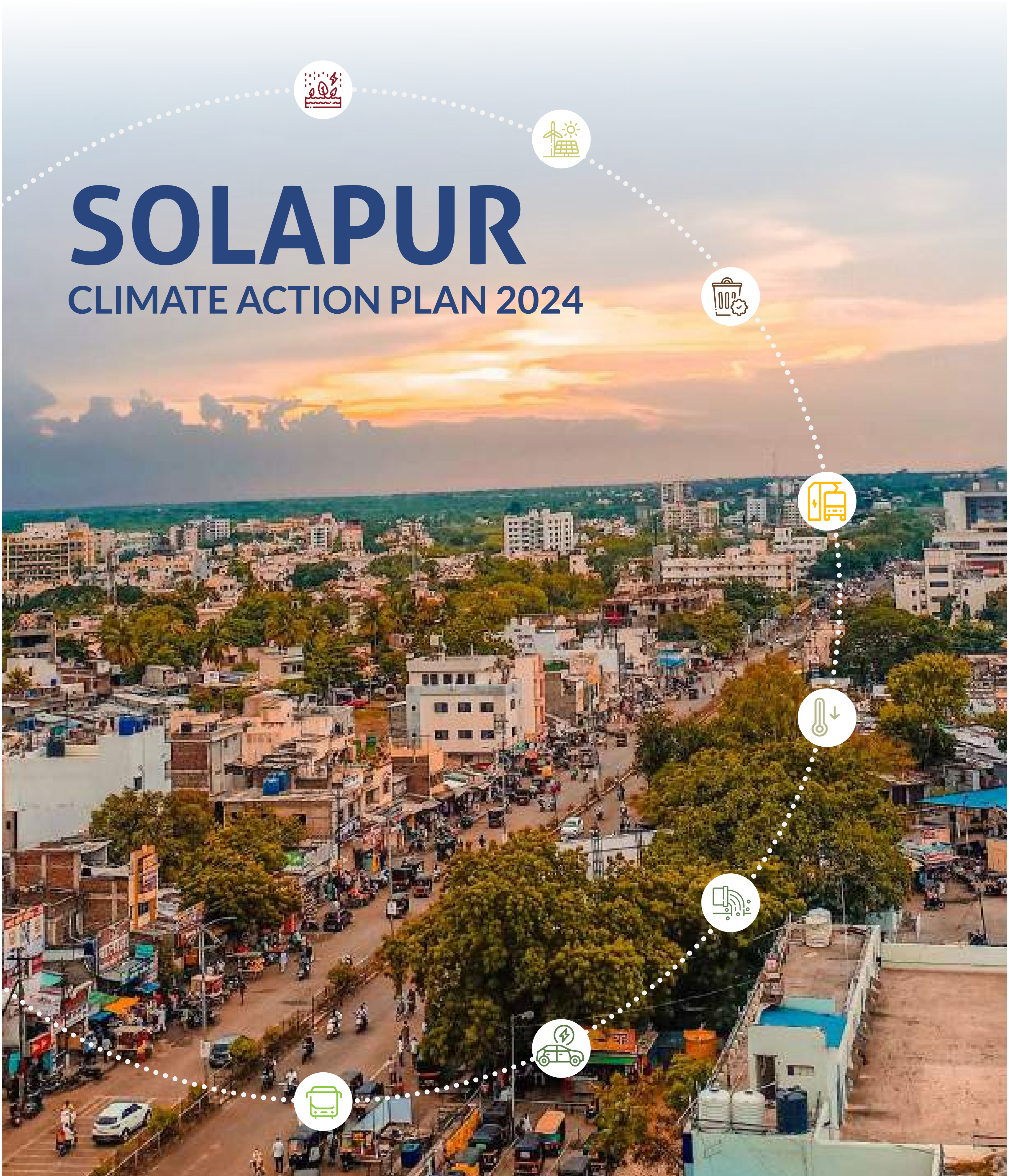
Government of Maharashtra
Environment and Climate Change Department

SOLAPUR

CLIMATE ACTION PLAN 2024



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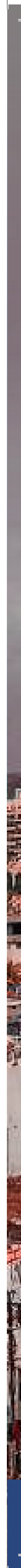

SOLAPUR

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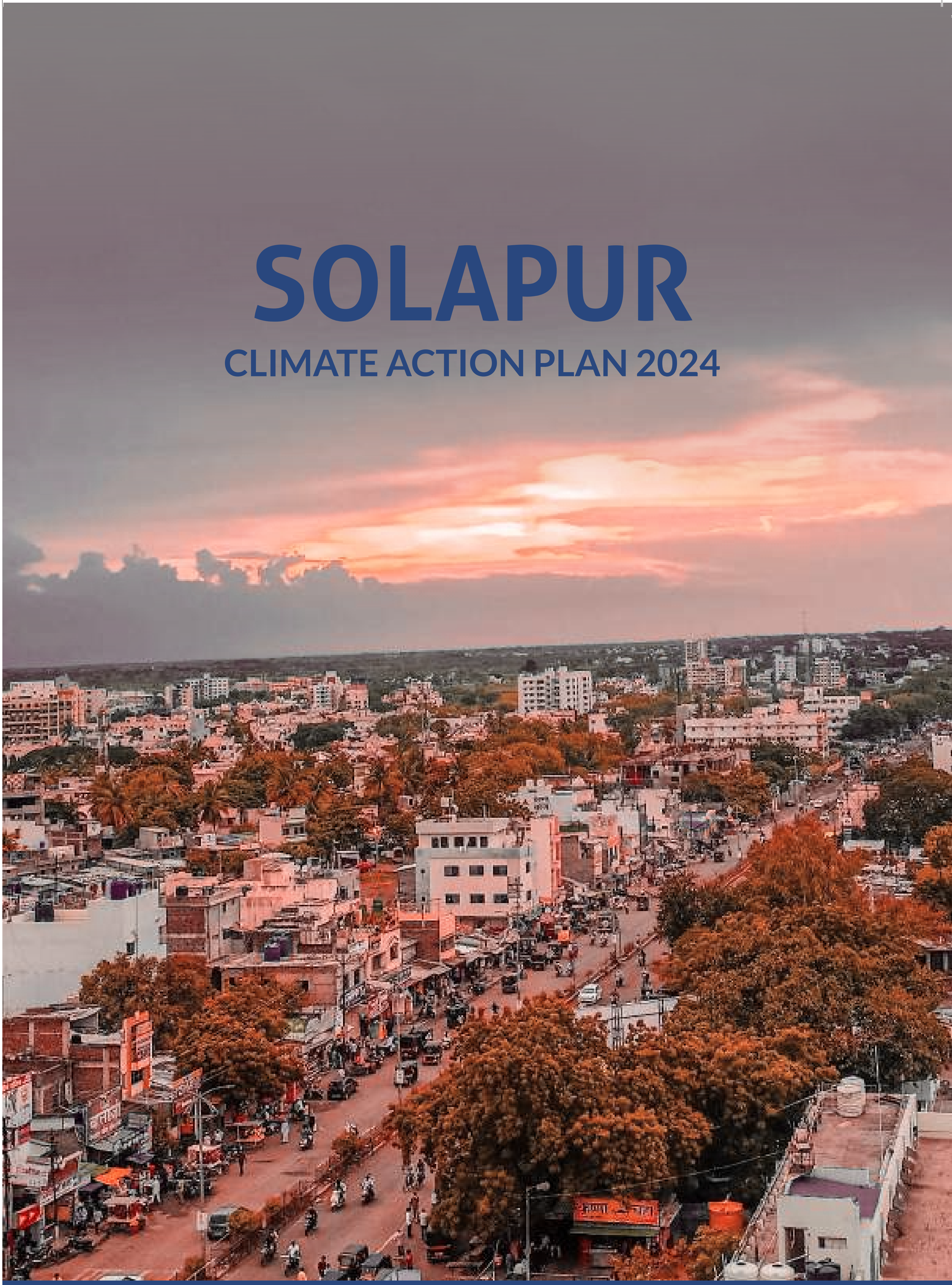

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KAMBAR TALAV
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ABBREVIATIONS

2W	Two Wheeler
3W	Three Wheeler
4W	Four wheeler
ADTP	Assistant Director Town Planning
AI	Artificial Intelligence
AMC	Additional Municipal Commissioner
AMRUT	Atal Mission for rejuvenation and urban transformation
APCD	Air Pollution Control Device
APMC	Agricultural Produce Market Committee
AQ	Air Quality
AQI	Air Quality Index
ASP	Activated Sludge Process
BAU	Business As Usual
BEE	Bureau of Energy Efficiency
BHEL	Bharat Heavy Electricals Limited
BOD	Biochemical Oxygen Demand
BOOT	Build-on-operate -transfer
BOQ	Bill of quantities
BPMC	Bombay Provincial Municipal Corporation
BRT	Bus Rapid Transit
BS-VI	Bharat Stage - VI
BWG	Bulk waste generators
C&D	Construction and demolition
CAAQMS	Continuous Ambient Air Quality Monitoring Stations
CAGR	Compound Annual Growth Rate
CAP	Climate Action Plan
CBUD	Capacity Building for Urban Development
CCC	Command and control centre
CDP	City Development Plan
CDP	Carbon Disclosure Protocol
CEAI	Central Electrical Authority of India
CETL	CICON Environmental Technologies Pvt. Ltd.
CFA	Central Financial Assistance
CGWB	Central Ground Water Board
CH_4	Methane
CHP	Combined Heat & Power
CIFF	Children's Investment Fund Foundation
CIRIS	City Inventory Reporting and Information System
CITIIS	City Investments to Innovate, Integrate and Sustain

