ocean 'pollute' the air. However, the pollutants usually referred to when talking about air pollution are those generated as a result of human activity, such as driving motor vehicles, burning of coal, oil and other fossil fuels, and manufacturing chemicals. Air quality is affected in many ways by the pollution emitted from these sources.[117]

Outdoor ambient air is the air to which the general public has access, i.e. any unconfined portion of the atmosphere. There are hundreds of pollutants in ambient air. Air pollutants can be in the form of solid particles, liquid droplets, or gases, which can be classified as either primary or secondary. Primary pollutants are substances directly emitted from a process, such as ash from a volcanic eruption, carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from powerplants and factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact.

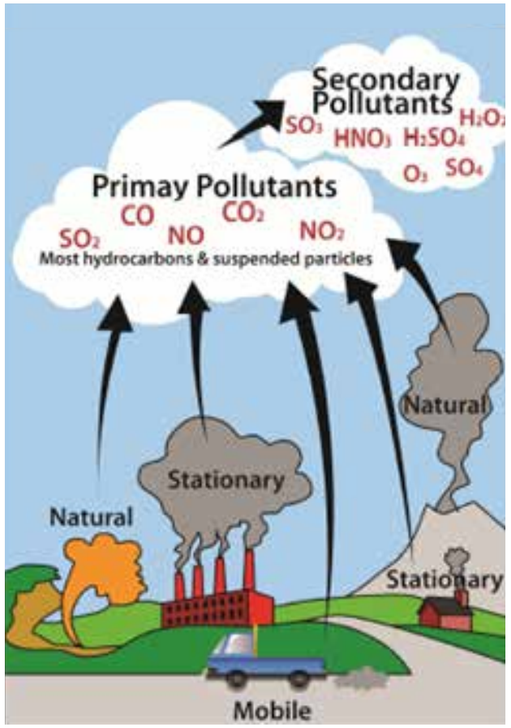

Figure 15: Sources of Air Pollution

115 Conrad Storad, What is Atmosphere? August, 2009
116 Gary Hutton, A Scorecard for Humanity: Air Pollution, 2011
117 Air Quality, Air Quality Standards and Planning, United States Environmental Protection Agency

Examples of major primary air pollutants produced by human activity include Particulate Matter (PM), Sulfur Oxides (SO_x) Nitrogen Oxides (NO_x), Carbon monoxide (CO), and Volatile organic compounds (VOCs). Secondary air pollutants on the other hand include ground level O_3, and smog. Smog is the haze that can cover large areas and is composed of both gaseous and particulate air pollution. The word smog comes from the combination of 'fog' and 'smoke'.

For regulatory purposes, air pollutants are further classified as criteria pollutants and hazardous air pollutants (HAPs). Criteria pollutants are pollutants that have been identified as being both common and detrimental to human welfare[118]. Hazardous air pollutants or air toxics are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.[119]

5.2 Effects Of Air Pollution On Human Health And Ecosystems

5.2.1 Effects on human health

A healthy adult human breathes about 16 kilograms of air every day. Ambient air pollution has significant impacts on human health. Many air pollutants have been classified as carcinogenic, and cause a variety of respiratory, cardiovascular diseases and physiological disorders in humans (see Figure 16).

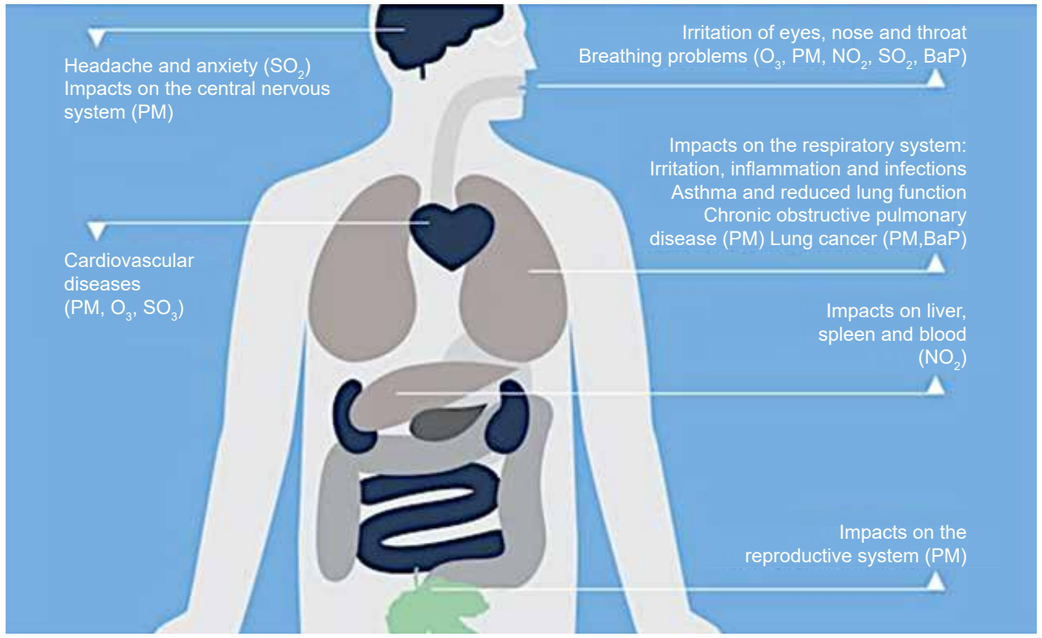

Figure 16: Air Pollution and Health[120]

Air pollution can affect our health in many ways with both acute (short-term) and chronic (long-term) effects. Acute effects are usually immediate and often reversible when exposure to the pollutant ends[121]. Some acute health effects include eye irritation, headaches, nausea, and upper respiratory infections such as bronchitis and pneumonia. Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends[122]. Some chronic health effects include decreased lung capacity, heart disease, lung cancer, and even damage to the brain, nerves, liver or kidneys resulting from long-term exposure to toxic air pollutants. There is growing evidence that air pollution not only affects physical health but also mental and cognitive health.

118 EVS Project, Jinjus
119 Ambient Air Monitoring Program, Georgia Air Monitoring
120 EEA (2014) Health impact of air pollution. European Environmental Agency, Copenhagen, Denmark.
121 G. Kavin, M. Anbalakan and Dr. N. Shivasankaran, Air Pollutions Effect and Control methods in Foundrie Industries, International Journal of Engineering Research and Technology, 2007
122 ibid

Different groups of individuals are affected by air pollution in different ways. Some individuals are much more sensitive to pollutants than others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted[123].

Individual reactions to air pollutants also depend on the individual's health status and genetics. The extent to which an individual is harmed by air pollution usually depends on their total exposure to the damaging chemicals, i.e. both the duration of exposure and the concentration of the chemicals must be taken into account. Therefore, air pollution exposure is dependent on where people live, work and how they travel in between. Certain occupations, for example those who work near roads, are likely to receive greater exposures.

Both gaseous and particulate air pollutants can have negative effects on the lungs. Solid particles can settle on the walls of the trachea, bronchi, and bronchioles. Most of these particles are removed from the lungs through the cleansing (sweeping) action of 'cilia', small hair like outgrowths of cells, located on the walls of the lungs[124]. This is what occurs when you cough or sneeze.

The lungs are the organs responsible for absorbing oxygen from the air and removing carbon dioxide from the blood-stream. Damage to the lungs from air pollution can inhibit this process and contribute to the occurrence of respiratory diseases such as bronchitis, emphysema, and cancer. This can also put an additional burden on the heart and circulatory system.[125]

Air pollution also influences visibility. Visibility defines the distance that an observer can differentiate between an object and the background. Visibility is often a measure of aesthetic value and the ability to enjoy scenic views, but it also can be an indicator of general air quality. Visibility degradation results when light encounters tiny pollution particles (commonly composed of the following chemicals: sulfates, nitrates, organic carbon, soot, and soil dust) and some gases (nitrogen dioxide) in the air. Some light is absorbed by the particles and other light is scattered away before it reaches the observer. More pollutants mean more absorption and scattering of light, resulting in more haze. Haze obscures the clarity, color, texture, and form of what we see. High humidity magnifies the haze problem because some particles, such as sulfates, attract water under high humidity and grow in size, scattering more light.[126] Poor visibility can contribute to accidents, injuries and loss of life.

Figure 17: Reduced Visibility (Image by Rahmad Gunawan)

123 Public health, environmental and social determinants of health, World Health Organisation
124 Richa and Smirti, Malfunctioning of Pulmonary Health, International Journal od Geology, Earth and Environmental Sciences, Volume 1 Issue 2, 2014
125 Air Pollution Effects on Lungs
126 Nicole Pauly Hyslop, Impaired visibility: the air pollution people see, Atmospheric Environment, Volume 43, 2009

Table 6 summarizes the sources, health, and welfare effects for the criteria pollutants as per Environmental Protection Agency and Central Pollution Control Board. Hazardous air pollutants may cause other less common but potentially hazardous health effects, including cancer and damage to the immune system, and neurological, reproductive, and developmental problems.

Table 6: Sources, health, and welfare effect for criteria pollutants

Pollutant	Sources	Health effects	Welfare effects
Carbon mon-oxide (CO)	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death	Contribute to the formation of smog
Sulfur dioxide (SO_2)	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage
Nitrogen di-oxide (NO_2)	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing)	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment
Ozone (O_3)	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage	Plant and ecosystem damage
Lead (Pb)	Metal refineries, lead smelters, battery manufacturers, iron and steel producers	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ	Affects animals and plants, affects aquatic ecosystems
Particulate matter (PM)	Diesel engines, power plants, industries, windblown dust, wood stoves	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects	Visibility impairment, atmospheric deposition, aesthetic damage

Source: www.epa.gov

As an emerging economy, India, is accelerating its growth rate to reduce its widespread poverty. This rapid development has simultaneously increased the challenge of air pollution. Ironically, air pollution affects the health, employability, and coping capabilities of those living in poverty the most.

In Indian cities, poor air quality is a serious concern because of its impact on human health. Long-term exposure to air pollution has shown that people living in more polluted locations die prematurely, compared with those living in areas with lower levels of pollution.

5.2.2 Estimates of burden of disease due to air pollution globally and in India

The WHO estimate 4.2 million premature deaths globally are linked to ambient air pollution, mainly from heart disease, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, and acute respiratory infections in children. Research indicates that cities worldwide show that when air pollution levels increase, so do the number of deaths.

In India, WHO estimates that exposure to ambient air pollution, particularly $PM_{2.5}$, have caused 6.73 lakh premature deaths nationwide (2017). Furthermore, over 38 million years[127] of healthy life were lost due to air pollution in 2017. The Global Burden of Disease (GBD) study[128] ranks air pollution as the fifth most important risk of premature death worldwide.

The GBD study shows that India has the second largest share of the ambient $PM_{2.5}$ related deaths worldwide with an estimated 6.73 lakh deaths in 2017. Approximately 23% of these cases are in India. This is also the case with premature deaths worldwide due to ground-level O_3 exposure, with India accounting for approximately 31% of such deaths or 1.45 lakh cases (2017).

Table 7 summarises in detail, the effect criteria pollutants as well as toxic air pollutants, secondary pollutants, VOC and heavy metals have on human health.

Table 7: Health impact of air pollutants[129]

Pollutant	Potential Health Impact
Particulate matter (PM_{10})	Exposure to particles of aerodynamic diameter less than 10 µm can pose a variety of problems, including: • Decreased lung function • Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty in breathing • Irregular heartbeat • Nonfatal heart attacks • Aggravated asthma • Emergency department visits • Hospital admissions for cardiovascular or respiratory diseases • Premature death in people with heart or lung disease People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.
Sulphur dioxide (SO_2)	Short-term exposures to SO_2 can affect the human respiratory system and make breathing difficult. Children, the elderly, and asthmatics are particularly sensitive to the effects of SO_2.
Ozone (O_3)	Short-term inhalation exposure to O_3 can cause the following impacts: • Difficulty to breathe deeply and vigorously • Shortness of breath, and pain when taking a deep breath • Coughing and sore or scratchy throat • Inflame and damage the airways • Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis • Make the lungs more susceptible to infection • Continue to damage the lungs even when the symptoms have disappeared • Chronic obstructive pulmonary disease • Increased school absences • Increased medication use, visits to doctors and emergency rooms, and hospital admissions • Increased mortality
	Long-term exposure to O_3 can aggravate asthma and is likely to be one of the many causes of asthma development. Long-term exposures to higher concentrations of O_3 causes asthma development and may also be linked to permanent lung damage, such as abnormal lung development in children, as well as increasing the risk of death from respiratory causes.
Nitrogen dioxide (NO_2)	Short-term inhalation exposure due to a high concentration of NO_2 can irritate human airways and aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency departments. Long-term exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. Asthmatics, as well as children and older people, are generally at a greater risk for the health effects of NO_2. Older people are more vulnerable to the negative health effects of NO_2.
Carbon monoxide	Inhalation exposure to high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain. It can also cause dizziness, confusion, chest pain, unconsciousness, and death. Such levels can be of particular concern for people with some types of heart disease, reduced ability for getting oxygenated blood to their hearts in situations when exercising or under increased stress.
Benzene (C_6H_6)	Short-term inhalation exposure of humans to C_6H_6 may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation. At high levels, C_6H_6 can cause unconsciousness. Long-term inhalation exposure can cause various disorders in the blood such as reduced numbers of red blood cells, and leukaemia (cancer of the tissue that form white blood cells) in humans occupationally exposed to C_6H_6.
Arsenic (As)	Short-term inhalation exposure to high levels of As dust or fumes can cause gastrointestinal effects such as nausea, diarrheal and abdominal pain. Inorganic As compounds can cause peripheral nervous system disorders in occupationally exposed humans. Long-term inhalation exposure to inorganic arsenic compounds can lead to irritation of the skin and mucous membranes, effects in the brain and gastrointestinal system, anaemia, peripheral neuropathy, skin lesions, hyperpigmentation, liver or kidney damage, and lung cancer. Ingestion of inorganic as compounds can cause skin, bladder, liver, and lung cancer.
Cadmium (Cd)	Short-term inhalation exposure to Cd compounds may cause pulmonary irritation. Long-term inhalation or oral exposure can cause kidney disease.
Chromium (Cr)	Short-term inhalation exposure to CrVI compounds can cause shortness of breath, coughing, and wheezing. Long-term inhalation exposure to CrVI compounds can cause perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and lung cancer.
Lead (Pb)	Inhalation and ingestion exposure of Pb compounds can cause effects on the blood, as well as the nervous, immune, renal and cardiovascular systems. Early childhood and prenatal exposures are associated with slow cognitive development and learning deficits. Ingestion exposure to high amounts of lead can cause gastrointestinal symptoms, severely damage the brain and kidneys, and may cause reproductive effects.

127 The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries.

128 The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) is the single largest and most detailed scientific effort ever conducted to quantify levels and trends in health.

129 Clean Air Asia (2018) Mainstreaming air quality in urban development in Asia. Clean Air Asia, Manila, the Philippines.

Pollutant	Potential Health Impact
Mercury (Hg)	Short-term exposure to high levels of elemental Hg can result in central nervous system (CNS) effects such as tremor, mood changes, and slowed sensory and motor nerve function. Long-term exposure to elemental Hg can affect the CNS, with effects such as increased irritability, excessive shyness, and tremors. Short-term ingestion exposure to inorganic Hg compounds may result in effects such as nausea, vomiting, and severe abdominal pain. Long-term exposure to inorganic Hg compounds can cause kidney damage. Short-term exposure to methyl mercury can cause CNS effects such as blindness, deafness, and impaired level of consciousness. Long-term exposure to methyl mercury can affect the CNS with symptoms such as a sensation of pricking on the skin, blurred vision, malaise, speech difficulties, and constriction of the visual field. Ingestion exposure of methyl mercury of pregnant women to high levels of methyl mercury can cause mental retardation, ataxia, and constriction of the visual field, blindness, and cerebral palsy in new born children.
Nickel (Ni)	Short-term inhalation exposure to Ni can cause respiratory effects. Long-term inhalation exposure to Ni compounds (Ni refinery dust and Ni subsulfide) may result in an increased risk of lung and nasal cancers.

As per World Health Organisation the ambient air pollution in both urban and rural areas is estimated to cause 4.2 million premature deaths worldwide. Population of the low- and middle-income countries disproportionately experience the burden of outdoor air pollution with more than 89% facing this burden. The greatest burden is in South Asia and some parts of East Asia and Western Pacific region with more than 3 million premature deaths every year.[130] Latest burden estimation reflects the significant role played by the ambient or outdoor air pollution in cardiovascular illness and death. WHO estimated in 2016, that 58% outdoor air pollution related premature deaths were due to ischemic heart disease and stroke.[131] Some deaths may be attributed to multiple risk factors, for example a combination of smoking and ambient air pollution increases the risk of developing lung cancer. Some lung cancer deaths could have been averted by improving ambient air quality or by reducing tobacco smoking.

WHO's, International Agency for Research on Cancer (IARC) concluded in an assessment in 2013, that ambient air pollution is carcinogenic to human, with the PM component of air pollution closely associated with increasing cancer incidences, especially lung cancer. An association also observed between outdoor air pollution and increase in cancer of the urinary bladder/tract[132].

5.2.3 Emerging evidence linking poor air quality to COVID-19

We know that air pollution can cause health problems, like heart attacks, strokes, diabetes, and high blood pressure, that have been identified as the pre-existing medical conditions[133] that raise the chances of death from COVID-19 infection. Emerging research, including a study from Harvard T.H. Chan School of Public Health[134], finds that breathing more polluted air over many years may itself worsen the effects of COVID-19.

Long-term exposure to air pollution has been linked to an increased risk of dying from COVID-19 and, for the first time, a study has estimated the proportion of deaths from the coronavirus that could be attributed to the exacerbating effects of air pollution for every country in the world.[135]

Study by Xiao Wu and Rachel Nethery and senior author Francesca Dominici found an association between air pollution over many years with an 11% increase in mortality from COVID-19 infection for every 1 microgram/cubic meter increase in air pollution (for comparison, many Americans breathe air with 8 micrograms/cubic meter of particulate matter).

Estimates for individual countries show, for example, that air pollution contributed to 29% of coronavirus deaths in the Czech Republic, 27% in China, 26% in Germany, 22% in Switzerland, 21% in Belgium, 19% in The Netherlands, 18% in France, 16% in Sweden, 15% in Italy, 14% in the UK, 12% in Brazil, 11% in Portugal, 8%in the Republic of Ireland, 6% in Israel, 3% in Australia and just 1% in New Zealand.[136]

130 Ambient (Outdoor) air pollution
131 Ambient (outdoor) Air Pollution
132 ibid
133 Jing Yang, Ya Zheng, Xi Gou, Ke Pu, Zhaofeng Chen, et al., Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis, International Journal of Infrctious Diseases, 2020
134 X. Wu, R.C. Nethery, M.S..Sabath, D. Barun, and F. Dominici, et. Al, Air pollution and COVID-19 mortality in the United States: Strengths and limitations of an ecological regression analysis, Science Advances, Volume 6, Issue 45, 2020
135 European Society of Cardiology (2020), Study estimates exposure to air pollution increases COVID-19 deaths by 15% worldwide

5.2.4 Effects on the ecosystem

5.2.4.1 Greenhouse Effect

The earth's climate is fuelled by the sun. Most of the sun's energy incident upon the earth, called solar radiation, is absorbed by the earth, but some is reflected into space. Clouds and a natural layer of atmospheric gases absorb a portion of earth's heat and prevent it from escaping into space. This keeps our planet warm enough for life and is known as the natural 'greenhouse effect'. Without the natural greenhouse effect, the earth's average temperature would be much colder, and the planet would be uninhabitable.

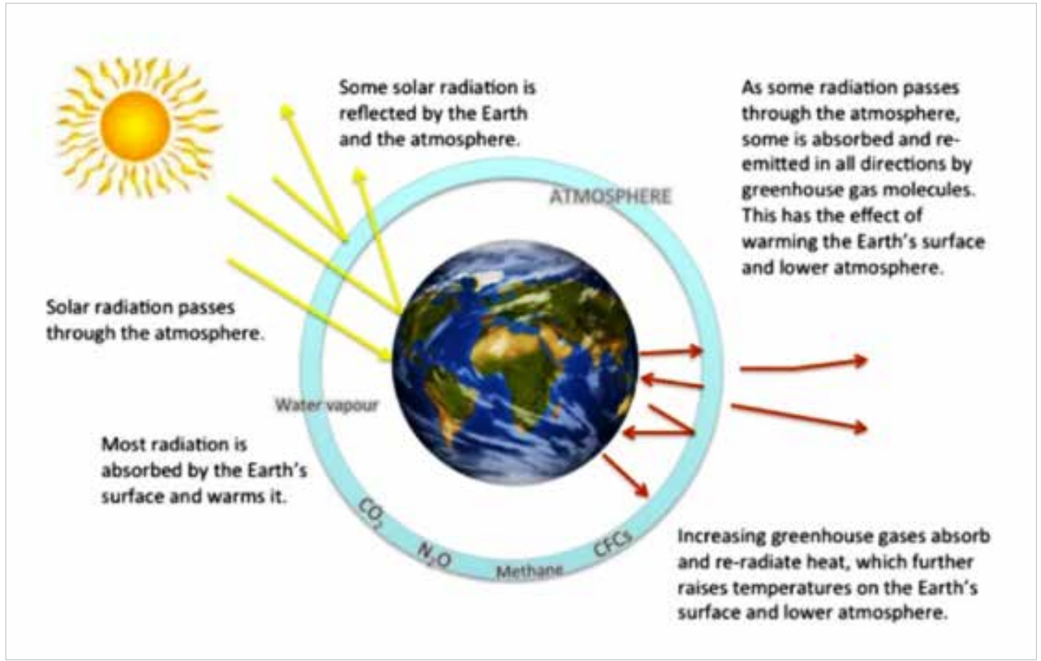

Figure 18: Greenhouse Effect

Scientific evidence shows that the greenhouse effect is being increased by the release and accumulation of certain gases into the atmosphere that cause the earth's temperature to rise. This is called **global warming**. Carbon dioxide, methane, particulate matter (especially black carbon or soot), nitrous oxide, fluorinated compounds, and ozone are some of the common compounds contributing to global warming.

Carbon dioxide (CO_2) is a greenhouse gas emitted from combustion but is also a gas vital to living organisms. It is a naturally occurring gas in the atmosphere. Carbon dioxide accounts for the major greenhouse gas released in the world. CO_2 emissions are largely due to the combustion of fossil fuels in electric power generation, motor vehicles, and industries. Plants convert carbon dioxide back to

136 European Society of Cardiology (2020), Study estimates exposure to air pollution increases COVID-19 deaths by 15% worldwide

oxygen, but the release of carbon dioxide from human activities is higher than what the world's plants can process. The situation is made worse since many of the earth's forests are being removed, and plant life is being damaged by acid rain. Thus, the amount of carbon dioxide in the air is continuing to increase.

Methane (CH_4) emissions, which result from agricultural activities, landfills, and other sources, are the next largest contributors to greenhouse gas emissions in the world. Methane is not toxic; however, it is extremely flammable and may form explosive mixtures with air. Methane has a global warming potential of 21, which indicates that it is approximately 21 times more heat absorptive per unit of weight higher than carbon dioxide. Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming.

Nitrous oxide (N_2O) is a greenhouse gas released from biomass burning, nitrogen fertilizers, and sewage. Nitrous oxide is most commonly used as an anaesthetic in dentistry and a propellant in the food industry. It has a GWP of 310 indicating that it is approximately 310 times more heat absorptive per unit weight higher than carbon dioxide.

Other greenhouse gases which are subject to the Kyoto Protocol include sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). SF_6 is used as a gas medium in the electrical industry and medical applications. HFCs are used in refrigeration and air conditioning, solvents, degreasing agents, and cleaning agents. Use of PFCs is found in medical and non-medical applications such as in insulation, refrigerating unit, and fire extinguisher.

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC) aimed at fighting global warming. The UNFCCC is an international environmental treaty with the goal of achieving stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Continued emissions of **greenhouse gases** could cause rise in temperature and global warming. This could lead to more extreme weather events such as drought and floods, threaten coastal resources and wetlands by raising the sea level as a result of increased polar ice cap melting, and increase the risk of certain diseases by producing new breeding sites for pests and pathogens. Agricultural regions and woodlands are also susceptible to changes in climate that could result in increased insect populations and plant disease. This degradation of natural ecosystems could lead to reduced biological diversity.

5.2.4.2 Ozone Depletion

Chemicals released by human activities affect the stratosphere. Release of chlorofluorocarbons (CFCs) as propellants, cooling systems and refrigerator equipment accumulate in the lower atmosphere and are eventually transported to the stratosphere, where they are converted to more reactive gases that participate in stratospheric ozone destroying reactions. The stratospheric ozone layer is crucial for protecting the Earth from harmful ultraviolet radiation from the sun. The depletion of stratospheric ozone due to the release of gases containing chlorine and bromine allows additional ultraviolet radiation to pass through the atmosphere and reach the Earth's surface. Additional ultraviolet radiation leads to increases in ultraviolet-related health effects, such as skin cancer and cataracts, and damaging effects on plants and wildlife.

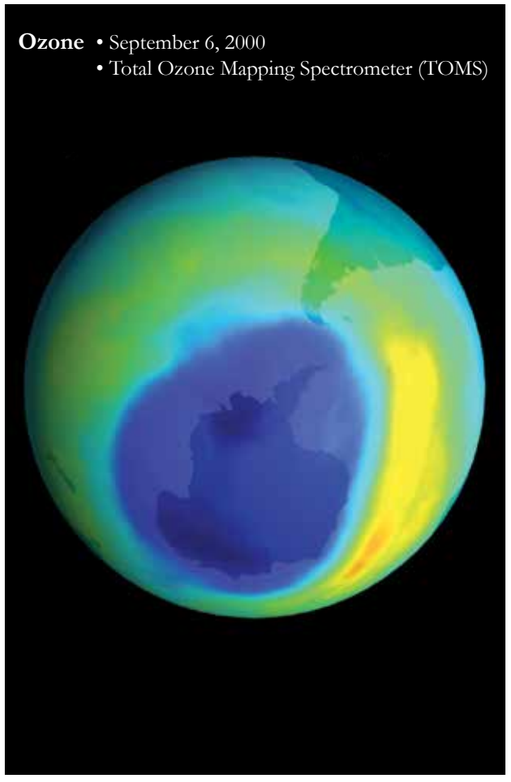

Figure 19: Ozone hole over Antarctica

5.3 Minimizing Exposure To Air Pollution – Outdoor And Indoor

Ambient air pollution is the world's leading environmental risk factor contributing more to global morbidity and mortality than many other common risk factors.[137] In a recent report from 5 national academies[138,139,140] the evidence associating fine airborne particulate matter air pollution ($PM_{2.5}$, or particulate matter <2.5 µm in aerodynamic diameter) produced from the combustion of fossil fuels, with heart disease, stroke, chronic obstructive lung disease, lung cancer, and premature birth was determined to be unequivocal.