CMP	Comprehensive Mobility Plan
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
COP	Conference of the Parties
CPCB	Central Pollution Control Board
CREDAI	Confederation of Real Estate Developers' Associations of India
CRI	Climate Risk Index
CSCAF	Climate Smart Cities Assessment Framework
CSO	Civil Society Organisation
CSR	Corporate Social Responsivity
CTS	Chain and Triangulation Survey Number
CURB	Climate Action for Urban Sustainability
CWC	Central Water Commission
DCR	Development Control Regulations
DEM	Digital Elevation Model
DFO	District Forest Office
DG	Diesel Generator
DISCOM	Distribution Companies
DM	District Magistrate
DMC	Deputy Municipal Commissioner
DoE	Directorate of Establishment
DP	Development Plan
DPR	Detailed Project Report
E&P	Existing and Planned
E&B	Energy and Building
EC	Environmental Clearance
ECBC	Energy Conservation Building Code
ECC	Environment and Climate Change
ECCC	Environment & Climate Change Cell
EESL	Energy Efficiency Service Limited
EPR	Extended Producer Responsibility
ERE	Extreme Rainfall Event
ESR	Elevated surface reservoir
EV	Electrical Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
FGD	Focus Group Discussion
FSI	Floor Space Index
FSTP	Faecal Sludge Treatment Plant
FY	Financial year
GB	General Board
GCM	General Circulation Model
GDP	Gross Domestic Product

GHG	Green House Gas
GIS	Geographic information system
GPC	Global Protocol for Communities
GPS	Global Positioning System
GSDA	Groundwater Survey and Development Agency
GW	Ground Water
GWP	Global Warming Potential
GWRP	Ground Water Recharge Potential
HAP	Heat Action Plan
HDV	High Duty Vehicle
HFCs	Hydrofluorocarbons
HH	Household
HT	High tension
HVAC	Heating Ventilation and Air conditioning
ICAP	Inclusive Climate Action Plan
ICE	Internal Combustion Engine
ICLEI	International Council for Local Environmental Initiatives
IEC	Information, Education and Communication
IGBC	Indian Green Building Council
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public transport
IT	Information Technology
ITDP	Institute for Transportation and Development Policy
ITMS	Intelligent Traffic Management System
JNNURM	Jawaharlal Nehru national urban renewable mission
KG	Kilogram
KM	Kilometre
KPI	Key Performance Indicator
LDV	Light-Duty Vehicle
LED	Light Emitting Diode
LEZ	Low Emission Zones
LNB	Low NOx burner
LOS	Level of Service
LPG	Liquified Petroleum Gas
LST	Land Surface Temperature
LT	Low tension
MAHADISC	Maharashtra Distribution Companies
MAHAGENCO	Maharashtra State Power Generation Company
MBR	Membrane BioReactor
MCAP	Mumbai Climate Action Plan

Mcorp	Municipal Corporation
MEDA	Maharashtra Energy Development Agency
MEEP	Municipal Energy Efficiency Program
MER	Monitoring Evolution Reporting
MHSEC-2050	Maharashtra State Energy Calculator - 2050
MIDC	Maharashtra Industrial Development Corporation
MLA	Member of Legislative Assembly
MLD	Million litres per day
MM	Millimetre
MODIS	Moderate Resolution Imaging Spectroradiometer
MoHUA	Ministry of Housing and Urban Development
MP	Member of Parliament
MPCB	Maharashtra Pollution Control Board
MRF	Material Recovery Facility
MRV	Measuring, Reporting and Verification
MSAAPCC	Maharashtra State Adaptation Action Plan on Climate Change
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSME	Ministry of Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
MT	Metric tonnes
MVA	Majhi Vasundhara Abhiyan
MW	Megawatts
N_2O	Nitrous Oxide
NA	Not Applicable
NAAQ	National Ambient Air Quality
NAMP	National Air Quality Monitoring
NASA	National Aeronautics and Space Administration
NBS	Nature Based Solutions
NCAP	National Clean Air Program
NCEI	National Centers for Environmental Information
NDC	Nationally Determined Contributions
NDVI	Normalised Difference Vegetation Index
NEE	Non exhaust emission
NEERI	National Environmental Engineering Research Institute
NEPRA	National Electric Power Regulatory Authority
NEX-GDDP	NASA Earth Exchange Global Daily Downscale Projections
NGO	Non-government organisation
NH	National Highway
NHAI	National Highway Authority of India
NIUA	National Institute of Urban Affair
NMT	Non-motorised transport
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxide

NPO	Non-profit organisation
NRW	Non-revenue Water
NTPC	National Thermal Power Corporation
O&M	Operating & Maintaining
O_3	Ozone
OEM	Original Equipment Manufacturer
OWC	Organic Waste Converter
PBR	People Biodiversity Report
PBS	Public Bicycle Sharing
PHE	Public Health Engineer
PM	Particulate Matter
PMPML	Pune Mahanagar Parivahan Mahamandal Ltd
PMUY	Pradhan Mantri Ujwala Yojana
PNG	Piped Natural Gas
PPP	Public Private Partnerships
PR	Public Relations
PT	Public Transport
PUC	Pollution Under Control
PV	Photo Voltaic
PWD	Public Works Department
RCP	Representative Concentration Pathways
RDF	Refuse Derived Fuel
RE	Renewable Energy
RERA	Real Estate Regulatory Authority
RSPM	Respirable Suspended Particulate Matter
RTO	Regional Transport Office
RWA	Resident Welfare Association
RWH	Rainwater Harvesting
SBESPL	Solapur Bio-Energy Systems Private Limited
SBM	Swachh Bharat Mission
SBR	Sequential Batch Reactor
SC	Scheduled Caste
SCADA	Supervisory Control and Data Acquisition System
SCDCL	Solapur City Developmental Corporation
SDG	Sustainable Development Goals
SEDA	Solapur Electronics Dealers Association
SHG	Self Help Groups
SLB	Service Level Benchmark
SLCP	Short lived Climate Pollutants
SLF	Scientific Landfill Facility
SM	Sustainable Mobility
SMC	Solapur Municipal Council
SMT	Solapur Municipal Transport
SO_2	Sulphur Dioxide

SPM	Suspended Particulate Matter
SPV	Special Purpose Vehicle
SRPF	State Reserve Forest Force
SRTM	Shuttle Radar Topography Mission
ST	Scheduled Tribe
STP	Sewage Treatment Plant
SUP	Single used plastic
SW	Sustainable Waste
SWM	Solid Waste Management
TERI	The Energy and Resources Institute
TOF	Trees Outside Forest
TPD	Tonnes Per Day
TSS	Total Suspended Solids
UFW	Unaccounted for Water
UHI	Urban Heat Island
UNFCCC	United Nations Framework Convention on Climate Change
UPI	Unified Payments Interface
URDPFI	Urban and Regional Development Plans Formulation and Implementation
USGS	United States Geological Surveys
VA	Vulnerability Analysis
VFD	Variable frequency drive
VKT	Vehicles kilometres travelled
W2E	Waste to Energy
WIT	Walchand Institute of technology
WSF	World Settlement Footprints
WTP	Water treatment plant

PREFACE

SHRI. PRAVIN DARADE, IAS

Principal Secretary,
Department of Environment and Climate Change,
Government of Maharashtra

It gives me an immense pleasure and a profound sense of accomplishment to acknowledge Solapur is leading the way forward in tackling the climate crisis by adopting the Solapur Climate Action Plan.

The increasing number of extreme weather events worldwide that directly affect our local communities has made it more urgent to address the climate crisis. During the COP26 summit in Glasgow, Hon. Prime Minister of India announced a target to achieve net-zero emissions by 2070. Hon. Prime Minister of India also introduced a new concept called "Lifestyle for the Environment (LiFE)" during the COP on 1st November 2021. This initiative encourages people to adopt mindful and deliberate practices to protect and preserve the environment rather than mindless and destructive consumption. The program is people-centric and aims to tackle climate change while also calling for global action.

Maharashtra is leading India's efforts to combat the imminent climate crisis by implementing policy reforms and encouraging climate action culture within society. The state has a history of pioneering initiatives such as the 'Sant Gadge Baba Gram Swacchata Abhiyan' and 'Swachh Bharat Abhiyan' and is now spearheading the 'Majhi Vasundhara Abhiyan' in Urban Local Bodies and Panchayati Raj Institutions. While India is working towards achieving its Nationally Determined Contributions, Maharashtra's commitment to the cause sets an example for the nation.

Climate change requires tailored solutions that address the environmental concerns of our diverse urban landscapes. The Solapur Climate Action Plan is aligned with the Paris Agreement's goal of limiting global warming to 1.5°C. Additionally, formation of the Climate Action Cell at the state level inspires the city to establish its own city-level Climate Action Cell within the Solapur Municipal Corporation.

I personally congratulate the Solapur Municipal Corporation and WRI India for their leadership in advancing the ambitious climate agenda for a 'Climate Forward Maharashtra'.

FOREWORD

SHRI. ABHIJIT GHORPADE

Director, State Climate Action Cell, Department of Environment and Climate Change, Government of Maharashtra

Climate Change is the greatest challenge faced by man in this century. In the pursuit of a sustainable and resilient future, acting on climate change has never been more crucial. With its dynamic communities and diverse landscapes, Maharashtra stands at the centre stage of this global challenge. I am proud to share that Solapur city is actively contributing to the effort of tackling the climate crisis by adopting its own Solapur Climate Action Plan. This plan adheres to a global standard, highlighting the significant role the city plays in addressing the pressing issue of climate change.

Maharashtra, the third most urbanized state in India, has around 45% of its population living in urban areas. As cities continue to grow and offer education, healthcare and job opportunities, they also present a unique challenge to climate adaptation and mitigation due to their diverse landscapes. Cities therefore, should not only be at the centre of climate change, but also at the forefront of climate action. In recent decades, the Government of Maharashtra has increased its focus on climate resilience to address the rising heatwaves, changing rainfall patterns, cyclones, and other extreme weather events.