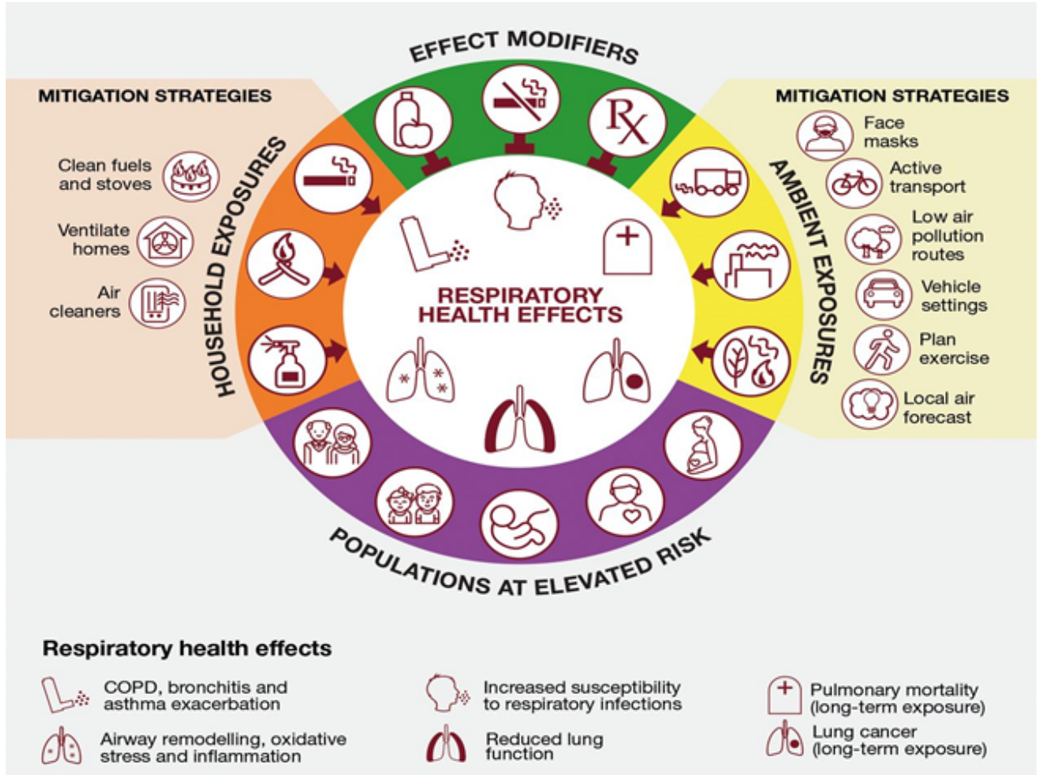

Figure 20: Key elements in mitigating air pollution exposure and protecting respiratory health[141]

Approximately 2.8 billion people are exposed to household air pollution from cooking with polluting fuels[142]. Few monitoring studies have systematically measured health-damaging air pollutant (i.e., fine particulate matter [$PM_{2.5}$] and black carbon) concentrations from a wide range of cooking fuels across diverse populations. This multinational study aimed to assess the magnitude of kitchen concentrations and personal exposures to $PM_{2.5}$ and black carbon in rural communities with a wide range of cooking environments.[143]

137 Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, Baldé AB, Bertollini R, Bose-O'Reilly S, Boufford JI, et al..,The Lancet Commission on pollution and health, Lancet, 2018
138 Rajagopalan S, Al-Kindi SG, Brook RD. Air pollution and cardiovascular disease: JACC state-of-the-art review. J Am Coll Cardiol. 2018
139 Burnett R, Chen H, Szyszkowicz M, Fann N, Hubbell B, Pope CA, Apte JS, Brauer M, Cohen A, Weichenthal S, et al.. Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. Proc Natl Acad Sci U S A. .2018;
140 Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, Balakrishnan K, Brunekreef B, Dandona L, Dandona R, et al.. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015.Lancet. 2017
141 C. Carlsen, S. Salvi, GWK Wong et al. , Personal Strategies to minimise effects of air pollution on respiratory health: Advice for Providers, Patients and Public, European Respiratory Journal, 2020
142 International Bank for Reconstruction and Development, World Bank Group, Tracking SDG 7: the energy progress, 2018
143 Household and personal air pollution exposure measurements from 120 communities in eight countries: results from PURE-AIR Study, The Lancet Planetary Health, Volume 4 Issue 10, October 2020

There are certain key elements which can assist in mitigating personal exposure to ambient air pollution and indoor air pollution. These are evidence-based recommendation which have been reiterated in many reports and studies.

5.3.1 Facemasks

Use of filtering facemasks to reduce inhalation of high air pollution levels is becoming more commonplace and socially acceptable around the world, especially within Asia.[144] Evidence has shown that the impact of N95 facemask has limited impact on cardiopulmonary health as there is not much research available on the efficacy of use of facemask and improvement in cardiopulmonary health. Close fitting N-95 masks (defined as filtering >95% of 0.3 μm particles under test conditions) are recommended when exposure to ambient air pollution exceeds recommended levels. When anticipating unavoidable exposure to ambient air pollution exceeding recommended levels, consider close-fitting N95 facemasks after becoming informed about their limitations and pitfalls. When using a facemask, follow manufacturers' guidance on correct mask usage, maintenance and fit, including a user seal check.[145] People with chronic respiratory, cardiac or other conditions that make breathing difficult should check with their healthcare provider before using an N95 facemask.[146]

5.3.2 Shift from motorized to active transport whenever possible

High exposures to traffic-related air pollution (TRAP) can occur inside vehicles due to the proximity of air intake of exhaust emissions from neighbouring vehicles as well as while walking or cycling alongside roads[147]. Research that compared air pollution exposures related to active versus motorised travel modes found the highest exposures for air pollutants such as $PM_{2.5}$, black carbon and ultrafine particles (UFPs) were in car drivers and the lowest exposures were in cyclists or pedestrians[148,149] although other studies have reported conflicting results[150,151,152]. Proximity to motorised traffic was associated with high cyclist and pedestrian exposure concentrations[153,154] particularly when cycling along roads shared with motor vehicles.[155]

A shift from car and public transport use to active transport (cycling or walking) has been advocated[156] with benefits derived from a reduction in traffic volume and related air pollution emissions leading to overall health benefits[157] in spite of minor reductions in lung function in some contexts[158].

5.3.3 Monitor air pollution levels

Evidence is limited for AQI alerts facilitating exposure-minimising behaviour. Daily text messaging regarding air quality, air pollution risk communication and self-care increased behaviours to reduce exposure to outdoor air pollutants versus standard of care in pregnant women[159]. In contrast, adherence to health advice accompanying AQI alerts in another study was suboptimal[160]. Furthermore, receiving information from a healthcare provider (HCP) significantly increased knowledge of the AQI for individuals with respiratory disease versus no information, but did not affect behaviour modification in response to index values[161].

144 SA Rajper, S. Ullah, Li Z., Exposure to air pollution and se;f reported effects on Chinese students: a case study of 13 megacities, PLOS One, 2018
145 Ronald Shaffer, PhD, Jaclyn Krah Cichowicz, MA, Ginger Chew, ScD and LCDR Joy Hsu, MD,MS, Non-occupational uses of respiratory protection – what public health organisations and user need to know, Centers for Disease Control and Prevention, 2018
146 N95 Respirators, Surgical Masks and Face Masks, US Food and Drug Administrators
147 Dons E,Int Panis L,Van Poppel M, et al., Personal exposure to black carbon in transport microenvironments. Atmospheric Environment, 2012
148 Audrey de Nazelle A, Olivier Bode, Jaun Pablo Orjuela. Comparison of air pollution exposures in active vs. passive travel modes in European cities: a quantitative review. Environment International 2017
149 Karanasiou A, Viana M, Querol X, et al. Assessment of personal exposure to particulate air pollution during commuting in European cities – recommendations and policy implications. Science of the Total Environment 2014
150 Chaney RA, Sloan CD, Cooper VC, et al. Personal exposure to fine particulate air pollution while commuting: an examination of six transport modes on an urban arterial roadway. PLoS One 2017
151 Okokon EO, Yli-Tuomi T, Turunen AW, et al. Particulates and noise exposure during bicycle, bus and car commuting: a study in three European cities. Environmental Research 2017
152 Ozgen S, Ripamonti G, Malandrini A, et al. Particle number and mass exposure concentrations by commuter transport modes in Milan, Italy. AIMS Environmental Science 2016
153 Carvalho AM, Krecl P, Targino AC. Variations in individuals' exposure to black carbon particles during their daily activities: a screening study in Brazil. Environmental Science and Pollution Research, 2018
154 Hankey S, Lindsey G, Marshall JD. Population-level exposure to particulate air pollution during active travel: planning for low-exposure, health-promoting cities. Environmental Health Perspectives 2017
155 Good N, Mölter A, Ackerson C, et al. The Fort Collins Commuter Study: impact of route type and transport mode on personal exposure to multiple air pollutants. Journal of Exposure Science and Environmental Epidemiology, 2016
156 National Institute for Health and Care Excellence. Air pollution: outdoor air quality and health. 2018
157 Raza W, Forsberg B, Johansson C, et al. Air pollution as a risk factor in health impact assessments of a travel mode shift towards cycling. Global Health Action 2018
158 Gaffney AW, Hang J-Q, Lee M-S, et al. Commuting mode and pulmonary function in Shanghai, China. European Respiratory Journal 2016
159 ibid
160 D'Antoni D, Smith L, Auyeung V, et al. Psychosocial and demographic predictors of adherence and non-adherence to health advice accompanying air quality warning systems: a systematic review. Environmental Health 2017
161 Borbet TC, Gladson LA, Cromar KR. Assessing air quality index awareness and use in Mexico City. BMC Public Health 2018

Studies assessing the ability of air pollution sensors to induce exposure-minimising behaviour are limited[162]. While use of portable pollution sensors generated greater awareness of urban air pollution than traditional information sources, air pollution-reducing behaviour change did not follow[163], underscoring the current gap between empowering patients and true benefit to health therein.

5.3.4 Cleaner cooking fuels

Over 3 billion people worldwide use traditional cookstoves that burn wood, animal dung or crop residues to cook food or heat water[164]. This produces very high levels of indoor air pollution (such as CO and particulate matter) because of poor combustion efficiency[165]. Replacing biomass fuels with cleaner cooking fuels (LPG or electricity) reduced the risk of acute respiratory infection in children <5 years of age[166], was associated with shorter hospital stays for acute respiratory infections, lowered the risk of all-cause mortality versus persistent solid fuel users, and combined with improved kitchen ventilation reduced decline of lung function and COPD incidence[167]. Replacing solid fuels for cooking with cleaner fuels also reduced respiratory symptoms in women, and the incidence of bronchitis, phlegm and chest illness in women and children[168].

5.3.5 Improved ventilation

In some cultures, cooking is often conducted outdoors in well ventilated spaces and, when compared with indoor cooking, can reduce the prevalence of acute respiratory infection in children aged <5 years[169]. Among those who cook indoors, improving ventilation reduced the levels of CO and particulate matter, and was associated with improved health outcomes, such as reduction in respiratory symptoms[170], reduced risk of asthma and prevalence of asthma-related symptoms among children, reduced risk of lung cancer, COPD incidence and pneumonia, and improved respiratory health-related quality of life in women[171].

Household ventilation can be improved by ensuring cross-ventilation via windows and doors, or by using chimneys, flues, hoods or exhaust fans[172]. While our recommendations are focused on combustion-related air pollution, ventilation may also serve to decrease the impact of chemicals in the home (e.g., from cleaning products and off-gassing from carpets and furniture), although a recent review suggests that indoor volatile organic compounds are attenuated more by time than by ventilation[173].

5.3.6 Use portable air cleaners as an indoor environmental intervention

The use of portable air cleaners can lower indoor air pollution from cooking, cigarettes, and other sources as well as outdoor pollution that infiltrates indoors, and these may provide an additional benefit by reducing volatile organic compounds associated with household chemicals[174]. Air filters such as HEPA filters capture particles on fibrous materials, while electronic air cleaners such as ionisers or electrostatic precipitators rely on electrostatic forces to remove airborne particles. Some air filters include adsorbent media such as activated carbon to remove gaseous air pollutants or convert them to harmless by-products[175].

162 Steinle S, Reis S, Sabel CE. Quantifying human exposure to air pollution – moving from static monitoring to spatio-temporally resolved personal exposure assessment. Science of the Total Environment 2013
163 Oltra C, Sala R, Boso À, et al. Public engagement on urban air pollution: an exploratory study of two interventions. Environmental Monitoring and Assessment, 2017
164 Lamichhane P, Sharma A, Mahal A. Impact of cleaner fuel use and improved stoves on acute respiratory infections: evidence from India. International Health 2017
165 ibid
166 Gordon SB, Bruce NG, Grigg J, et al. Respiratory risks from household air pollution in low- and middle-income countries. Lancet Respiratory Medicine 2014
167 Zhou Y, Zou Y, Li X, et al. Lung function and incidence of chronic obstructive pulmonary disease after improved cooking fuels and kitchen ventilation: a 9-year prospective cohort study. PLoS Med 2014
168 Choi J-Y, Baumgartner J, Harnden S, et al. Increased risk of respiratory illness associated with kerosene fuel use among women and children in urban Bangalore, India. Occupational and Environmental Medicine 2015
169 Buchner H, Rehfuess EA. Cooking and season as risk factors for acute lower respiratory infections in African children: a cross-sectional multi-country analysis. PLoS One 2015
170 Alexander D, Linnes JC, Bolton S, et al. Ventilated cookstoves associated with improvements in respiratory health-related quality of life in rural Bolivia. Journal of Public Health 2014
171 Kile ML, Coker ES, Smit E, et al. A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. Environmental Health 2014
172 Hadley MB, Baumgartner J, Vedanthan R. Developing a clinical approach to air pollution and cardiovascular health. Circulation 2018
173 Holøs SB, Yang A, Lind M, et al. VOC emission rates in newly built and renovated buildings, and the influence of ventilation – a review and meta-analysis. International Journal of Ventilation, 2019
174 Kabrein H, Yusof MZM, Leman AM. Progresses of filtration for removing particles and gases pollutants of indoor; limitations and future direction; review article. ARPN Journal of Engineering and Applied Science, 2016
175 US Environmental Protection Agency (2018) Residential air cleaners

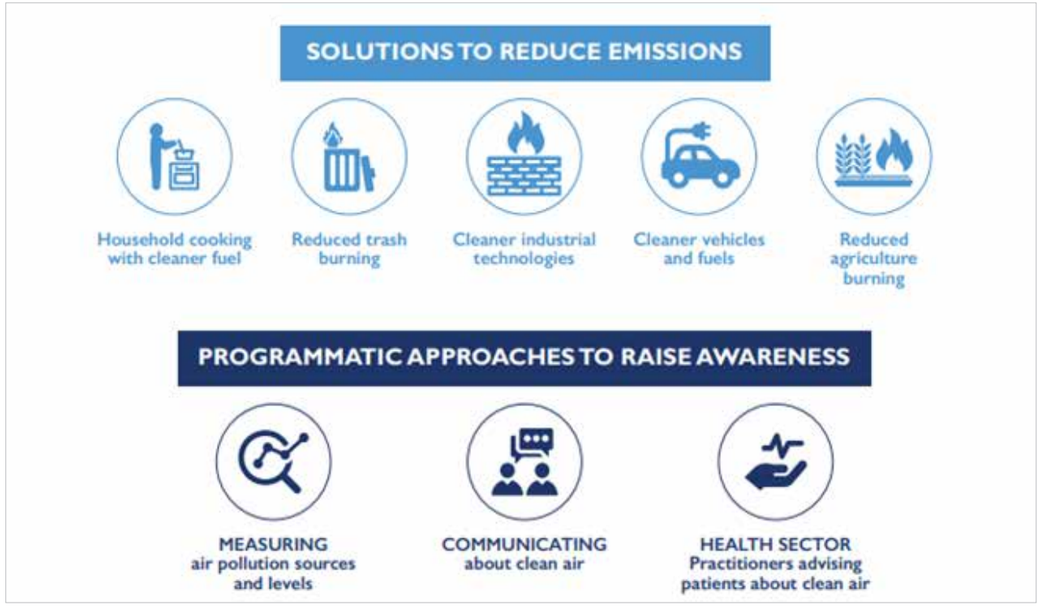

Figure 21: Solutions for reducing air pollution[176]

5.4 Key Messages

Air quality is closely linked to earth's climate and ecosystems globally. Many of the drivers of air pollution (i.e., combustion of fossil fuels) are also sources of high CO_2 emissions. Some air pollutants such as ozone and black carbon are short-lived climate pollutants that greatly contribute to climate change and affect agricultural productivity. Policies to reduce air pollution, therefore, offer a "win-win" strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to the near- and long-term mitigation of climate change.

Air pollution can be significantly reduced by expanding access to clean household fuels and technologies, as well as prioritizing: rapid urban transit, walking and cycling networks; energy-efficient buildings and urban design; improved waste management; and electricity production from renewable power sources.

176 USAID (2019), LMIC Urban Air Pollution Solutions, BreatheLife2030

6. The Regulatory Framework For Air Pollution In Indian Cities

6.1 Need For Mainstreaming Air Quality[177]

Mainstreaming air quality involves the active promotion of better air as a component while identifying, planning, designing, and implementing development strategies and policies. Mainstreaming in this context refers to addressing air quality issues strategically as a cross-cutting aspect of development and goes beyond just air pollution mitigation to a more holistic and strategic approach to achieving sustainable development. Mainstreaming requires considering the impact of air quality in the earliest stages of the decision-making process, when development challenges and proposed implementation plans are being designed. Taking into consideration air quality as an integral part of development planning- especially in the context of our cities can play a major part in achieving broader development objectives (World Health Organization 2014). It can also define how initiatives outside the conventional environment sector can be designed to support environmentally sustainable development.

Mainstreaming air quality means identifying interventions that create long-term economic development benefits and take better air quality into account. While the benefits of mainstreaming air quality exist, some basic considerations need to be understood for its practical and effective application. Attention to a problem such as air pollution is typically understood in the development community as an exercise in recognizing and mitigating adverse environmental impacts of projects. This traditional understanding is the result of the emphasis placed on the implementation of policies designed to reduce adverse environmental impacts by development agencies. The protectionist approach focuses on compliance with certain procedural standards. However, we must go beyond this traditional approach to a conservation perspective and think about benefits. Instead of emphasizing cleaning up of air, we must therefore talk about clean approaches

177 Prarthana Borah, Addressing Air Pollution with Development Policy: How mainstreaming air quality in India's existing policies beyond environment can help address in air pollution, The Journal of Governance, Special Issue on Environment, Volume 18, January 2019 (Page 251-258)

that take externalities into account and highlight economic benefits. The integration of air quality requires consideration of air at the earliest stages of the decision-making cycle in the context of development challenges and proposed interventions. Mainstreaming requires us to consider how interventions aimed at improving air quality can play an integral role in achieving environmental standards as a condition for achieving other objectives. It therefore requires a focus on proactive investment in policies and projects promoting air integration into development strategies.

To reduce air pollution in India, it requires the mainstreaming of air pollution into the national dialogue. Mainstreaming is best approached by asking the right questions, involving stakeholders and creating a consultative decision-making that promotes innovative strategies and is inclusive.

6.2 Policies And Standards For Air Pollution

Government of India enacted the Air (Prevention and Control of Pollution) Act 1981 to arrest the deterioration in the air quality. The act prescribes various functions for the Central Pollution Control Board (CPCB) at the apex level and State Pollution Control Boards at the state level[178] and Pollution Control Committees for the Union Territories.

The CPCB has established Continuous Ambient Air Quality Monitoring Stations across India. In particular, the Continuous Ambient Air Quality Monitoring System (CAAQMS), as the name suggests, is used for monitoring ambient air quality on a real-time basis. Continuous monitoring is an important tool for better compliance enforcement through credible pollution monitoring and reporting practices.[179]

A continuous monitoring system is comprised of several components. It contains hardware for the sampling, conditioning, and the measurement of the properties of air and the pollution it contains. The software component takes the signals generated by the hardware and converts them to air pollution data. This data provides direct, real-time, continuous measurements of pollution.

The continuous monitoring system provides credible and accurate pollution measurement to the operator. This data allows for assessment of mitigation measures ensuring they occur in a timely fashion. Measurement is a key component of air pollution management and control without trustworthy measurements it is impossible to assess efforts to reduce air pollution. Industrialised nations such as the US, UK, Germany etc. have successfully adopted, experienced, and benefitted from this technology for more than three decades.[180]

India, in 2014, initiated installation of Continuous Emission Monitoring System (CEMS) and Continuous Effluent Quality Monitoring System (CEQMS) in 17 categories of highly polluting industries and common pollution treatment facilities. In addition, grossly polluting industries (GPIs) located in the Ganga basin are also required to install CEQMS for monitoring and reporting of effluent quality on real-time basis. The CEQM system is used for monitoring the quality of water or wastewater parameters such as pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solid, total suspended solids (TSS) and dissolved oxygen (DO). The CPCB had issued the directions to SPCBs and PCCs to mandate the installation of CEMS and CEQMS is industries. CAAQMS is installed both by the government as well as industries to monitor ambient air quality in the respective regions.[181]

Central Pollution Control Board has executed a nation-wide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP). The network consists of 793 operating stations covering 344 cities/ towns in 29 states and 6 Union Territories of the country.

The objectives of the NAMP are to determine status and trends of ambient air quality; to ascertain whether the prescribed ambient air quality standards are violated; to Identify Non-attainment Cities; to obtain the knowledge and understanding necessary for developing preventive and corrective measures and to understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated.

178 Guidelines for Ambient Air Quality Management, Central Pollution Control Board, April 2003 http://www.indiaairquality.info/wp-content/uploads/docs/2003_CPCB_Guidelines_for_Air_Monitoring.pdf
179 What is CEMS? https://www.cseindia.org/what-is-cems--8442
180 ibid
181 A Policy Brief to sustain the benefits of the COVID -19 lockdown on air, water and noise pollution levels in India, GIRHA, July 2020

Under NAMP four air pollutants viz., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_X, Respirable Suspended Particulate Matter (RSPM / PM_{10}) and Fine Particulate Matter ($PM_{2.5}$) have been identified for regular monitoring at all the locations. The monitoring of meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality. Meteorological parameters are important for the understanding of atmospheric pollutant removal processes.

The monitoring is being carried out with the help of Central Pollution Control Board; State Pollution Control Boards; Pollution Control Committees; National Environmental Engineering Research Institute (NEERI), Nagpur. CPCB co-ordinates with these agencies to ensure the uniformity, consistency of air quality data and provides technical and financial support to them for operating the monitoring stations. NAMP is being operated through various monitoring agencies. Large number of personnel and equipment are involved in the sampling, chemical analyses, data reporting etc. It increases the probability of variation and personnel biases reflecting in the data; hence it is pertinent to mention that these data be treated as indicative rather than absolute[182].

6.3 Available Air Quality Measurement Data In India

Over the years, together with a spreading of environmental consciousness, there has been a change in the traditionally-held perception that there is a trade-off between environmental quality and economic growth as people have come to believe that the two are necessarily complementary. The current focus on environment is not new—environmental considerations have been an integral part of the Indian culture. The need for conservation and sustainable use of natural resources has been expressed in Indian scriptures, which are more than three thousand years old and is reflected in the constitutional, legislative and policy framework, as also in the international commitments of the country.[183]

There are various centrally sponsored and central sector schemes undertaken for pollution abatement. The major objectives of these schemes are to ensure pollution abatement through various means such as assessment and monitoring of air and water quality, introduction of cleaner technologies for resource conservation, research and development, upgradation of laboratories etc.[184]

The maintenance and improvement of air quality is a major environmental challenge in the backdrop of various developmental activities. Air quality, therefore, has been a major concern particularly in urban and industrial sites and their surrounding regions. The contribution of various air pollutants could be attributed to vehicular emission exhaust, developmental activities, operations of diesel generator (DG) sets, re-suspension of dust and burning of fuel for domestic purposes.

6.3.1 Policy regulation framework for air quality monitoring system in India

India has set ambient air quality standards for several pollutants. According to the rules of the Central Pollution Control Board (CPCB), the annex monitoring agency, the national ambient air quality standards (NAAQS) should be met for at least 98 per cent of the days in a year[185]. They may exceed the limit only for 2 per cent of the time, but not on two consecutive days of monitoring. But air-quality monitoring carried out in at least 263 cities shows that the majority do not meet standards. Further, pollution levels continue to rise in many cities, even smaller ones[186]. According to the IQ Air Global Report data, 22 out of 30 of the most polluted cities are in India.[187]

Ambient air quality parameters include sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), ozone (O_3) and particulate matter (PM- PM_{10}, $PM_{2.5}$). Under the country's National Air Monitoring Programme (NAMP), four air pollutants viz. SO_2, NO_2, Respirable Suspended Particulate Matter (RSPM / PM_{10}) are monitored regularly at all the locations.[188] The Central Pollution Control Board (CPCB) has notified National Ambient Air Quality Standards. In order to assess the air quality against these standards, ambient air pollutant concentrations are monitored in all the states by CPCB and SPCBs

182 About NAMP, Central Pollution Control Board
183 The Legal and Regulatory framework for Environmental Protection in India, Ministry of Environment, Forest and Climate Change
184 Report of the Working Group on Environmental and Environmental Regulatory Mechanism in Environment and forests for the Eleventh Five Year Plan (2007-2012), Planning Commission, Government of India, August 2007
185 National Ambient Air Quality Status and Trends in India, Central Pollution Control Board, January 2012
186 Legal Framework for Clean Air in Cities, Centre for Science and Environment, 2016
187 Twenty-two of the world's 20 most polluted cities are in India, as per IQAir Global Report
188 Strengthening Green Fiscal Federalism in India, The Energy and Resource Institute, 2019

under NAMP through a network of 739[189] manual operating stations covering 344 cities/towns in the country. In addition to manual stations, CPCB has installed 278[190] real-time Continuous Ambient Air Quality Monitoring stations (CAAQMS) in 71 cities across 17 states monitoring eight pollutants viz. PM_{10}, $PM_{2.5}$, SO_2, NO_X, ammonia (NH_3), CO, ozone (O_3), and benzene. An Air Quality Index (AQI) was launched in 2014 for effective and simpler communication of air quality status.[191] The index converts complex air quality data of eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) into a single value and category (good to severe).