Solapur has a unique opportunity to shape its future urban development while considering the impact of climate change. The newly created Solapur Climate Action Plan (CAP) is designed to align with important government schemes and policies, such as the National Clean-Air Action Plan (NCAP), the Swachh Bharat Mission, Majhi Vasundhara Abhiyan targets, and the Climate Smart Cities guidelines. The city should prioritise climate actions by utilizing funds from these schemes and missions.

The Government of Maharashtra aims to expedite localized measures to achieve the objectives of the Paris Agreement, which seeks to limit global warming to 1.5°C. The creation and release of the Solapur CAP marks a significant achievement for the city, encouraging other AMRUT cities to emulate its example and attain the ambitious target of achieving Net Zero emissions by 2050.

As the Director of the Maharashtra State Climate Action Cell, I extend my heartfelt gratitude and appreciation to the administrative leadership of the Solapur Municipal Corporation and WRI India's team for their unwavering commitment to combating climate change by implementing the ambitious climate action plan. As the city of Solapur is working towards the goal of climate resilience, I urge all cities and towns in Maharashtra to tread the path towards a sustainable and resilient future for our urban communities and realize the dream of a 'Climate-Forward Maharashtra'.

PLEDGE

SMT. SHEETAL BASAVARAJ TELI UGALE, IAS

Municipal Commissioner and Administrator, Solapur Municipal Corporation

I feel incredibly proud and fortunate to present the Solapur Climate Action Plan (CAP) on behalf of the Solapur Municipal Corporation (SMC) in our pursuit of progressing towards a sustainable future. This milestone is a testament to the unyielding support of the Department of Environment and Climate Change, Government of Maharashtra, in making the CAP a reality.

I would like to congratulate the Additional Municipal Commissioner, the Deputy Municipal Commissioner (Environment), the City Engineer, the Environment Officer, and the SMC team for their tireless efforts in developing the CAP. I extend my heartfelt thanks to our knowledge partners, WRI India. This CAP is our initial contribution towards making 'Climate Forward Maharashtra'.

The city of Solapur faces significant crisis in terms of water stress and increasing urban heat. Climate change expedites these crisis, leaving the city with more challenges. The CAP document provides a baseline assessment of Solapur's preparedness for climate risks. The document carefully charts out recommendations to address Solapur's climate vulnerabilities. The plan has been diligently formulated after extensive data collection, critical analysis, and extensive consultations with multiple stakeholder groups, including departments from the SMC. The plan highlights areas of concern through the spatial mapping exercise grounded in rigorous scientific analysis and ground truthing.

This is probably the first time Solapur City has prepared its comprehensive Greenhouse Gas (GHG) emissions inventory. To implement the CAP, SMC is looking forward to strengthening the environment mandate by creating a climate action cell within SMC. We will focus on implementing various actions recommended under the CAP and mainstreaming climate actions in our plans, programs, and projects. Increasing urban greening, mitigating urban heat and air pollution hotspots, recharging groundwater, recycling and reusing wastewater, etc., are our top priorities going forward. All the stakeholders, including government and non-government organisations and citizens, play essential roles in this endeavour.

Solapur CAP aims to guide the city towards achieving net zero emissions in the future through inclusive low-carbon, green, and water-sensitive development. I humbly request all citizens, government agencies, and civil society to support SMC's efforts to successfully implement the CAP.

PLEDGE

SHRI. MACCHINDRA GHOLAP

Deputy Municipal Commissioner, Solapur Municipal Corporation

I appreciate the visionary leadership of the Environment and Climate Change Department of the State Government of Maharashtra for their progressive vision. Thanks to their efforts, the Solapur Climate Action Plan (CAP) has become a reality.

I feel honoured to have been given the opportunity to head the team of the Solapur Municipal Corporation (SMC) in the preparation of the CAP. I would like to express my sincere gratitude to all the departments of SMC, various parastatal agencies, and Shri. Swapnil Solankar for their support in providing data and their insights, coordination, and assistance towards this initiative. Furthermore, I deeply appreciate our knowledge partners, WRI India, for their technical guidance and support in preparing and compiling the Solapur CAP.

Cities like Solapur, which are classified as Tier-II cities, are becoming increasingly important as emerging growth centres in the next few decades. It is crucial that these cities adopt sustainable practices in their development trajectory. The Solapur CAP is vital for ensuring climate-resilient urban development in Solapur, and it is centred around the needs of its citizens. The Solapur CAP focuses on six critical sectors that are closely aligned with India's commitments to the Sustainable Development Goals (SDGs). Through On-going initiatives such as increasing green cover, implementing sustainable waste management practices, promoting sustainable mobility, creating accessible footpaths, and building cycling infrastructure, the Solapur Municipal Corporation (SMC) is making efforts to align with climate goals.

I am highly confident that Solapur CAP will make significant contributions to SMC's efforts in addressing the causes and effects of climate change and improving the quality of life for people in Solapur.

MESSAGE

SHRI. MADHAV PAI

CEO, WRI India

Tier II cities are crucial to India's growth, and the Solapur Climate Action Plan (CAP) is a pivotal tool in ensuring this growth is sustainable and resilient to climate impact; along with meeting the needs of the city's residents. The Plan's six key areas of action – energy and buildings, sustainable mobility, sustainable solid waste management, urban greening and heat mitigation, water resource management and air quality – are closely aligned with the Sustainable Development Goals (SDGs). The Plan is also in line with India's commitments to chart decarbonization pathways for the energy and transport sector.

Working with the Solapur Municipal Corporation's team in shaping the city's first every climate action plan brings me immense joy, and I extend my heartfelt thanks to all departments and agencies for their invaluable contributions. I also want to acknowledge Children's Investment Fund Foundation (CIFF) for their unwavering support towards climate-centric development which fosters positive change for children and other communities across India.

I am excited about the Solapur Climate Action Plan's transformative potential, not only for the city, but also for other Tier II cities that could take forward these learnings to create their own climate action plan. This is an opportunity for the city to build capacity across multiple sectors paving the way for sustainable, equitable and resilient development.

As we witness the Plan unfold, WRI India looks forward to working with local authorities, communities, and other stakeholders to shape Solapur into becoming a more resilient city that fosters innovative thinking and sustainable practices.

JUNA PUNA NAKA
Photo credit: Pravin Gaikwad

ACKNOWLEDGEMENTS

WRI India prepared and compiled the Solapur Climate Action Plan under the leadership and direction of the Department of Environment and Climate Change, Government of Maharashtra, and Solapur Municipal Corporation (SMC).

We extend our heartfelt gratitude to the following individuals for their invaluable support and remarkable contributions to the Solapur Climate Action Plan (Solapur CAP).

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All maps in this report are intended as visualizations to communicate city-wide data analysis for information purposes only and are not to scale.

This report should be referred to as the ‘Solapur Climate Action Plan, 2024’

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Cover page Photo credit: **Pravin Gaikwad**

SECTION - I

Climate Action Plan Process

REVANSIDDHESHWAR TEMPLE
Photo credit: Pravin Gaikwad

1. CLIMATE ACTION PLANNING – APPROACH AND METHODOLOGY

1.1 BACKGROUND

India accounts for nearly 6.5% of the global greenhouse gas emissions (GHGs), with almost half of the country's emissions having urban origins - industries, transport modes, buildings and waste[1]. This, coupled with rapid urbanisation and the depletion and degradation of natural resources, escalates the occurrence of more frequent and severe climate events. Indian cities are particularly vulnerable to water stress, prolonged hot (or cold) days, heat island effect, flash floods, urban water logging, droughts and deteriorating air quality.

At the national level, the Government of India has committed to addressing climate change impacts by implementing national-level policies down to the local level. Through large-scale urban infrastructure investment programmes led by the Ministry of Housing and Urban Affairs (MoHUA), many sub-missions and programmes with low-carbon development strategies have been financed to make cities sustainable.

Metros or large cities in the country have begun focussing on causes and impacts of climate change using the lens of adaptation and mitigation strategies. However, Tier II cities, i.e. those that have a million-plus population, have neither the capacity nor the capability to understand and focus on climate-related risks. Keeping this in mind, the Government of Maharashtra in collaboration with Children's Investment Fund Foundation (CIFF) and C40 Cities, selected three Tier II cities as project cities in Maharashtra, namely Solapur, Nashik, and Chhatrapati Sambhajinagar (Aurangabad), to the develop three Climate Action Plans (CAPs), one for each city.

WRI India has been appointed to develop the CAPs for Solapur, Nashik and Chhatrapati Sambhajinagar (Aurangabad) cities and support in implementation. This will enable the local governments to integrate climate change actions with their urban development initiatives.This report presents the Climate Action Plan for Solapur city in detail.

1.2 WHAT IS CLIMATE ACTION PLAN?

The World Bank's[2] latest Climate Change Action Plan 2021-2025 recognises city systems as one of the key generators of GHG emissions and facing significant adaptation challenges. Indian cities are continually dealing with the negative impacts of climate change (heat waves, floods, drought etc.), with piecemeal measures to tackle such extreme events. There is an urgent need for informed climate action planning that would integrate climate science with mitigation and adaptation strategies within the framework of development strategies.

The CAP would enable city stakeholders to use the relevant knowledge and frameworks to a) consolidate their actions under a comprehensive strategy b) understand the co-benefits of climate action, and c) take a systemic approach to move from reactive to proactive climate action. The CAP is in alignment with the Climate Smart Cities

Assessment Framework (CSCAF) with respect to the five sectors that the two frameworks have in common. While the CSCAF is a first step towards cities mainstreaming climate-centric measures, the CAP strengthens this through a comprehensive process that includes localised measures.

The CAP focuses on two key strategies:

Adaptation focuses on the impacts of climate change and sectoral sub-strategies and actions to enhance the capacities of the city and community to cope with climate change, and

Mitigation focuses on the causes of climate change i.e. assessing GHG emissions and its sectoral contribution to it, likely scenarios of future GHG emissions and sectoral sub-strategies and actions to reduce the emissions.

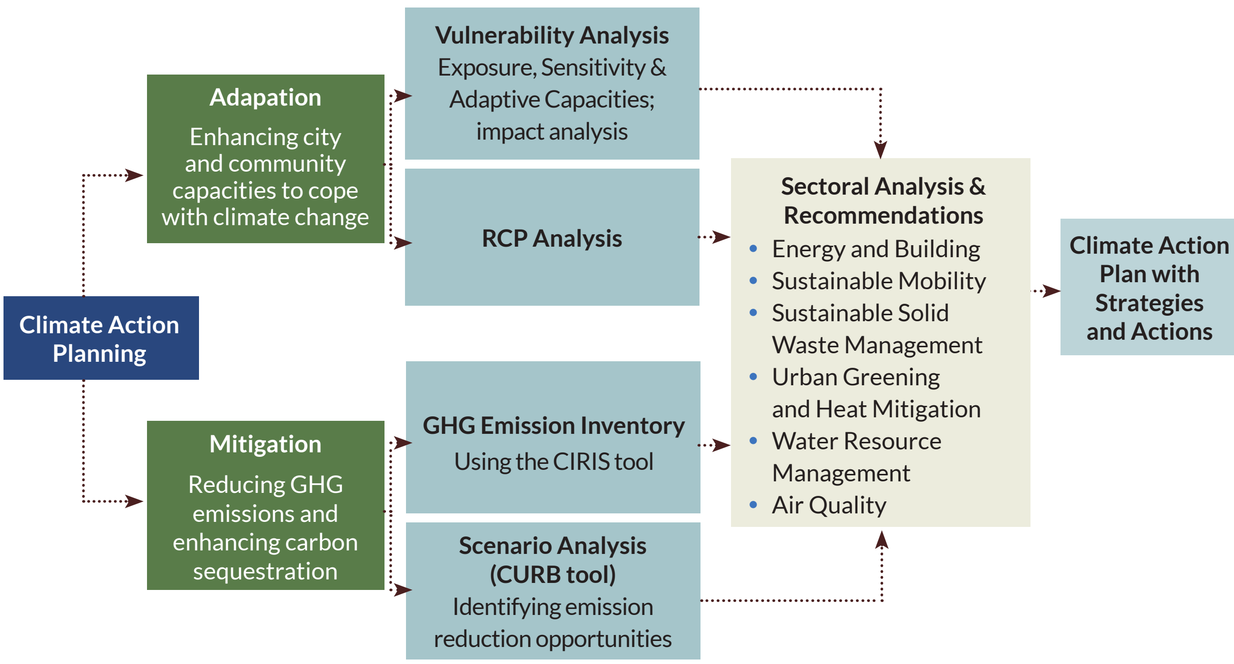
These strategies act as powerful tools for monitoring progress towards the climate goal as it allows cities to formulate evidence-based adaptation and mitigation goals and actions. Refer to Figure 1-1.

1.3 CLIMATE ACTION PLANNING PROCESS - APPROACH AND METHODOLOGY

1.3.1 CAP process in Solapur

The Solapur CAP process began in January 2022, with a kick-off meeting and the virtual signing of the Letter of Intent at an event chaired by the Hon'ble Commissioner and officials from various departments. Following which, an inclusive and consultative process was undertaken by WRI India to develop the CAP as detailed in the 12 step process below.

Figure 1-1: Climate Action Plan - tools and strategies



Source: WRI India Analysis

Project inception
Setting up of a core team, signing the Letter of Intent with Solapur Municipal Corporation, setting the context, mapping stakeholders, and conducting initial discussions with city officials and parastatal agencies. 1

Baseline Assessment
Data collection, data validation and identification of data gaps, and addressing the same 2

Stakeholder consultations
Stakeholder consultations - Data validation and mapping of vulnerable areas, identification of waterlogging and air pollution hotspots, etc. 3

Developing Climate Profile
Developing Vulnerability Assessment (VA) and Greenhouse Gas (GHG) Emissions Inventory, identifying climate risks, identifying key sectors 4

Stakeholder consultations
Capacity building workshop on VA and GHG emissions inventory 5

Scenario Analysis and RCP Analysis
Carrying out future scenario analysis and Representative Concentration Pathways (RCP) Analysis 6

Stakeholder Consultations
Validate various assumptions under the Scenario Analysis 7

Sectoral analysis
Develop sectoral goals, strategies, and actions, review with WRI India's sectoral experts 8

Finalisation of draft CAP
Compilation of the VA, GHG Emissions Inventory, sectoral assessment, recommendations, and sectoral strategies; developing the structure of the Climate Action Cell, development of the Monitoring, Evaluation, and Reporting (MER) framework, acceleration of plans to projects, stakeholder consultation and presentation of the draft Solapur Climate Action Plan 9

Stakeholder consultations — 10
Inputs and feedback on the draft Solapur Climate Action Plan

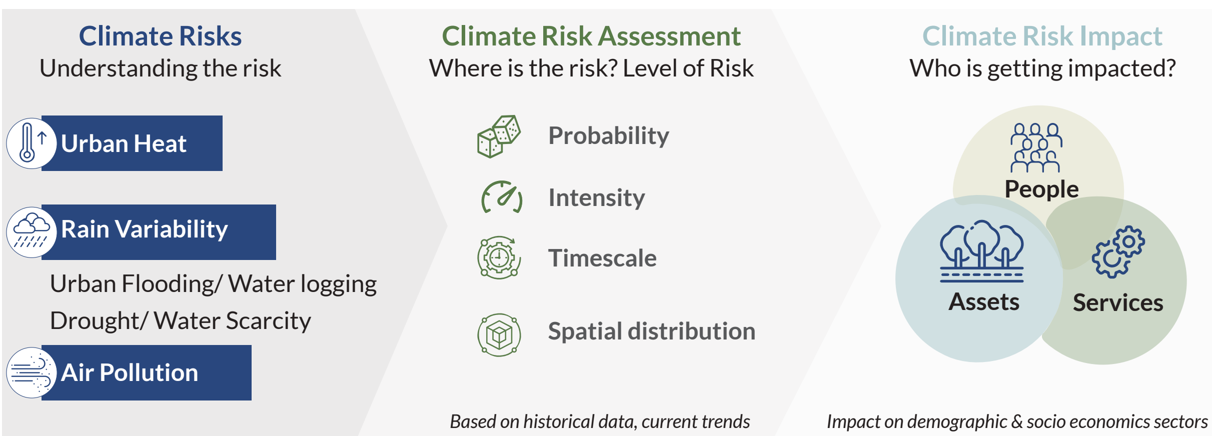
Finalisation of the CAP — 11
Finalise Solapur CAP addressing comments from various stakeholders

Launch of the CAP — 12
Launch of the CAP

1.3.2. Vulnerability Assessment Framework

WRI India's spatial VA framework is based on the Intergovernmental Panel on Climate Change (IPCC) approach (Exposure, Sensitivity and Adaptive Capacities) that helps cities assess differential vulnerabilities based on varied exposure to climate and disaster risks, pre-existing socio-economic sensitivities and access to essential services and amenities that are critical for rescue and recovery processes during extreme weather events. Geospatial vulnerability maps are created using a combination of climate risk data, remote sensing data, census data, and GIS-based data sourced from city authorities, which highlight differential vulnerabilities and adaptation needs of the city. Refer to Figure 1-2

Figure 1-2: Vulnerability Assessment Framework



Source: WRI India Analysis

1.3.3 GHG Emissions Inventory and Scenario Analysis - Framework

The GHG emissions inventory for Solapur is aligned with the Global Protocol for Communities (GPC) framework, a robust GHG accounting and reporting framework for cities prepared by WRI, C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability as seen in Figure 1-3. The inventory helps identify opportunities for emissions reduction.

The Scenario Analysis will be in line with low carbon action pathways and develop three scenarios: 1. Business-as-usual, 2. Existing and planned scenario, 3. Ambitious climate action scenario. The scenario analysis will be guided by the data collection and consultation activities with sectoral experts.

1.3.4 Key stakeholders

Solapur Municipal Corporation is the nodal agency that plans, implements, and regulates development in the city. There are several other agencies involved in developing the CAP that have shared relevant data. Table 1-1 presents a list of all agencies involved in the CAP development in Solapur city.

Figure 1-3: Identified sectors in the Scope 1 of GHG Emission Inventory

Energy & Building	On Road Transportation	Solid Waste	Domestic Wastewater Treatment
• Residential buildings • Commercial buildings • Manufacturing industries* and construction • Streetlights • Public Utilities	• Multiple vehicles of 2/3/4 wheelers and multi-axle vehicles with different fuel based engine	• Waste Compost • Waste to Energy • Incineration (Scope-3)	• Wastewater generated in the city

*Note: *industries outside municipal limits, coal consumption was not included due to difficulty in obtaining data*
Source: CIRIS tool

Table 1-1: Key agencies and their roles

S.N.	Name of agency	Role/ sector
1	Solapur Municipal Corporation	City administration managing - water supply, sanitation, solid waste management, roads and bridges, development plan, streetlights, etc.
2	Regional Transport Office (RTO)	Vehicle Registration
3	Oil companies	Sale of petrol, diesel and CNG
4	Maharashtra State Electricity Distribution Company Limited (MSEDCL)	Electricity distribution and supply
5	Maharashtra State Power Generation Company (MAHAGENCO)	Electricity generation
6	GSDA	District Ground water management
7	Traffic police	Traffic management
8	Indian Meteorological Department IMD	Rainfall and temperature data
9	MPCB	Control and regulation - Air, Water and land pollution
10	District Forest Office	Social forestry program and greening measures
11	Disaster Management Authority	Preparation and response during disasters

1.3.5 Aligning with Global, National and Sub-National Planning Goals

The Solapur CAP is aligned with the United Nations' Sustainable Development Goals (SDGs) and India's Nationally Determined Contributions (NDCs). To leverage policy and financial support, the CAP considers key elements from various national and sub-national schemes and missions. Refer to Figure 1-4.