Figure 22: Policies Adopted for Air Mitigation (A)

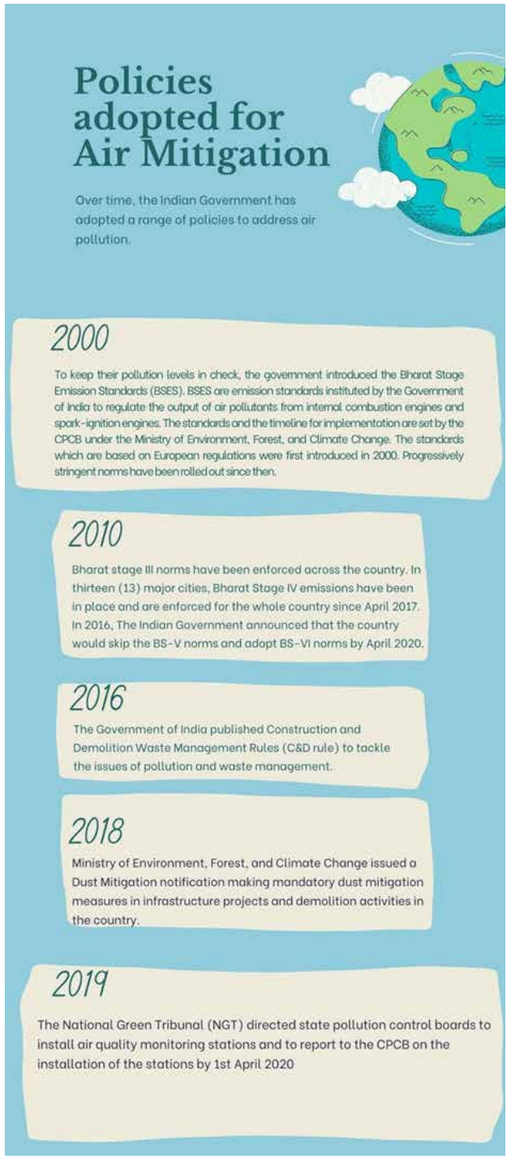

Figure 23: Policies adopted for Air Mitigation (B)

189 List of NAMP Station in India, Central Pollution Control Board https://cpcb.nic.in/uploads/Stations_NAMP.pdf
190 List of Continuous Ambient Air Quality Monitoring Stations https://cpcb.nic.in/national-air-quality-index/
191 Monitoring Network, Central Pollution Control Board https://cpcb.nic.in/monitoring-network-3/

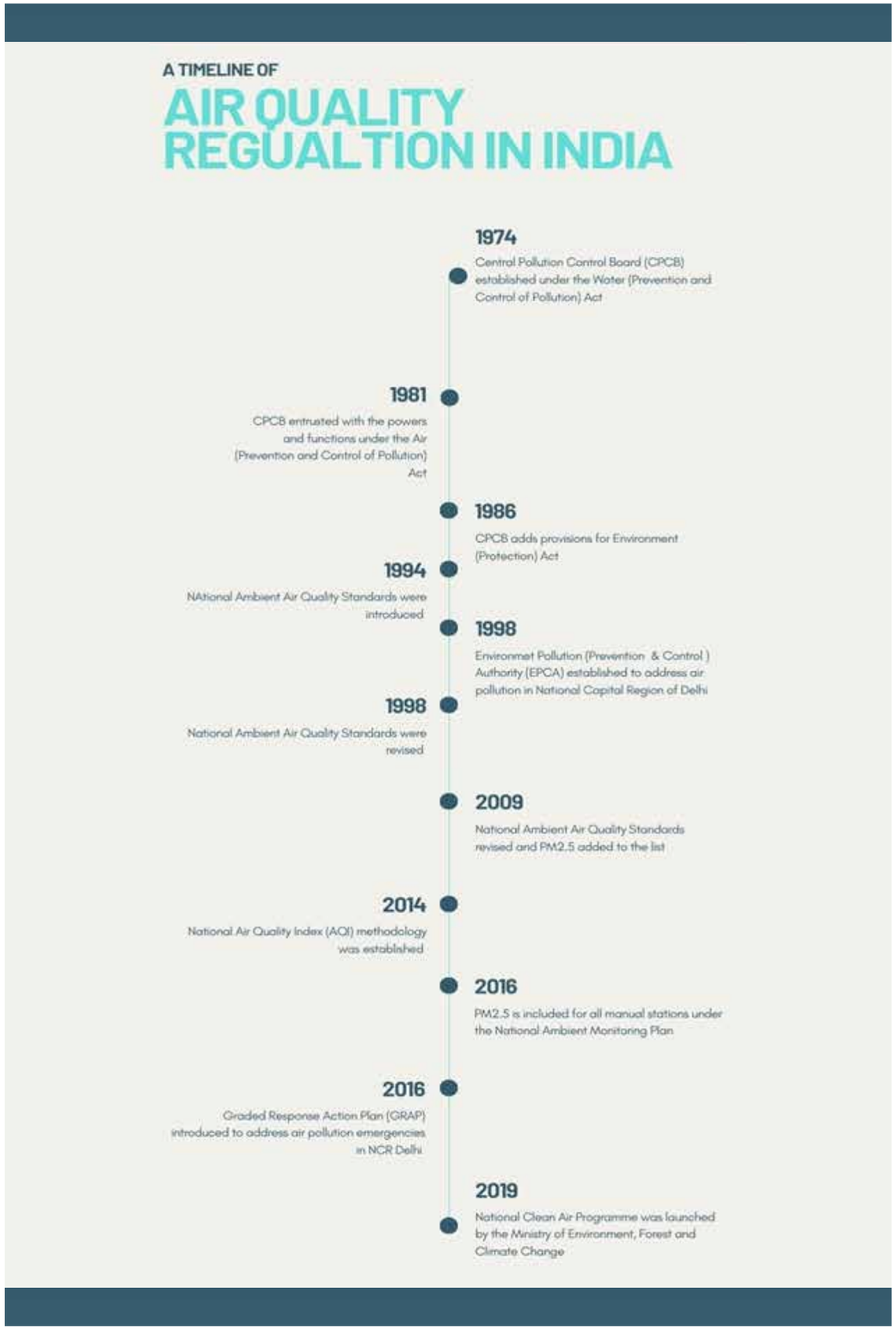

Figure 24: Air Quality Regulations in India

6.3.1.1 National Clean Air Programme

On the 10 January 2019, the Indian Ministry of Environment, Forest and Climate Change (MoEF&CC) launched a five-year national clean air programme (NCAP) to tackle the problem of air pollution (see Figure 25[192]). The overall objective of the NCAP is to take comprehensive mitigation actions to prevent, control and abate air pollution while supporting the national air quality monitoring programme and strengthening awareness and capacity.

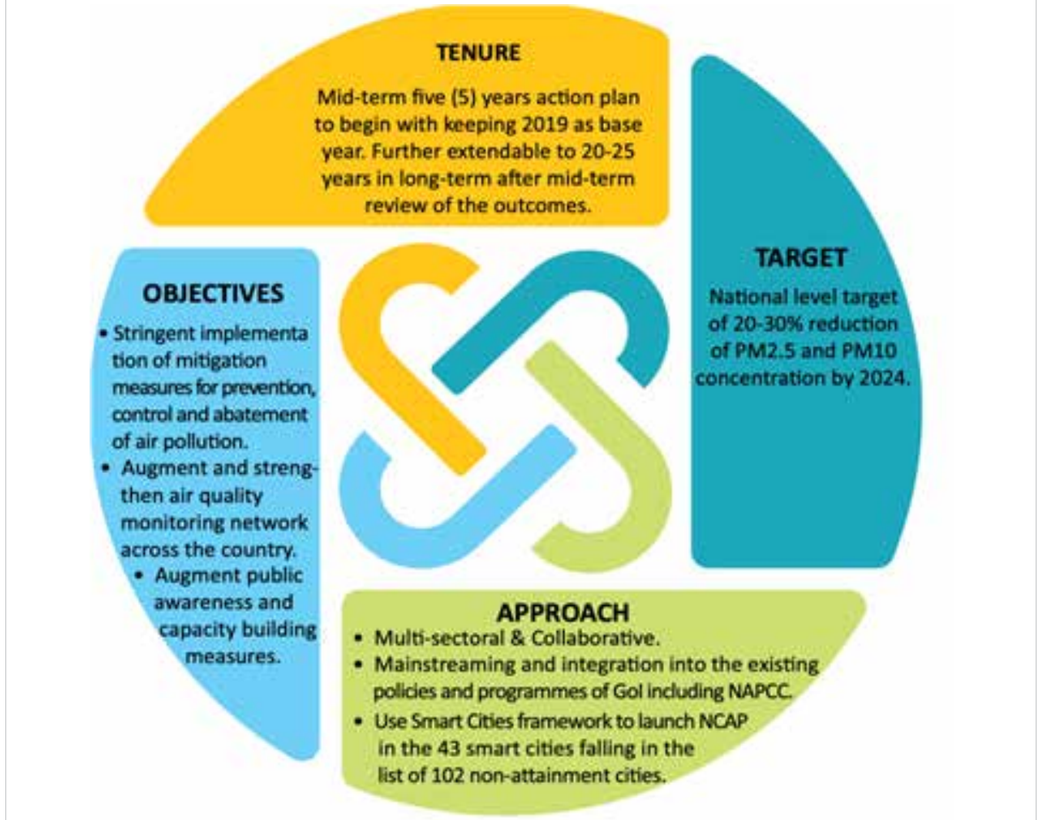

Figure 25: Overview of the National Clean Air Programme

NCAP initially identified 102 non-attainment cities that were not meeting the annual average ambient air quality standards for PM_{10}.These cities have been identified based on ambient air quality data obtained (2011-2015) under National Air Quality Monitoring Programme (NAMP), a further 20 cities were added in August 2019, increasing the total number of non-attainment cities in India to 122.[193] (See Table 1) NCAP has set a tentative national level target of 20-30% reduction of PM ($PM_{2.5}$ and PM_{10}) concentrations by 2024 using 2017 as the base year.

NCAP's approach includes collaborative, multi-scale and cross-sectoral coordination between the relevant central ministries, state governments and local bodies. This includes coordination with existing policies and programmes, such as the National Action Plan on Climate Change (NAPCC) (see Box 19) and the Climate Smart Cities Assessment Framework. Under NCAP, as of August 2021, there are 132 non-attainment cities who must develop city specific action plans to implement mitigation actions.

192 Government of India (2019) National Action Clean Air Programme. New Delhi, India
193 The Times of India (2019) 20 more cities added to CPCB's 'polluted list'. 18 August 2019.

Box 19: National Action Plan on Climate Change (NAPCC)

Launched in 2008, NAPCC included eight core "national missions" which represents a multi-pronged, long-term and integrated approach for achieving key goals in the context of climate change. These include: National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, National Mission for Sustainable Agriculture, and National Mission on Strategic Knowledge for Climate Change. In 2016, India ratified the UN Paris Agreement to combat climate change. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs). NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve.

Source: UNFCCC (n.d.) What is the Paris Agreement? United Nations Framework Convention on Climate Change, Berlin, Germany.

The Pollution Control Board and other environmental agencies have set a target that NCAP, will be implemented in these 132 cities across India to develop a city level action plan and aim to mitigate the strategies for ambient PM concentration and improve the air quality at a constant level. It has been over a year since the NCAP was implemented and unfortunately it has failed to legally enforce its target and hence has remained ineffective on the ground.

With the absence of a legal mandate, the NCAP will not be able to implement the action plan. In response to the failure of the implementation for Clean Air Action Plan, the NCAP itself notes the lack of coordination between the implementing agencies and need for appropriate training on monitoring and inspection element. There are data related implementation hurdles as well as poor data capture due to the substandard state of monitoring stations, lack of appropriate knowledge to leverage real time data for reporting trends, and a dearth of data cleaning methods to fill the gaps of missing or inaccurate data in the monitoring system. Moreover, there is still relatively sparse knowledge on the urban and rural disparity in terms of air quality. This means that only a small section of the Indian population is being closely monitored for air pollution with the ratio of one monitoring station for every 6.8 million people[194]. Although, while the issue of air pollution has generated a significant political traction, to see these conditions India has not been able to make any significant progress towards achieving the targets which were set under the NCAP.

6.3.1.2 National Ambient Air Quality Standard (NAAQS)

After the 1972 Stockholm Conference on the Human Environment, it became clear that the nation needed a uniform environmental law. As a result, Air Act 1981 was passed by the Parliament in 1981. Agencies responsible for air quality standard creation and monitoring include CPCB and several State Pollution Control Boards (SPCBs). All these entities are under the control of the Ministry of Environment, Forest, and Climate Change (MoEF&CC). The CPCB, working together with the SPCBs, provides technical advice to MoEF&CC to fulfil the objectives outlined in the Air Act, 1981.

NAAQS are set taking into consideration geographical conditions, pollutant background concentrations, available air pollution control technologies and the cost of treatment, international standards (WHO, USEPA, EU and Chinese) and the sensitivity/tolerance of the receptor (see Table 8). The SPCBs/PCCs can set more stringent standards than the existing national standards in their respective states but do not have the powers to relax these standards. Such a process is like the local divisions used within the USEPA with the goal of providing for the prevention, control, and abatement of air pollution.

Regulatory authorities need to undertake concrete measures to ensure that the standards are implemented and met, considering the existing air quality in the region, number of complaints

194 Aparna Roy, Tanushree Chandra and Aditi Ratho "Finding Solutions to Air Pollution in India: The Role of Policy, Finance, and Communities," ORF Special Report No. 120, September 2020, Observer Research Foundation. https://www.orfonline.org/research/finding-solutions-to-air-pollution-in-india-the-role-of-policy-finance-and-communities-74311/#:~:text=The%20imperative%20is%20to%20create,solutions%20to%20improve%20air%20quality.

received, directions from the courts, based on the carrying capacity of the specific area, the cost of control strategies, etc. The process takes years or even decades, especially for pollutants where the level of standards is not easily available. The air pollution areas can be identified and designated as attainment and non-attainment areas. Two types of State Implementation Plans (SIP) can then be developed - an attainment-maintenance SIP if the area is designated as attainment, and an attainment-demonstration.

Table 8: Different Air Quality Standards[195]

Sr. No.	Pollutant	Time weighted average	Indian AQS		Chinese AQS		USEPA AQS	EU AQS	WHO AQS
			Industrial, Residential, Rural area	Ecological sensitive area	Natural Protection Area	Residential, Commercial, Industrial and Rural Area			
1	Particulate Matter Pm10 (µg/m3)	Annual	60	60	40	70	-	40	20
		24 hours	100	100	50	150	150	50	50
2	Particulate Matter PM2.5 (µg/m3)	Annual	40	40	15	35	12	-	10
		24 hours	60	60	35	75	35	25	25
3	Sulphur Dioxide So2 (µg/m3)	Annual	50	20	20	60	75ppb (1 hour)	125	-
		24 hours	80	80	50	150	-	350	20
4	Nitrogen Dioxide No2 (µg/m3)	Annual	40	30	40	40	53 ppb	200	40
		24 hours	80	80	80	80	100ppb (1 hour)	-	-
5	Ozone O3 (µg/m3)	8 hours	100	100	100	160	0.070 ppm	-	100
		1 hour	180	180	160	200	-	-	-
6	Lead Pb (µg/m3)	Annual	0.5	0.5	-	-	-	-	-
		24 hours	1.0	1.0	-	-	0.15 (Rolling 3 month average)	-	-
7	Carbon Monoxide CO (mg/m3)	8 hours	2.0	2.0	-	-	9.0	10	-
		1 hour	4.0	4.0	10	10	35.0	-	30
8	Ammonia Nh3 (µg/m3)	Annual	100	100	-	-	-	-	-
		24 hours	400	400	-	-	-	-	-
9	Benzene C6H6 (µg/m3)	Annual	5	5	-	-	-	5	-
10	Benzo(a)pyrene BaP (µg/m3)	Annual	1	1	-	-	-	-	-
11	Arsenic As (ng/m3)	Annual	6	6	-	-	-	-	-
12	Nickel Ni (g/m3)	Annual	20	20	-	-	-	-	-
13	Poly Aromatic Hydrocarbon PAH (1 ng/m3)	Annual	-	-	-	-	-	1	-

195 Compiled through various sources, WHO, USEPA, NAAQS, EU, Bejing AQI

6.3.1.3 National Air Quality Index

In 2015, a national air quality index (AQI) was launched (see Figure 26). This was initially for 14 cities but was extended to 57 cities. AQI is an effective tool to communicate the air quality status to the public in an understandable way. It transforms ambient air quality data of various pollutants into a single number (index value), nomenclature and colour.

There are six AQI categories: Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe.

Each category is based on the ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints).

The lower value of the range is known as a health breakpoint[196] (e.g., 51 is the minimum for the category 'satisfactory'). AQ sub-index and health breakpoints have been developed for eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3 and Pb) for which short term (up to 24 hours) NAAQS exist.

AQI	Associated Health Impacts
Good (0-50)	Minimal Impact
Satisfactory (51-100)	May cause minor breathing discomfort to sensitive people
Moderate (101-200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201-300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure.
Very Poor (301-400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Figure 26: Air Quality Index[197] Source: Control of Urban Pollution series CUPS/82/2014-15, Air Quality Index, CPCB

The AQI is useful for:

- The general public to know air quality in a simplified way
- A politician to ensure quick actions
- A decision maker to know the trend of events and to outline corrective pollution control strategies

Considering the available international experiences and national studies, the tentative national level target of 20%–30% reduction of $PM_{2.5}$ and PM_{10} concentration by 2024 is proposed under the NCAP, keeping 2017 as the base year for the comparison of concentration.

Whenever there is an increase in the concentration of $PM_{2.5}$ or PM_{10} and the AQI achieve a poorer quality category, actions in the form of Graded Response Action Plan (GRAP)[198] similar to the New Delhi-NCR region plan must be adopted.

196 USEPA (2012) Air Quality Index. United States Environmental Protection Agency, Washington DC, USA.
197 MoEFCC (2019) Government launches National Clean Air Programme (NCAP).. Ministry of Environment, Forests and Climate Change, New Delhi, India.
198 A Graded Response Action Plan (GRAP) is a set of stratified actions that are taken once the pollution level reaches a certain specified limit. The Supreme Court had mandated the Environmental Pollution Control Authority (EPCA) to come up with such a plan.

6.3.1.4 National Air Monitoring Programme (NAMP)[199]

The objectives of the NAMP are as follows:

- To determine status and trends of ambient air quality
- To ascertain whether the prescribed ambient air quality standards are violated
- To Identify Non-Attainment Cities
- To obtain the knowledge and understanding necessary for developing preventive and corrective measures
- To understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind-based movement, dry deposition, precipitation, and chemical transformation of pollutants generated

The monitoring under the NAMP is being carried out with the help of State Pollution Control Boards (SPCB), Pollution Control Committees (PCC) and National Environmental Engineering Research Institute (NEERI), Nagpur and Central Pollution Control Board (CPCB) head and Zonal Offices. CPCB co-ordinates with these agencies to ensure uniformity, consistency of air quality data and provides technical and financial support to them for operating the monitoring station.

6.4 Current Policies Towards Air Pollution

There are many policies and programs that have been implemented by the government to address the issue of air quality problem. Over 674 million Indian citizens are likely to breath heavily polluted air with high concentration of $PM_{2.5}$ by 2030, even if the country were to comply with its existing pollution control pollution and regulation.[200]

One of the most recent policies launched by the government of India is National Clean Air Program (NCAP) a five-year plan to curb air pollution and build a pan – India air quality network while improving citizen's awareness. It was launched in January 2019 by the Ministry of Environment, Forest, and Climate Change (MoEF&CC) to prepare action plans with an objective to reduce $PM_{2.5}$ pollution by 20-30% by 2024 as compared to 2017.[201] The NCAP identifies these 132 polluted cities from the 24 states and refer to them as non-attainment cities on the basis that these cities did not meet to the National Ambient Air Quality Standard (NAAQS) for the period of 2014 – 15 under the National Ambient Monitoring Plan (NAMP).

The Pollution Control Board and other environmental agencies have set a target that NCAP, will be implemented in these 132 cities across India to develop a city level action plan and implement to mitigate the strategies for ambient PM concentration and improve the air quality at a constant level. It has been over a year since the NCAP was implemented and unfortunately it has failed to legally enforce its target and has remained ineffective on ground.

6.5 Involvement Of Stakeholders[202]

The stakeholders in air quality management include the national and local governments, private sector, and civil society. In most countries, the legislative and executive bodies are the major constituents of the governance structures. The legislatures are responsible for framing the laws which are to be implemented by the concerned agencies of the government. At the national level, the national policies and laws are formulated by the national legislatures and the national government for adoption and implementation through local government. The local governments, through their respective elected bodies and concerned government agencies, are also responsible for formulation of policies and laws for implementation within their jurisdictions.

Cities all over the world have found that involvement of a broad range of city stakeholders is essential for successful air quality management. Wide-ranging participation by all interested groups and organisations is vital for any type of urban, environmental or development management process.

199 National Ambient Air Quality Status and Trends in India – 2010, Central Pollution Control Board, January 2012 https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMzJfMTQ1ODEyNjU5MV9OZXdJdGVtXzE5Ml9OQUFRU1RJLnBkZg

200 International Institute for Applied Systems Analysis and Council on Energy, Environment and Water (2019) 'Pathways to Achieve National Ambient Air Quality Standards (NAAQS) in India', March. https://www.ceew.in/sites/default/files/CEEW-IIASA-Pathways-to-National-Ambient-Air-Quality-Report-02May19.pdf

201 National Clean Air Programme, Ministry of Environment, Forest and Climate Change, Government of India, 2019 http://moef.gov.in/wp-content/uploads/2019/05/NCAP_Report.pdf

202 UNEP-UNHSP, Urban Air Quality Management Toolkit, accessed on 17th June, 2021

Stakeholders must be involved at all stages of the process including: information collection and analysis, prioritization of issues, review and assessment of strategies, formulation of strategies, action planning, and most importantly implementation of investment projects and institutionalising the entire process. Cities have been successful in addressing air quality problems by bringing in a wide range of relevant stakeholders. These stakeholders include:

- Those who possess expertise in air quality management and/or have important information about different aspects of the issue
- Those whose interests are directly affected by urban air quality management issues
- Those who control or influence important instruments or mechanisms of management
- Those whose actions directly impact the air quality situation

Box 20: Types of Stakeholders

Public Sector:

- City Council (political authority)
- Mayor and/or Chief Executive Office
- City government administrative departments (sectoral) – usually several
- Municipal companies & autonomous organizations
- Regional or provincial government departments
- Central or national government departments
- Regulatory Bodies (at whichever level) concerned with AQM
- Public research organizations
- Police

Private Sector:

- Private Sector Organizations (industry groups, Chamber of Commerce, etc.)
- Industrial or commercial companies with major impacts on AQM
- Informal sector groups
- Private research institutions & technical consultants
- Professional associations

Popular or Community Sector:

- Non-Government Organizations (NGOs) focused on AQM issues
- Community-Based Organizations (CBOs) in areas affected by air pollution
- Special interest groups (such as environmental pressure groups, motoring organizations)
- Unions

Other:

- Universities, colleges, higher education
- Public research institutions with knowledge pool on AQM issues (chemical, environmental, economic, social, health, life-style etc.)
- Media
- Others not included in above-mentioned categories, but who have a stake, i.e., hospitals, doctors, forest rangers, primary schools, parents

Source: UNEP-UNHSP, Urban Air Quality Management Toolkit, accessed on 17th June,2021.

Air quality issues can be clarified with as much detail as possible through many means including the preparation of an Air Quality Profile and mapping exercises for air quality purposes in the city. Depending on the level of information obtained from these various means, working groups with representatives from a broad range of stakeholders can be constituted.

It is important to be able to identify the right sources for information needed to further clarify an issue. It is equally important that this exercise produces all relevant information necessary for the working group to be able to follow the EPM process and come up with strategies and action plans.

The involvement of technical experts helps clarify and prioritize issues. Their technical expertise and experience bring credibility to the process. They not only enrich the information available but are also instrumental in facilitating the process of consensus building. However, the role of experts is subordinate to that of the stakeholders. Even with the best experts around, not much can be done without the support of the stakeholders.

6.6 Key Messages

There is an impending urgency to address deteriorating air quality, degradation of water resources and waterways, non-existent treatment and disposal of solid waste, and recurring risks from natural disasters. Both short-term and long-term climate risks need to be integrated in long-range planning processes to mainstream urban resilience and risk mitigation practices in urban environmental planning.

Air pollution mitigation requires innovative, collaborative solutions from public, private, and civil society stakeholders. Institutions, governments, philanthropies, and members of the academe have been fighting the battle for clean air for decades; it is now time to tap into the power of a multi-stakeholder framework to overcome this challenge.[203]

203 Aparna Roy, Tanushree Chandra and Aditi Ratho, "Finding Solutions to Air Pollution in India: The Role of Policy, Finance, and Communities," ORF Special Report No. 120, September 2020, Observer Research Foundation. https://www.orfonline.org/research/finding-solutions-to-air-pollution-in-india-the-role-of-policy-finance-and-communities-74311/

7. Urban Governance And Its Relevance To Air Quality Management In India

7.1 Urban Governance

Urban governance is a concept of governance in relation to urban areas to be reflective of how the various constituents of public service delivery are organized to increase the current and future welfare of the citizens.[204] It can be measured subjectively as to how effective the institutions are in terms of the principal of sustainability, decentralization, efficiency, equity, participation, transparency, accountability, civic management, security and citizenship.[205]

In 1992, the 74th constitutional amendment formally recognized the urban local bodies (ULBs) as the third tier of government and mandated that state government will transfer local government some of its specified functions under the 12th schedule and identified and assigned the responsibilities of urban planning, including the town planning, regulation of land use and construction of building, roads and bridge, provision of Public health, water and sanitation along with the solid waste management as part of their functions. As per article 243S, ULBs should constitute the ward committees consisting of one or more wards within the territorial area of all the municipalities with a population of 3 lakhs or more. State government have an important role to play not only in transferring the functions, funds and functionaries but also in providing an enabling environment through legislative and institutional reform, whereas the government of India can be providing the strategic leadership.[206]

A number of very important functions such as town planning continue to be held by most state governments[207]. Town planning is significant because it can be a powerful instrument for mobilizing finances in a transparent manner to help meet the growing investment needs for urban infrastructure.[208]

204 Ramakrishna Nallathinga (2005), Institutional innovations of Urban Governance: Some examples of Indian Cities, Urban India Volume 24(2): 1-28
205 UN-HABITAT (2002), Principles and Realities of Urban Government in Africa, Global Campaign on Urban Governance
206 Isher Judge Ahluwalia (2017), Urban Governance in India, Journal of Urban Affairs, Volume 41(1): 83-102
207 Arvind Panagariya (2014), Space, Services and the State, Governing Urban Futures, 39
208 Isher Judge Ahluwalia (2017), Urban Governance in India, Journal of Urban Affairs, Volume 41(1): 83-102

In addition, some states include a peculiar provision in their municipal legislation stipulating those specific functions may be assigned to the local governments by the state government from time to time, thereby precluding unambiguous assignment.