- The six sectors of the Solapur CAP line up with the five sectors of the Climate Smart Cities Assessment Framework 2.0 developed by Climate Centre for Cities at NIUA that supports MoHUA's Smart Cities Mission.
- Solapur CAP has established linkages with Swachh Bharat Mission (Urban).
- Being a non-attainment city, the National Clean Air Program (NCAP) is applicable in Solapur city and measures are being taken accordingly.
- At the sub-national level, the planning goals for Solapur CAP are aligned with Maharashtra's Majhi Vasundhara Abhiyan (MVA), which is a climate action policy approach where urban local bodies champion localised actions on the five elements of nature (*Panchamahabhutas*): Earth (*Bhumi*), air (*Vayu*), water (*Jala*), energy (*Agni*) and enhancement (*Akash*). SMC received the award of Best Amrut City in Pune Division under MVA 2.0 and was ranked fourth in the state of Maharashtra. The goals and actions proposed in the Solapur CAP are in line with the indicators prescribed in MVA toolkit.

- The MVA also comprises indicators that are in compliance with the Race to Zero of the United Nations Framework Convention on Climate Change (UNFCCC), a global campaign where local governments strengthen their contributions to the Paris Agreement to achieve net zero by 2050. Solpaur city is a signatory in this campaign, and the Solapur CAP provides a robust roadmap to achieve this goal within the targeted timeframe.
- At the city level, the Solapur CAP is in alignment with AMRUT and Smart City Mission, which focus on infrastructure development for urban revival projects.

Figure 1-4: National and Subnational Schemes and Mission in India

1.4 CONSULTATIONS AND WORKSHOPS

The details of the city visits, meetings, consultations and workshops conducted by the WRI team in Solapur city are presented in Table 1-2.

Table 1-2: Meetings and Consultations held at Solapur for preparation of Draft CAP

Date	Purpose	Key agencies consulted
8 Feb 2022	Kick off meeting	Commissioner, PHE, City Engineer, Fuel agency, Zone representatives
9 – 11 Feb 2022	Data Collection & Stakeholders meetings	Meeting with SWM Department, site visits to STP, WTP, etc, Gardens department, RTO, Fuel agencies,
20 – 24 Feb 2022	Data Collection & Stakeholders meetings	Additional meetings for data collection
27 July 2022	Capacity Building Workshop on Vulnerability Assessment and GHG Emissions Inventory	Around 52 participants from SMC, SMT, MPCB, IMD MSEDCL fuel agency etc.
06 July 2023	Presentation of Draft Climate Action Plan	Around 20 participants from various departments of SMC and parastatal agencies chaired by AMC and DMC

Figure 1-5: Solapur Capacity Building Workshop (27 July 2022)

Source: *Sakal*

2. SOLAPUR CITY PROFILE

2.1 CITY BACKGROUND

2.1.1 Regional Setting

Solapur is known as an industrial city, with textile units that appeared with the introduction of the railways in 1860. The city of Solapur lies in the south-western region of Maharashtra – in the Rain Shadow Zone of the state (Kachkure & Suryawanshi, 2021).

Solapur is an important node, particularly with respect to its connectivity with major cities of Maharashtra, Andhra Pradesh, and Karnataka. The city shares its borders with Ahmednagar, Gulbarga, Osmanabad, Satara, Sangli, Pune, and others. It is connected with Pune through national highway 9 (NH-9), which also passes through Hyderabad. Solapur city is the headquarters for Solapur district administration and has a strong industrial presence. The major dialects spoken in the district are Marathi, Hindi, Kannada, Telugu, and Urdu.

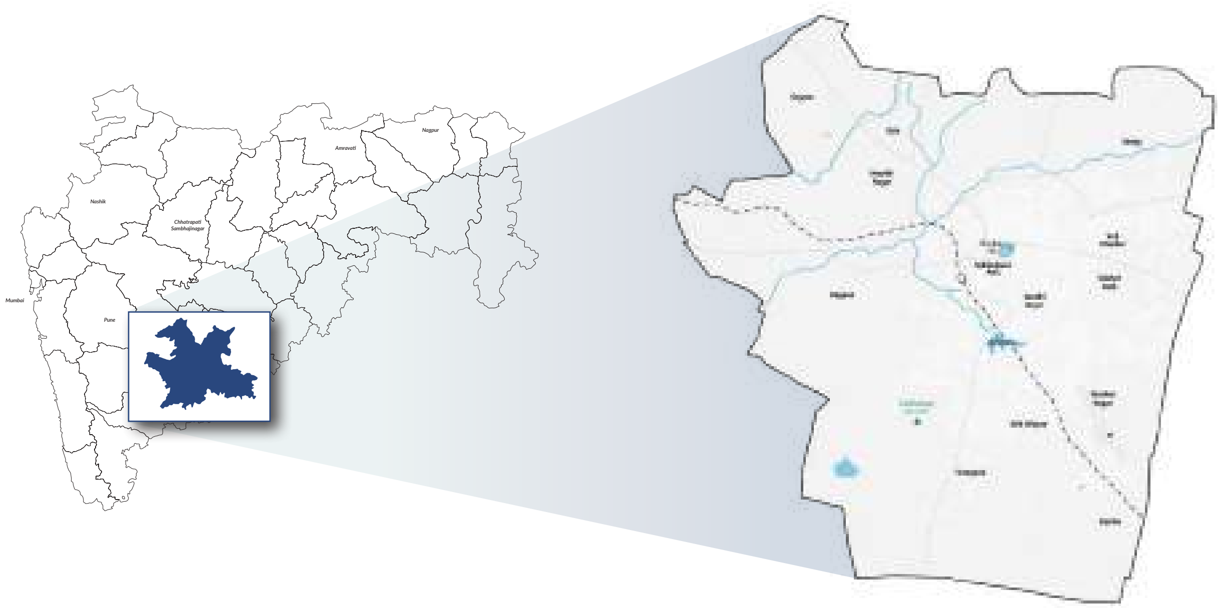
2.1.2 City History

The history of Solapur dates back to 90 BC, when it was a town called Sonnalage, according to the inscriptions of Shivayogi Shri Shankaracharya. The name came to be pronounced as Sonnalagi. During the Mughal period, its name changed to Sandalpur. Eventually, it came to be known as Solapur or, as the British pronounced it, Sholapur. The district of Solapur was ruled by various dynasties, including Andhrabhartyas, Chalukyas, Rashtrakutas, Yadavas, and Bahamanis.

2.1.3 City Economy

Solapur city is the major regional centre in the district for trade, commerce, and availability of health and education infrastructure. The industrial activity in Solapur city and its surrounding areas is mostly confined to small-scale industries, with a

Figure 2-1: Map showing regional setting of Solapur city



Source: www.d-maps.com; SMC, WRI India Analysis (2022) few medium and large-scale industries. The major economic sector activity is that of agriculture, particularly sugarcane cultivation in places where sugar-based industries are located. Animal husbandry too is practised in a small part of the city.

In terms of secondary sector, the city is known for its textiles (powerloom and handweaving industry), *beedi* industry, cement grinding units, and building and construction units. Solapur city is famous for its bed sheet weaving industry (*chaddar*), handlooms, power looms, and *beedi* making industries. The tertiary sector here includes commercial, retail, and educational institutes. Tourism is at its peak in the month of January. The Great Indian Bustard Sanctuary, which lies in the periphery of the city, attracts birdwatchers and wildlife tourists. The sanctuary is home to the Great Indian Bustard.

As per an inventory of industries prepared by Maharashtra Pollution Control Board in 2004, there are 633 industries in Solapur city, of which 7 are large scale, 4 are medium scale, and 622 are small scale. As per another categorisation of industries, 157 of the 633 industries in Solapur fall in the Red category (highly polluting), 74 in Orange (medium polluting), and 402 in Green (non-polluting).

2.1.4 Geography

The three major lakes in the city are Siddheshwar, Kambar, and Soregaon. The two major lakes — Ekrukh and Hotagi — located outside the Solapur city boundary are the sources of water for the city. Ekrukh lake is the oldest existing source, but many parts of the city rely on the Bhima River and ground water resources for water. Ground water is a source of water for drinking and irrigation purposes within the micro-catchment. Groundwater availability varies across the city due to a lack of continuity in groundwater flow at greater depths and the hard rock terrain. Recharging of the upper shallow aquifers takes place during the monsoons only.

The Great Indian Bustard Sanctuary stands on land that is drought-prone and semi-arid. It falls in the Deccan thorn scrub forests ecoregion. The areas around the city grasslands is often not conserved and is used for farming and grazing purposes.

2.2 LAND USE AND DEVELOPMENT

Solapur Municipal Corporation (SMC) was established on May 01, 1964, with a jurisdictional area of 23.23 sq. km. The Corporation was constituted under the provisions of the Bombay Provincial Municipal Corporations Act, 1949, (now Maharashtra Municipal Corporations Act, 2012) and is also governed by the provisions of 74th Constitutional Amendment Act, 1992. The city limit has been extended to keep up with the city's population growth and peripheral development (Refer to Table 2-1).