National Clean Air Programme (NCAP), launched in 2019, is India's flagship program for better air quality which guides cities to create Clean Air Action Plan to reduce air pollution. ULB needs to create action plan with implementation strategy considering all stakeholders for respective control measures.

Local bodies are institutions of the local self-governance, which look after the administration of an area or small community such as villages, towns, or cities. The 74th Constitutional Amendment Act, 1992, provided constitutional status to urban local bodies[209].

The Constitutional Amendment provides for three types of municipalities – Municipal Corporations, Municipal Councils and Nagar Panchayats. Notified area committees and town area committees were reconstituted as Nagar Panchayats.[210]

209 Wikipedia, Local Government in India, accessed on 17th June 2021
210 Rumi Aijaz (2008), Form of Urban Local Government in India, Journal of Asian and African Studies, Vol 43(2): 131-154, Sage Publications

Main characteristics of urban local governments

Type of municipality	Rationale for Constitution and brief characteristics: Before 1992	After 1992
Municipal Corporation	• Established in metropolitan areas or big cities • Wider functions and larger powers than councils, enjoys more autonomy and has larger revenue resources • Separation of deliberative from executive functions and vesting of all executive powers in an appointed authority who is independent of the elected body	• Constituted in 'large urban areas'[a]
Municipal Committee/ Council	• Most popular form of local government in urban areas • Set up in cities and large towns • Extent of state control is relatively larger than corporations	• Constituted in 'small urban areas'[a]
Nagar Panchayat	• Constituted after 1992	• Constituted in 'areas in transition from rural to urban'[a]
Notified Area Committee	• Set up by state government in medium and small towns • Created for areas which do not fulfill conditions for constitution of councils but are otherwise important • Also created for newly developing towns or areas where industries are being established • All members including chairman are nominated by state government and not elected	• Abolished
Town Area Committee	• Semi-municipal authority constituted for small towns • Members are either wholly nominated or wholly elected, or partly nominated and partly elected	• Abolished

Note: [a]A 'large urban area', a 'small urban area' and a 'transitional area' are defined as such area 'as the Governor may, having regard to the population of the area, the density of the population therein, the revenue generated for local administration, the percentage of employment in non-agricultural activities, the economic importance of such other factors as the Governor may deem fit, specify by public notification' (Constitutional Provisions Relating to Village Panchayats and Municipalities in India, 1999).

Source: Report of the Committee of Ministers Constituted by the Central Council of Local Self Government (1963); Government of India (1966); Sachdeva (1993); Constitutional Provisions Relating to Village Panchayats and Municipalities in India (1999).

Figure 27: Main characteristics of Urban Local Governments[211]

All urban local governments have common objectives and somewhat identical characteristics, the method of their constitution in the extent of delegated functions, powers, and resources available to them lends a distinct status to each category of local government (Figure 27).

211 Ibid

7.2 Urban Agglomeration

An urban agglomeration is a continuous urban spread constituting a town and its adjoining outgrowths (OGs), or two or more physically contiguous towns together with or without outgrowths of such towns. An Urban Agglomeration must consist of at least a statutory town and its total population.[212]

Outgrowth, is a viable unit such as a village or a hamlet or an enumeration block made up of such village or hamlet and clearly identifiable in terms of its boundaries and location. Some of the examples are railway colony, university campus, port area, military camps, etc., which have come up near a statutory town outside its statutory limits but within the revenue limits of a village or villages contiguous to the town.

For the purpose of identification of Urban Agglomerations for the 2011 Census, the following criteria[213] were adopted:

- The core town or at least one of the constituent towns of an urban agglomeration should necessarily be a statutory town; and
- The total population of an Urban Agglomeration (i.e., all the constituents put together) should not be less than 20,000 as per the 2001 Census.

	Type of Towns/UAs/OGs	Number of towns	
		2011 Census	2001 Census
1	Statutory Towns	4,041	3,799
2	Census Towns	3,894	1,362
3	Urban Agglomerations	475	384
4	Out Growths	981	962

Figure 28: Number of UAs/Town and Out Growths (OGs)[214]

India shares most characteristic features of urbanization in developing countries. A huge demographic change has been recorded over the last 100 years. For example, the number of total urban agglomeration / towns has grown form 1,827 in 1901 to 5,161 in 2001 as per the data of census of India. The total population has increased and recorded by the census of India from 23.84 crores in 1901 to 102.7 crores in 2001 whereas the population that has been residing in urban areas increased from 2.58 crores in 1901 to 27.78 crores in 2001. These statistics show the gradually increasing trend of urbanization in India.[215]

7.3 Urban Policy

Cities all over are now exploring more flexible ways to accommodate changes in land use and density patterns over time. The earlier approaches treating urban transportation as the consequence of land use planning are being given up in favour of simultaneous determination of policy, recognising the two-way relationship between land use planning and transportation. These changes are especially important for India in its current phase of structural transformation[216].

212 Census of India 2011, Urban Agglomerations and Cities, Provisional Population Total, accessed on 17th June 2021
213 Census of India 2011, Formation of Urban Agglomeration for the 2011 Census (Circular No.3), dated 3rd November, 2008, Office of Registrar General India, accessed on 17th June, 2021
214 Ibid
215 Neelamani Jaysawal and Sudeshna Saha (2014) Urbanisation in India: An Impact Assessment, International Journal of Applied Sociology, Volume 4(2): 60-65
216 Isher Judge Ahluwalia, Planning for Urban Development in India, 2017

Box 21: Lessons for Improved Urban Management

Experiences of few cities provide some important lessons for improved urban governance.

These lessons are:

- Build credibility of local government through improved administration;
- Make initial efforts in a few critical areas that are "visible" and affect daily lives of most residents;
- Changes must come from within the system, not forced by state or national government;
- Demonstration effects are important and more cities will learn from these success stories;
- Dissemination and networking of local governments is crucial;
- State and national governments may not always support the initiation of changes, but will yield only when citizen support is received; and
- Responsive administration for citizen grievances is essential. The strategy for improved governance should include enablement, participation, and capacity building.

Source: Chetan Vaidya (2009), Urban Issues, Reforms and Way Forward in India, Department of Economic Affairs, Ministry of Finance, Government of India. Cross reference: Mehta, D. (2006) "Urban Governance: Lessons from Best Practices in Asia" in Shah P.J. and Bakore, M. Handbook on New Public Governance, CCS, New Delhi.

Box 22: What is 'Urban' in India?

Urban settlements in India consist of:

Statutory towns: All places with a municipality, corporation, cantonment board or notified town area committee as declared by the state law.

Census towns: Places which meet the following criteria:

- A minimum population of 5,000
- At least 75 percent of male working population engaged in non-agricultural pursuits
- A population density of at least 400 persons per square kilometre

'Cities' are 'urban areas' with a population of at least one lakh (0.1 million). The others are termed as **'Towns'**.

'Metropolitan cities' are defined as those with a population of at least 10 lakh (1 million).

'Urban agglomerations' (UAs) are defined as continuous urban spreads constituting a town and its adjoining urban outgrowths (OGs) or two or more physical contiguous towns together and any adjoining urban outgrowths of such towns. A UA must consist of at least one statutory town, and its total population of all constituents put together should not be less than 20,000 as enumerated in the Census of 2001.

Size Class Classification (population)

Class I:	100,000 and more
Class II:	50,000 to 99,999
Class III:	20,000 to 49,999
Class IV:	10,000 to 19,999
Class V:	5,000 to 9,999
Class VI:	Less than 5,000

7.3.1 Urban policy framework in India

India is among the largest urban systems in the world, with 377 million people residing in urban areas in 2011. The transition, which will see India's urban population reach a figure close to 558.8 million by 2031, is not simply a demographic shift.[217] It places cities and towns at the centre of India's development trajectory. In the coming decades, the urban sector will play a critical role in the structural transformation of the Indian economy and in sustaining the high economic growth rate. Accelerated job creation emerges as a key issue in planning for India's urbanization within the larger context of its growth and development.

In the federal structure of India, powers and responsibilities of formulating policies and programmes are divided between state and central governments, and on certain subjects, both can make legislations. Urban policy and planning come under the ambit of state governments. Although the central government can provide guidelines, directives, advisory services, set up model legislations and fund programmes; formulating urban policies and their implementation under the guidance of central government are at the will of state governments. Few states have taken initiatives to formulate urban policies and programmes. After independence, Government of India set up a 'Planning Commission' to formulate Five Year Plans (FYPs) for effective and balanced utilization of resources and determining the priority sectors in each Plan period.[218]

In 1988, a policy document titled National Commission of Urbanization (NCU) Report was brought out. The NCU Report was in the form of recommendations for the balanced and sustainable development of urban centers in the country. The recommendations of NCU Report were advisory in nature and no effort either at central or at state level was taken to follow up the implementation of the recommendations[219]. In 2018, India undertook the formulation of a 'National Urbanization Policy Framework' for the first time, covering all aspects of urban development.

Urbanization in India has never been a product of effective formulation and implementation of urban policies. Until 2000s, the coverage of urban policies and programmes under different FYPs was limited to metropolitan cities and the small and medium towns largely remained unaffected[220].

The launch of Jawaharlal Nehru Urban Renewal Mission (JNNURM) in 2005 laid down the foundation of a centrally funded reform driven urban development programme in select cities. It was a large umbrella mission with multiple sub-missions. It aimed to achieve sustainable economic growth in urban areas through large-scale investments made for urban infrastructure. Subsequently, with the change of government at the centre, new missions targeting different components of urban development were launched during 2015. Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart Cities Mission (SCM), Swachh Bharat Mission (SBM), Heritage City Development and Augmentation Yojana (HRIDAY), National Urban Livelihood Mission (NULM) and Pradhan Mantri Awas Yojana (PMAY) are main missions covering almost all class I cities of India.

7.3.2 Urban development policies: A review

1990s saw an era of opening of the country's economy, although ad-hoc measures of liberalization were initiated in the mid-eighties. Following the balance of payment crisis, a programme of economic liberalization was launched in the country which propagated the idea of free-market with limited state intervention.

The Eleventh Plan launched an inclusive agenda and emphasized the need to bring about major changes in urban governance in order to boost investment in infrastructure development in urban areas[221]. During the Eleventh Plan, in pursuance of the vision to make India slum-free, Rajiv Awas Yojana (RAY) was launched. The scheme aimed to upgrade slums, assign title to their residents along with basic infrastructure and social amenities in each selected slum. RAY also extended financial support to States for creation of affordable housing stock through public-private partnership (PPP).

The launch of the JNNURM in 2005 was a landmark achievement, as for the first-time huge funds in the form of substantial additional central assistance (ACA) was allocated to cities for urban development which included infrastructure, housing and capacity building of officials. Besides, developing infrastructural facilities across 65 Mission cities, JNNURM aimed at providing urban infrastructure and housing through its component of Urban Infrastructure and Development Schemes for Small and Medium Towns (UIDSSMT) and Integrated Housing and Slum Development Programme (IHSDP) in non-mission cities.

By 2015 the Rajiv Awas Yojana scheme was replaced by 'Housing for All', which is aimed to operate under four verticals: rehabilitation of slum dwellers with participation of private developers using land as a resource; promotion of affordable housing for weaker section through credit linked subsidy; affordable housing in partnership with private and public sectors; subsidy for beneficiary-led individual house construction. Central funding is available for each vertical for a certain amount and the rest must be organized by the state/ULB and the private developers.

In 2015, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Mission, a reform-based programme akin to the erstwhile JNNURM was launched to provide basic services to households and build amenities in 500 cities. The central funding was Rs. 50,000 crores with matching contribution for states/UTs.

To address the challenges of urban infrastructure deficit, another initiative adopted during the Twelfth Plan was the Smart Cities Mission with an objective to promote cities that provide core infrastructure and give a decent quality of life to its citizens. With an estimated investment of Rs. 48,000 crores during 2015-2020, the core infrastructure elements to be provided in a smart city include adequate water supply, electricity, sanitation, solid waste management, efficient urban mobility and public transport, affordable housing for the poor, robust IT connectivity and digitalization, good governance and citizen participation, sustainable environment, safety and security of citizens, health and education. It is important to note that soft infrastructure like health and education was included for the first time.

The implementation of Smart City Plans has entrusted to Special Purpose Vehicle (SPV), a limited Company under the Companies Act, 2013. The SPV is supposed to plan, appraise, approve, release funds, implement, manage, operate, monitor and evaluate the Smart City development projects.

Smart Cities Mission of the Ministry of Housing & Urban Affairs, Government of India has initiated the "Climate Smart Cities Assessment Framework (CSCAF)" as a step towards holistic, climate responsive urban development. To achieve the targets set under the Paris Agreement, cities need to take steps in consonance with the NDCs and focus towards one single aim of combating impacts of climate change. To advance the actions of the said mission, the Ministry of Housing and Urban Affairs has launched the "CSCAF in February 2019 for 100 Smart Cities.

This assessment framework is aimed to be a guiding framework for cities towards climate actions and to help make them more responsive and less vulnerable to climate change. The objective of the CSCAF is to provide a clear roadmap for cities and in effect, urban India as a whole, towards combating climate change (mitigation and adaptation) while planning their actions including investments. CSCAF was finalized and formally launched on 26 February, 2019.