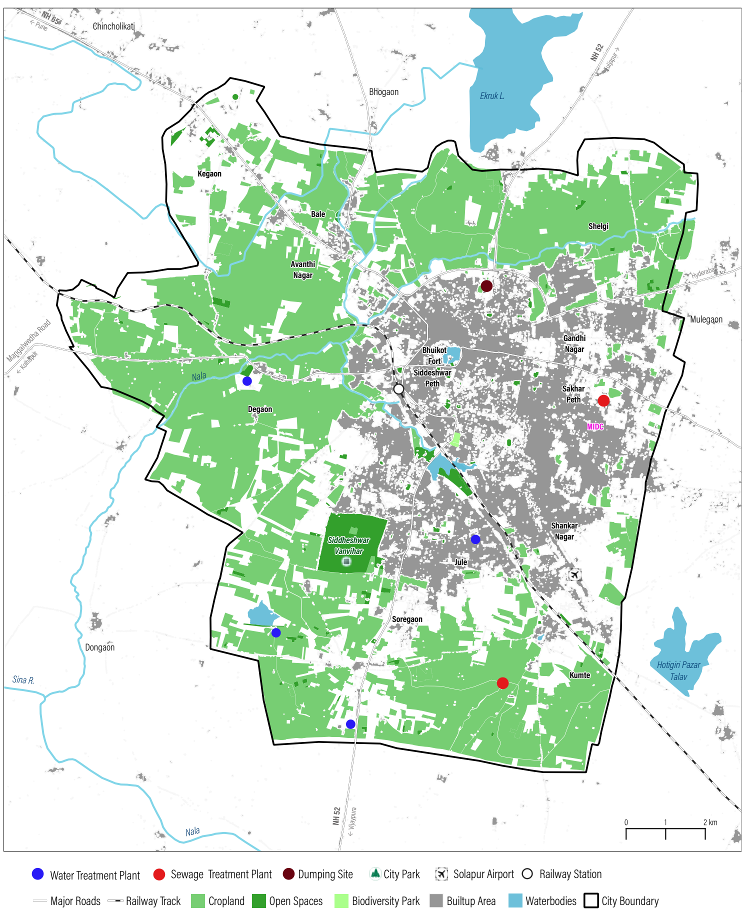
Table 2-1: Chronology of events in expansion of Solapur municipal limits

Year	City Limits/extension	Area in sq.km
29-09-1967	Original City Limit-SMC	23.23
01-07-1979	First extension- Vijapur and Hotgi road included	2.30
01-04-1989	Second extension - Salgarwadi, Beedi Kamgar Vasahat and S.No. 23 of Shelgi	7.50
05-05-1992	Third extension – 1992 Thirteen surrounding villages included in SMC	145.54
	Area as on 5/5/1992	178.57

Source: Revised City Development Plan for Solapur 2041

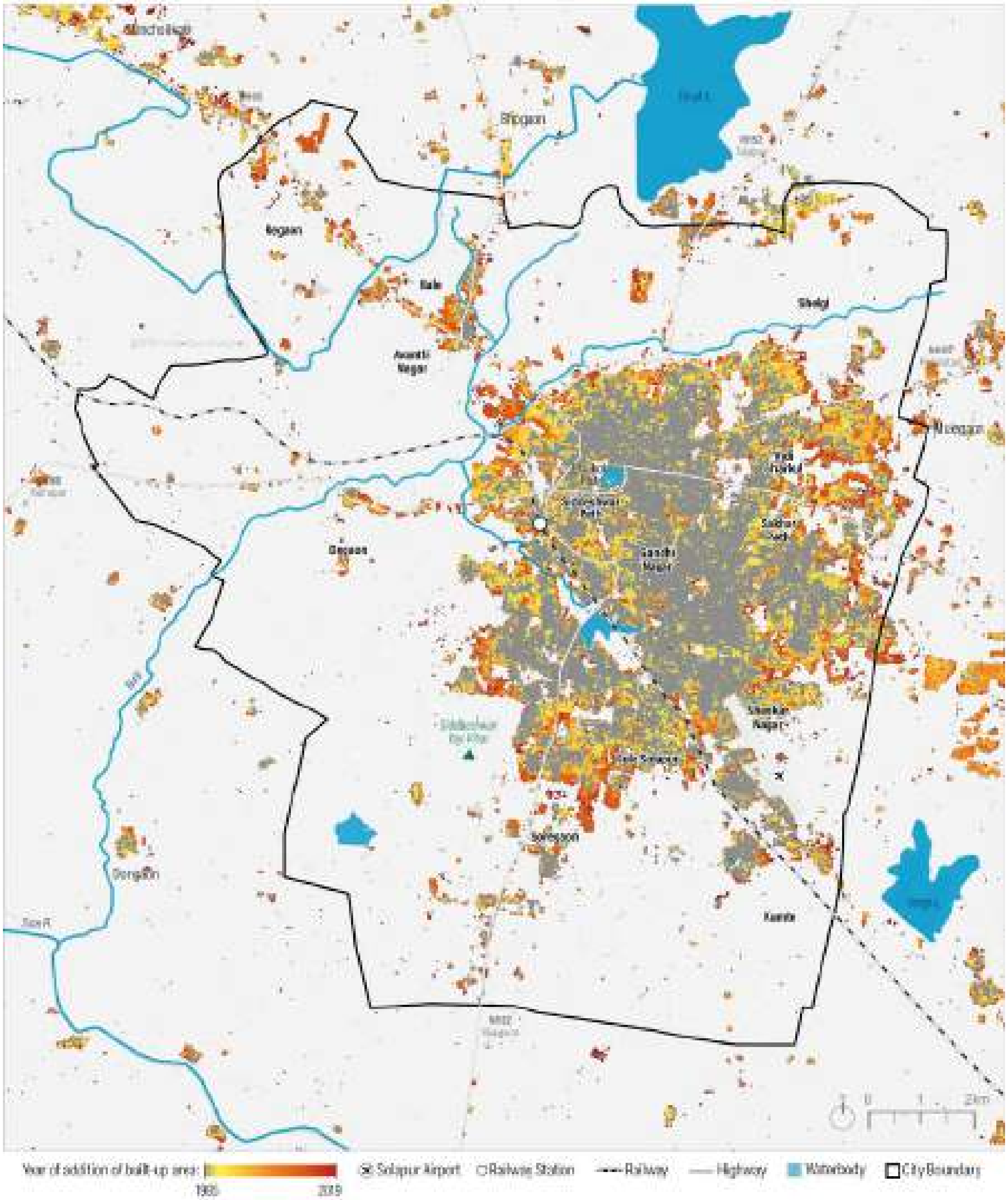
Built-up Area: The city area was massively extended in 1992, given that only one-third portion of the city has developed in terms of built-up area. Of the total municipal area of 179 sq. km, the built area[3] is 50.63 sq. km and cropland area[4] is 82.38 sq. km, with most of the built density concentrated in the eastern part of the city (Refer to Table 2-1). The Development Plan (land use plan) for Solapur city was prepared in the year 2006-07, and the existing land use shared by the GIS team of SMC was for the year 2012.

Figure 2-2: Study area: Solapur Municipal Corporation limits 2022



Source: WRI India; SMC 2022

Figure 2-3: Solapur city's historical growth and expansion



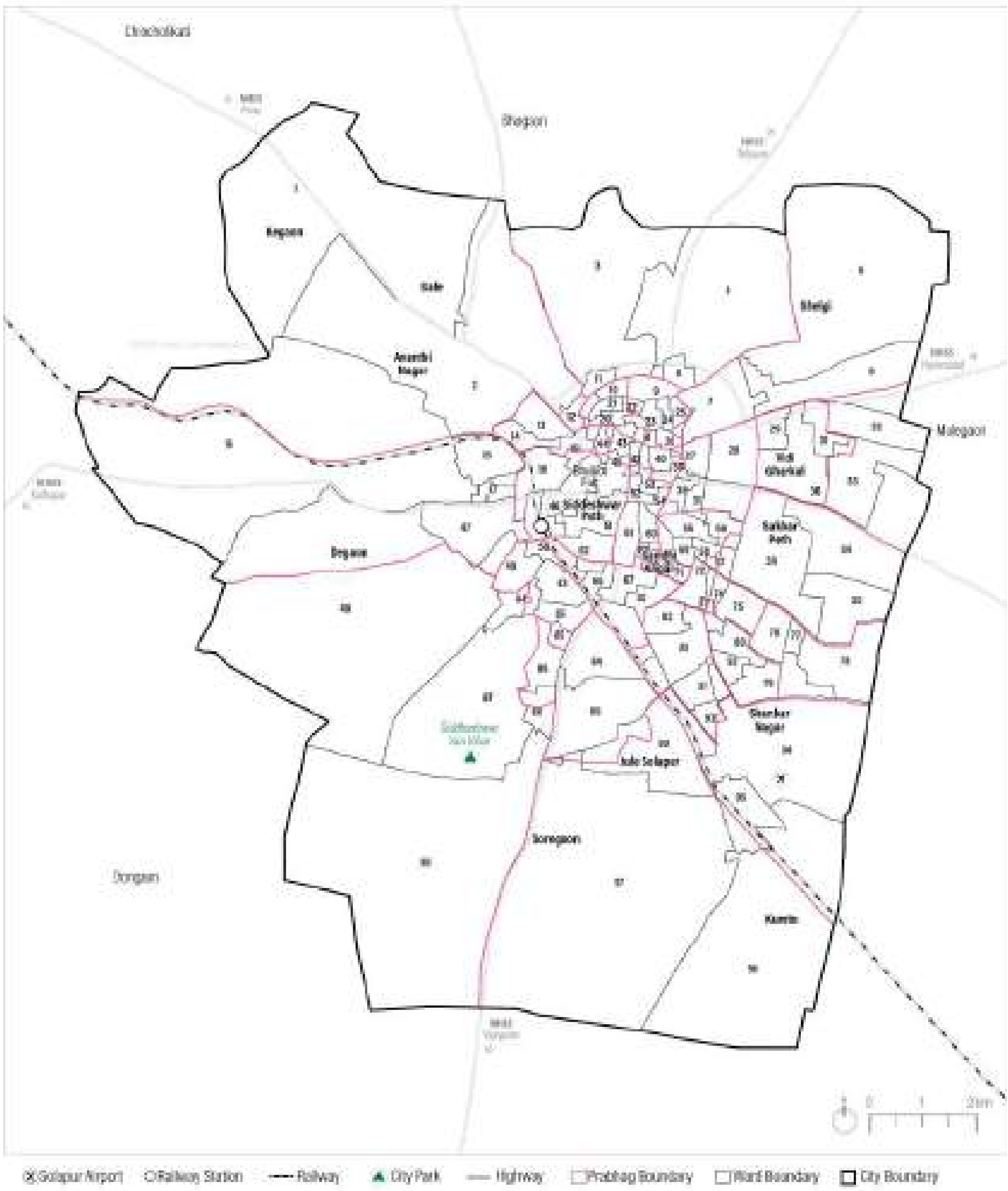
Source: WRI India using World Settlement Footprint, ESA, 1985 – 2019

2.3 CITY DEMOGRAPHICS

2.3.1 Historical population and demographics

Presently, the jurisdiction of SMC encompasses an area of 178.57 sq. km, with a residing population of 12.27 lakh (estimated for the year 2025), projected to grow from a population of 951,118 as per Census of India 2011 census. The city is divided into 8 administrative zones and subdivided into 26 election wards. There are 98 Census wards.