In the first phase, the assessment established a baseline for 96 cities that participated. The process was spread across a period of six months and involved more than 27 Government departments/ organisations from three tier governance structure- National, State and City along with other stakeholders in providing inputs for more than 120 data sets. In order to facilitate cities to participate in the assessment, 8 cluster workshops and 4 regional workshops were conducted. These workshops saw a participation of more than 300 state and city officials and were conducted between the months of April to July 2019. Cities submitted data on the portal and these submissions were evaluated by an Expert Committee. With an intent to inform cities on their climate readiness, the first baseline assessment for each city was announced. After the successful initiative and assessment, in September 2020, CSCAF 2.0 was launched.

Cities are responsible for the climate-sensitive development of their urban areas. While they are a significant contributor to climate change, they are also particularly vulnerable to its consequences. To facilitate cities in understanding these challenges and where they may improve, a 28 points diverse indicator across five categories has been framed as part of CSCAF.

217 Ministry of Housing and Urban Affairs (2020), National Urban Policy Framework: Strategic Intent, Government of India
218 India: National Urban Policies and City Profiles for Delhi and Madurai, National Institute of Urban Planning, 2018
219 Regional Centre for Urban and Environmental Studies (2011), V. Gnaneshwar, Housing the poor-emerging scenario in India, Urban Panorama (Journal of Urban Governance Ministry of Urban Development, Government of India
220 Annapurna Shaw, Urban Policy in Post-Independent India: An Appraisal, Economic and Political Weekly, 1996
221 Kundu, D., & Samanta, D. (2011). Redefining the inclusive urban agenda in India. Economic and Political Weekly, 46(5), 55-63

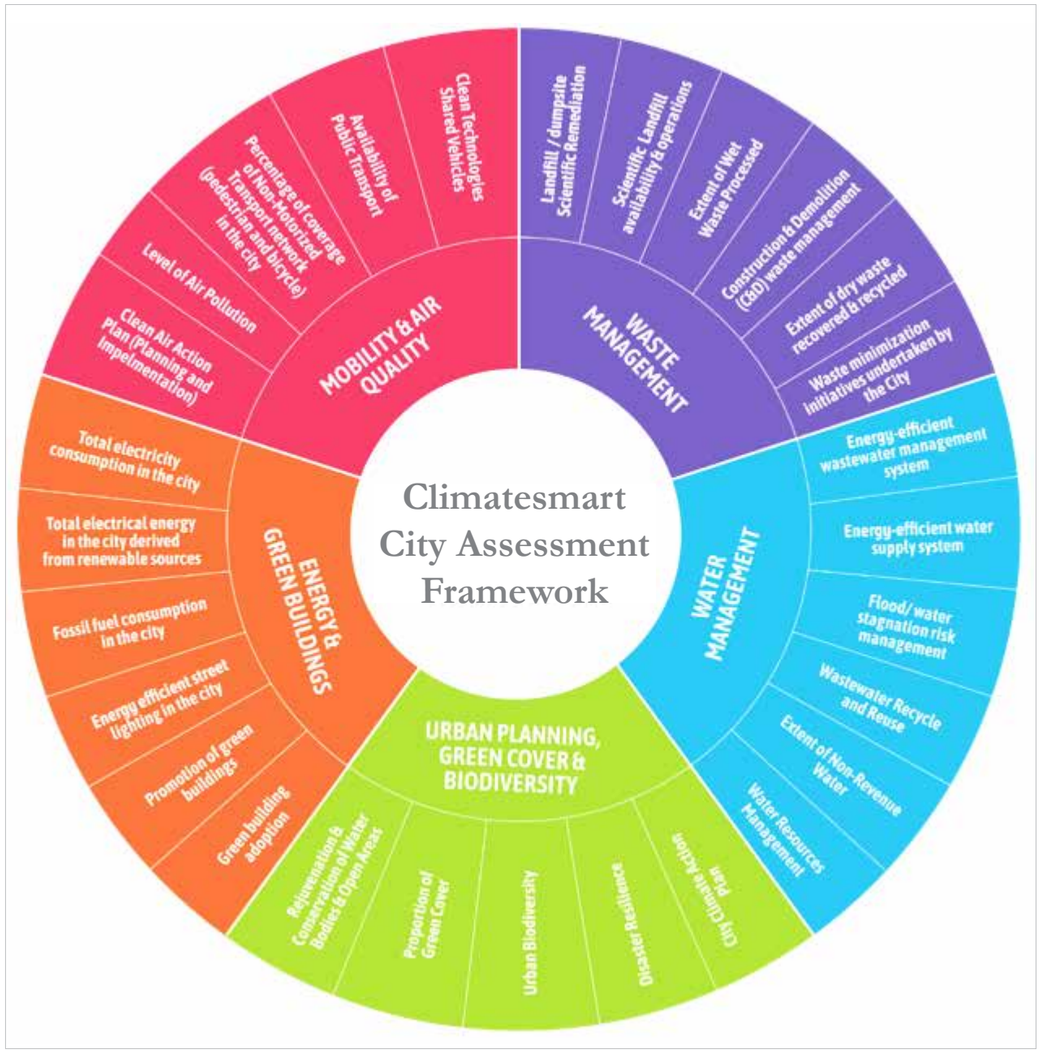

Figure 29: Climate Smart Cities Framework[222]

The Twelfth Five Year Plan projects that roughly 12-23 percent of the investment need in the urban sector can be met by taking projects on PPP, which has the added advantage of bringing in efficiency gains. As per the recommendations of the Working Group on Financing Urban Infrastructure[223], resource mobilization from instruments like PPP, borrowing and land-based instruments need to be scaled up to fund this magnitude of investment requirements and this would require concerted efforts from all tiers of the government.

222 National Institute for Urban Affair, Assessment Framework, Ministry of Housing and Urban Affairs, accessed on 3rd July, 2021
223 High Powered Expert Committee (HPEC) (2011). Report on Indian Urban Infrastructure and Services. New Delhi: Ministry of Urban Development, Government of India.

7.4 Smart Cities And Air Quality Monitoring

The intention of India's Smart City Mission program is to achieve better living conditions in a sustainable environment with smart solutions. This program identifies the key challenges of urbanization and the environment. The mitigation of these challenges depends on the monitoring and assessment of multiple factors, including demography, education, health, and the environment; however, the inclusion of environmental factors are limited. The monitoring and assessment of environmental factors will continuously generate big data and hence would require scientific and technological innovation for a sustainable management plan. These environmental factors include indicators of landscape and geography, climate, atmospheric pollution, water resources, energy resources, and urban green space as a major component of the environment.[224]

According to the World Cities Report[225], cities should focus on creating a just environment to ensure justice and equity for an improvement in our quality of life, and also for sustainable development. Making cities just will require focusing on things such as equal access to resources, poverty alleviation, disaster and hazard management, land use to reduce biodiversity loss and deforestation, and creating a low-carbon and energy-efficient society. The above goals have been integrated from the sustainable development goals, and goal number 11 particularly focuses on making cities more sustainable and liveable[226,227]. However, creating sustainable cities will need to use big data to overcome the dynamic challenges of cities[228,229]. Use of big data, generated from environmental and socio-economic sources, has the potential to prepare a better disaster plan, ensure equitable distribution of resources among people, to improve the liveability of cities, and to provide a rapid response to a changing environment[230].

Major cities are continuously facing the challenges of air pollution which blanket it from time to time. Air pollution is often caused by a lack of policy and forecasting in transportation, industries, energy use, and waste generation. The polluted air is known to affect large populations throughout the world. According to a World Health Organization (WHO) report, more than seven million people die prematurely due to air pollution each year[231]. India has one of the highest numbers of people affected due to air pollution in the world[232]. The rapid increase in population and its unsustainable policies had made cities in India amongst the most polluted in the world. It is imperative to know that a healthy body can be more productive and an asset to society and the economy. Smart cities in India needs to have better policies and frameworks for tackling air pollution. Continuous monitoring, identification of sources, and finding solutions to air pollution is a prerequisite for creating sustainable smart cities.

Institutions such as the Central Pollution Control Board (CPCB) and the State Pollution Control Board (SPCB) should have an adequate number of monitoring stations, and the Air Quality Index (AQI) should be maintained continuously. Satellite data can also be used to obtain more information about atmospheric changes, western disturbances, and also regarding areas adjoining smart cities. Many agents or pollutants combine with other entities in our environment to give rise to smog or acid rain, which can travel long distances[233]. Such pollutant movement, if predicted in advance, can help the authorities in taking/implementing suitable actions to control the negative impact of the pollutants. In smart cities, air pollution can be reduced effectively using green transport, separate lanes for bicycles, more green-belt areas, more renewable energy, and discouraging burning of municipal and agricultural wastes. The rapid collection of big data, modelling, analyses, and forecasting, and converting it to tangible information is important for the benefit of the smart city citizens.

224 Rajneesh Dwevedi, Vinoy Krishna and Aniket Kumar. Environment and Big Data: Role in Smart Cities of India, 2018, MDPI
225 Habitat, U.N. World Cities Report 2016. Urbanization and Development: Emerging Futures; United Nations: New York, NY, USA, 2016.
226 United Nations Development Programme. Sustainable Development Goals, Goal 11: Sustainable Cities and Communities.
227 United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development; United Nations: New York, NY, USA, 2015.
228 Michael Batty, Big Data, Smart Cities and City Planning, 2013, Dialogues in Human Geography
229 Rob Kitchin, The real-time city? Big data and smart urbanism, 2014, Geo Journal
230 Sun, Y.; Du, Y. Big Data and Sustainable Cities: Applications of New and Emerging Forms of Geospatial Data in Urban Studies; Springer: Berlin, Germany, 2017
231 WHO. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease; World Health Organization: Geneva, Switzerland, 2016.
232 Landrigan, P.J.; Fuller, R.; Acosta, N.J.; Adeyi, O.; Arnold, R.; Baldé, A.B.; Chiles, T. The Lancet Commission on Pollution and Health, Lancet, 2017
233 Shuxiao Wang, Jiming Hao, Air quality management in China: Issues, challenges, and options, Journal of Environmental Sciences, Volume 24 Issue 1, 2012

It is imperative that we include various components of the environment's ecosystem, as these parameters provide a holistic view to the Indian mission of smart cities. Many of the cities are already reeling under the stress of high pollution, and are amongst one of the most polluted cities in the world. As most of the Indian population will be living in cities in the future, the Indian government needs to prepare regarding the equitable use of resources to promote sustainable development. This initiative would require inclusion of the parameters discussed earlier as a vital component of smart city governance, as well as the generation of real-time spatial and temporal data. The digital ecosystem, consisting of big data, ICT, and IoT, should be integrated into our natural environment, which could well make the Smart City Mission in India a success.

7.5 Relevance Of Urban Governance From The Perspective Of AQM In India

As explained in Chapter 2, Mainstreaming air quality in urban development involves the active promotion of better air in the identification, planning, designing, and implementing urban development strategies and policies. Mainstreaming in this context, is a more holistic and strategic approach which refers to addressing air quality issues strategically as a cross-cutting aspect of urban development and goes beyond just air pollution mitigation to achieve low emissions urban development. Mainstreaming requires considering the impact of air quality in the planning phase of development plan at earliest stages of the decision-making process, when urban development challenges and proposed city implementation plans are being designed. Taking into consideration air quality as an integral part of urban development planning can play a major part in achieving broader development objectives. City planning that takes into consideration many different sectors. For example, how people get around from one place to another and reduces the need for private vehicle use means taking into consideration air quality impact right from the beginning. Another example can be waste disposal systems integrated within the urban planning process to prevent dumping and burning. Urban local body deals with such subjects including environment, waste management, health, Mobility within city etc. Decision-makers from ULBs need to make an effort to balance air pollution prevention and administer control with economic, environmental and health policy priorities, taking into consideration issues of intergenerational justice, equity across sectors, and environmental justice during the planning process.

A Clean Air Action Plan (CAAP) is being developed by many cities in India to improve air quality and public health by identifying cost-effective measures to reduce emissions. It is a collection of regulations, policies, and programs for improving air quality. The CAAP development process is led by the government and involves stakeholders. Implementation and enforcement of CAAP plays a vital role in reducing air pollutant emissions and achieving air quality objectives. As explained in Table 3 of Chapter 3, Implementation of Control Measures process involves many central, state and local govt. agencies, private entities, academia, non-governmental organizations and foundations, mass media, civil society, sectoral groups (e.g., public transport associations) and private citizens which makes it more diverse and complicated in terms of execution. A successful and implementable CAAP needs clear institutional framework and responsibilities, stakeholder coordination and communication, political support, allocation of financial resources, technical capabilities, and review and improvement.

7.6 Key Messages

Air pollution is the second largest risk factor contributing to the countries burden of disease. Urban air pollution reflects the fast rate of urban development with its associated increases in energy needs, rising transport requirements, and booming populations. This manual provides the participants guidance to develop or plan a city with the concept of Low Emission Urban Development. Green city and Low carbon cities concept is often discussed, but this manual lays down a different approach, which links air quality and urban development. The manual highlights techniques which enables the planning and development process to consider how an urban area will develop with green and sustainable principles in mind, by drawing instances from various development strategies like Green city development and Low carbon city development. It also calls to attention the importance of interplay between sectors, which is helpful in achieving such outcomes. It is important to look for various ways to integrate air quality in the urban sector to develop strategies for clean cities. Though there is a long way to go for achieving the goal of clean cities, this manual can initiate the thought process towards clean cities through the concept of Low Emission Urban Development.