Figure 2-4: **Ward boundaries based on Census 2011 and current administrative boundaries of Solapur**



Source: WRI India using Census 2011, SMC 2022

In the 1970s, Solapur grew rapidly as an industrial town, leading to a growth in population. In the 1971-'81 decade, the population in the city peaked owing to the growth of textile industries.

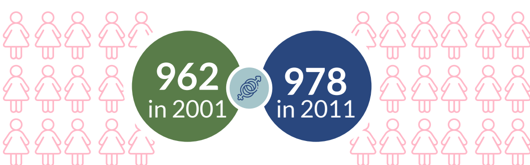
Table 2-2: Decadal growth in population (in %)

Year	Total population	Population growth, %
1971	398,361	-
1981	514,660	29.24
1991	604,215	17.36
2001	872,424	44.39
2011	951,558	9.07

Source: Revised City Development Plan 2041- Solapur

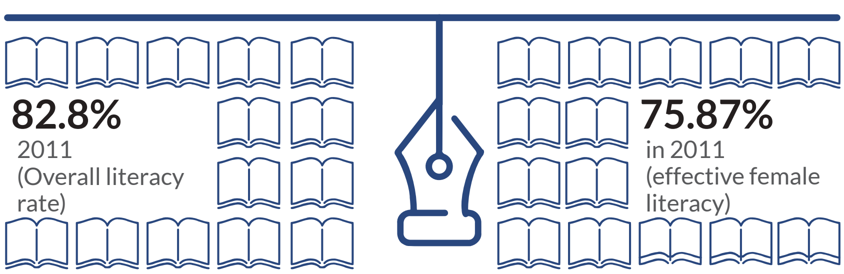
During 1991-2001, the population grew exponentially due to the tremendous development in the city. The city limits were increased in 1992, from 33.03 km² to 178.57 km², by including 13 villages in the territory. This expansion resulted in an increase in not only the city's population, but also a higher growth rate. Further, in the decade 2001-2011, the growth in population fell to 9.07% (Refer to Table 2-2)

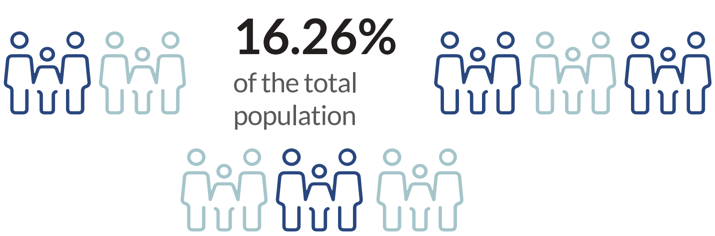
No. of HH and HH Size: The total number of households in the city has increased, from 1.61 lakh in Census of India 2001 to 1.88 lakh in Census of India 2011, and the average household size has reduced, from 5.41 to 5.05, during the same period.



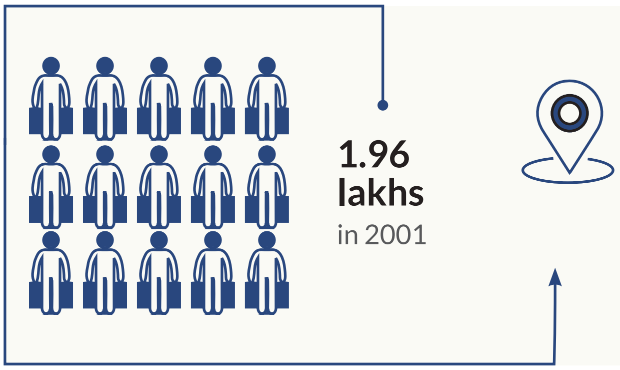
Gender Profile: The trend in the sex ratio of SMC indicates that the average sex ratio (number of females per 1000 males) of the city has improved, from 962 in 2001 to 978 in 2011 (Refer to Annex 2-2). When compared with the sex ratio of the district, the sex ratio of SMC is higher than the district-level sex ratio of 938.

Effective Literacy: The overall effective literacy rate of Solapur is 82.8% (Refer to Annex 2-3), however, the effective female literacy rate falls to 75.87% (Refer to Annex 2-4)





Social Composition: The city has overall 16.26% of the population belonging to the Scheduled Castes and Scheduled Tribes community. Wards no. 10, 11, 12 and 69 have more than 52% of population belonging to SC and ST community with a higher population density. (Refer to Annex 2-5)



Migration trends[5]**:** As per Census of India 2001, about 1.96 lakh people (22.51%) in the city are migrants. Of these, 81% belong to Maharashtra and the remaining 19% are from other states.

Of the total number of migrants from states other than Maharashtra, 88% are from the adjoining states of Karnataka (66.93%) and Andhra Pradesh (21%) while the remaining are from Gujarat (3.00%), Rajasthan (2.13%), Uttar Pradesh (1.59%), and Chhattisgarh (1.12%)[6].

2.3.1.1 Projected population

As per the revised City Development Plan (CDP) for Solapur, the population for the years 2021, 2031, and 2041 was projected using the geometric projection method (Refer Table 2-3). The projected population for the year 2041 is 2.4 million, considering a growth rate of 22.46%.

2.3.2 Solapur Municipal Corporation (SMC) and other key authorities

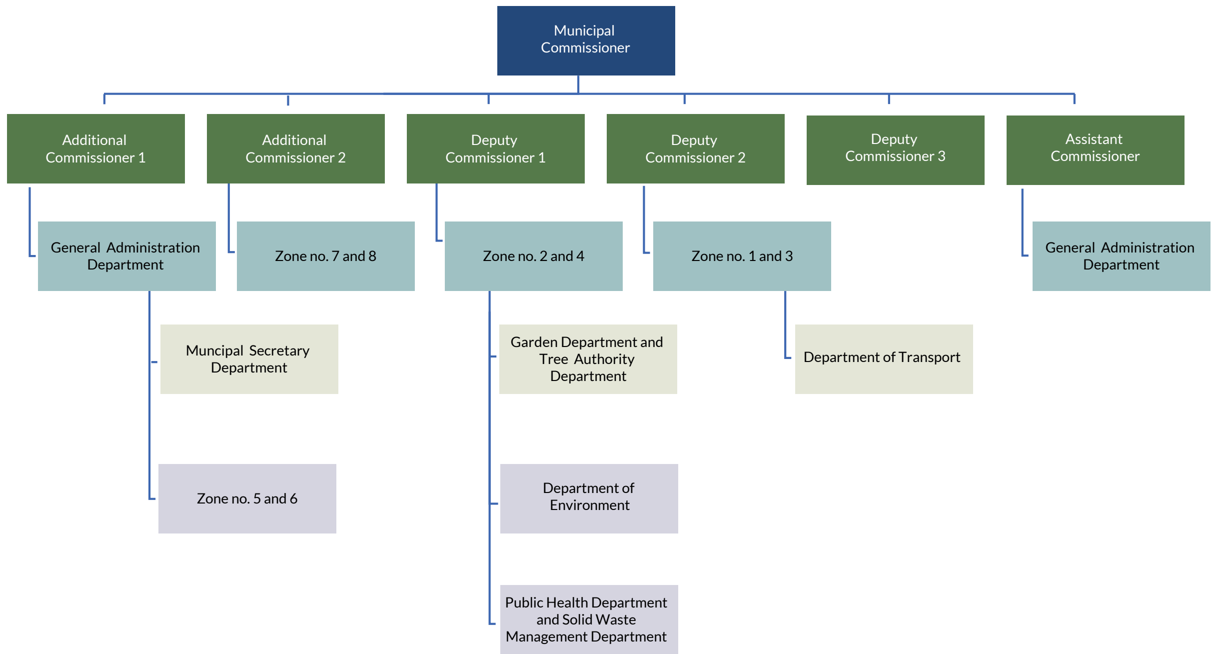
The Solapur city is divided into 26 administrative wards, 8 zones, and 98 Census wards for ease of administration. The SMC, which is headed by the Hon'ble Municipal Commissioner, has several departments, such as Public Health, Water Supply and Town Planning , as presented in Figure 2-5. These departments plan and provide basic infrastructure and services to the city. Other state-level agencies, such as MSEDCL, MPCB, IMD, District Forest Office (DFO), Groundwater Surveys and Development Agency (GSDA), Solapur City Development Corporation Limited and Solapur Bio-Energy Systems Private Limited (SBESPL)) also provide services to the city.

Table 2-3: **Projected population of Solapur city**

Year	2011 (Actual)	2021	2031	2041
Population	9,51,558	12,27,327	15,83,016	20,41,786

Source: Revised City Development Plan for Solapur (April 2015)

Figure 2-5: Solapur Municipal Corporation - Administrative structure



Source: SMC (2022)

3. CLIMATE CONTEXT – SOLAPUR CITY

3.1 CLIMATE OVERVIEW

Solapur, being a part of the semi-arid region, receives an average rainfall of 725 mm. Semi-arid regions are often regarded as being particularly vulnerable to climate change. The climate of the city is characterised by dry, semi-arid, and hot tropical (Bsh as per köppen's classification) with general dryness in the major part of the year (IMD, 2005).

Semi-arid ecosystems are highly dynamic, with bursts of productivity in the wet season in good years and have very low productivity in dry years often leading to temporary or longer-term land degradation. Such regions are known to be climatically stressed with high temperatures, lower rainfall, and longer dry seasons.

3.1.1 Temperature and Humidity

Data from the National Centers for Environmental Information (NCEI) was analysed from the years 1975 to 2021. From the analysis, since the year 2011, the hourly air temperature in the summer months (from March to May) has ranged from 25°C to 41°C. Temperatures as high as 47°C were recorded in the summer of 1976. Winters in Solapur begin in November and end in February, with the air temperature occasionally dropping as low as 11°C and rising to 38°C. Moreover, according to the IMD data (1970-2021), on average, July and August show the maximum relative humidity (71-72%) while March and April show the lowest relative humidity (34-37%).

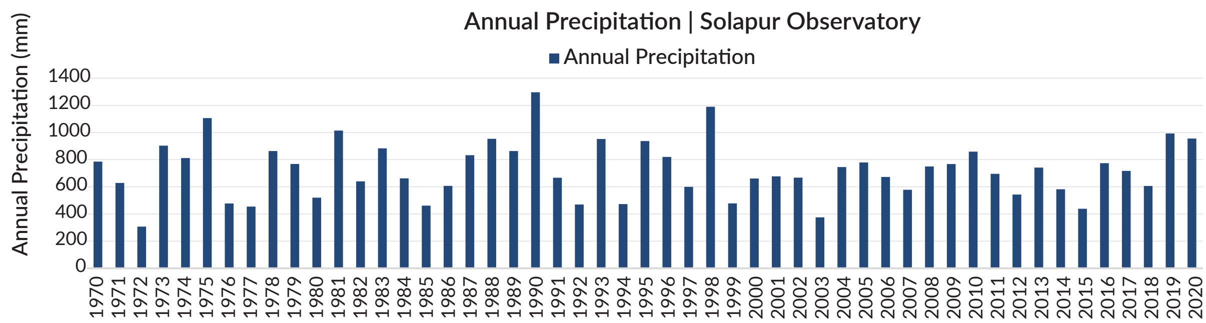
3.1.2 Rainfall analysis

Agro-climatically, Solapur district lies in the rain shadow region resulting into scanty and uncertain rainfall. The south-west monsoon commences in June and ends in September. The average annual rainfall in the area is around 725 mm, and the monsoon season lasts for around a month and a half (18 – 55 days in a year). The city received a maximum rainfall of 1300 mm in 1990, and the driest year with rainfall of 300 mm was 1972. The annual accumulated rainfall for the city between 1971 and 2020 is presented in Figure 3-1.

Rainfall in the months of June to September amounts to about 74% of the annual rainfall, with September being the wettest month for the city, while 17% of the showers are received during the post-monsoon months.

Solapur receives an average rainfall of 725 mm, but the rains are scanty and non-uniform which results in water distress conditions in the district, affecting the socio-economic condition of people adversely. The Ujani dam, which was built to provide water to the neighbouring drought-prone areas, can only suffice the water demand of the growing city up to a certain limit. Therefore as the city expands so will the demand for water.

Figure 3-1: Annual precipitation Solapur Observatory between 1970 & 2020

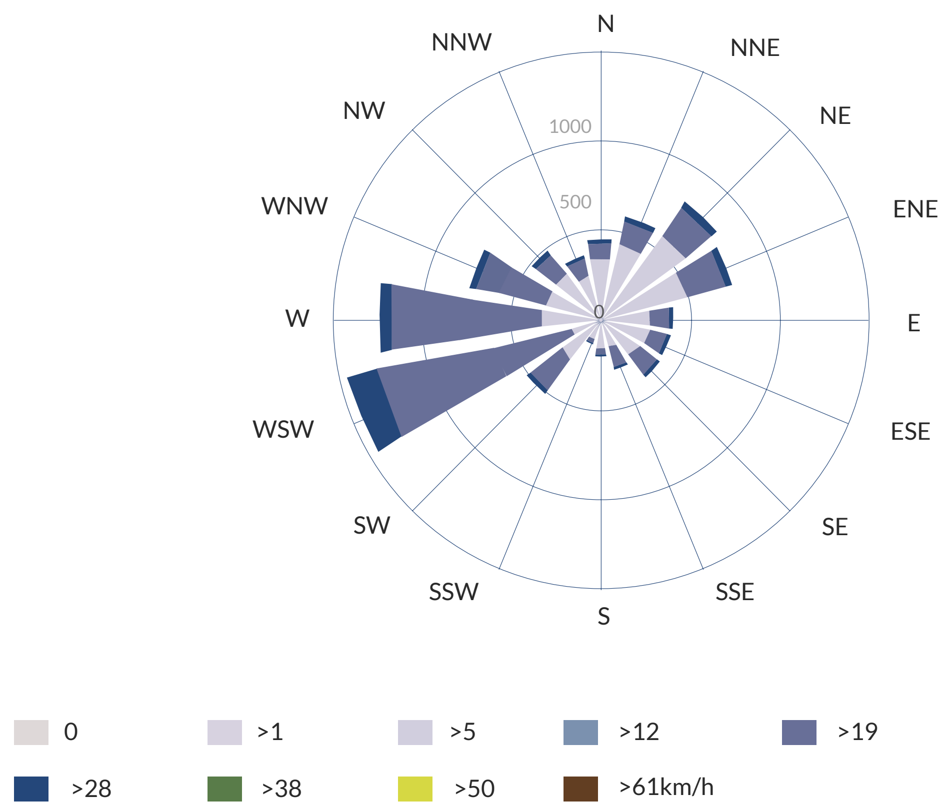


Source: WRI India using meteorological data from IMD, 2022

3.1.3 Wind speed and direction

The average wind speed in Solapur is 3.9 m/s, with the maximum wind speed of around 11 m/s[6]. The windrose for Solapur shows the number of hours per year that the wind blows from the indicated direction. The windrose of Solapur shows that predominantly, wind blows from the west and west of south-west.

Figure 3-2: Annual Windrose diagram for Solapur city



Source : https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/solapur_india_1256436

Winds are light to moderate in force, with some strengthening during the May-August period. During the south-west monsoons, winds blow mainly between the south-west and north-west directions. In the October-December period, winds blow between north-west and south-east in the mornings and north and east in the afternoons. In the following four months, the direction of the winds is variable. In May, winds blow mostly between the west and north[7] directions.

3.2 KEY CLIMATE RISKS

3.2.1 What is climate risk?

The climate risk context analysis is an attempt to understand risk exposure in the different geographical locations of Solapur city, using monitored weather data from sources such as IMD, air quality monitoring stations, remote sensing techniques and various other departments.

3.2.2 Key Climate Risks

The Climate Risk Index 2021[8] ranked India amongst the top 10 countries most affected and incurring maximum absolute losses of nearly $69 billion in 2019 from extreme weather events.

The Global Climate Risk Index (CRI) 2021 analyses quantified impacts of weather events both in terms of fatalities and economic losses incurred. India was 7th among the top 10 countries affected in the year 2019. The economic damage estimation due to intense rainfall was US $10 billion, further more due to 8 tropical cyclones, worse being Cyclone Fani in May 2019 India and Bangladesh incurred economic losses of US$8.1 billion. Nearly 60% of India's land area is prone to earthquakes of moderate to very high intensity and 12% to flood and river erosion; 5,700 kilometres of coastline is prone to cyclones and tsunamis; 68% of cultivable land is vulnerable to drought; the hilly areas are at risk from landslides and avalanches; and 15% of landmass is susceptible to landslides[9].

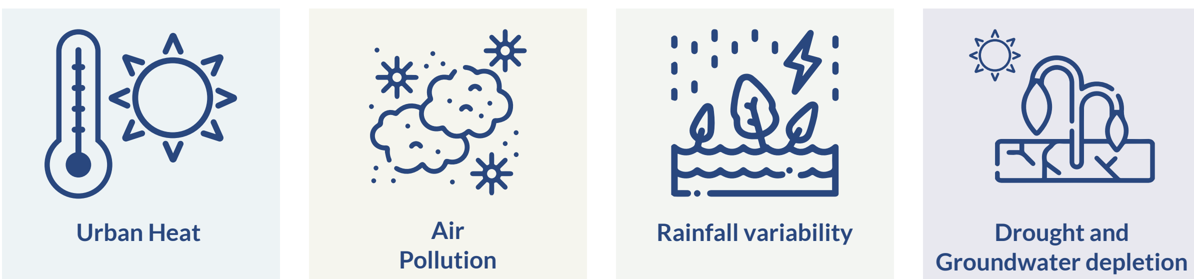
The IPCC Fifth Assessment Report analyses climatic drivers and estimates potential future risks for Asia in the near term between 2030 and 2040 and in the long term between 2080 and 2100. As per this assessment, Asia is bound to face medium to very high risk of water shortage in arid areas and a decline in agricultural productivity in the near and long terms, impacting food production and security, thus causing malnutrition. Coastal and marine systems are also projected to be under increasing stress, with rising sea levels, increased rates of coastal erosion, degradation of mangroves, salt marshes, saltwater intrusion and high sea surface temperatures. Increased riverine, coastal and urban flooding is projected with very low to medium risk in the near term and medium to very high risk in the long term, leading to widespread damage to livelihoods, infrastructure, and increased flood-related deaths and injuries. Asia is also projected to face more frequent and intense heat waves and intensified heat island effects, resulting in very high risk of heat-related mortalities in the long term, especially in vulnerable groups such as labourers in building & construction sector and residents of informal settlements. Consequently, Asia will witness exacerbated poverty, inequalities, and new vulnerabilities with medium to very high risk.

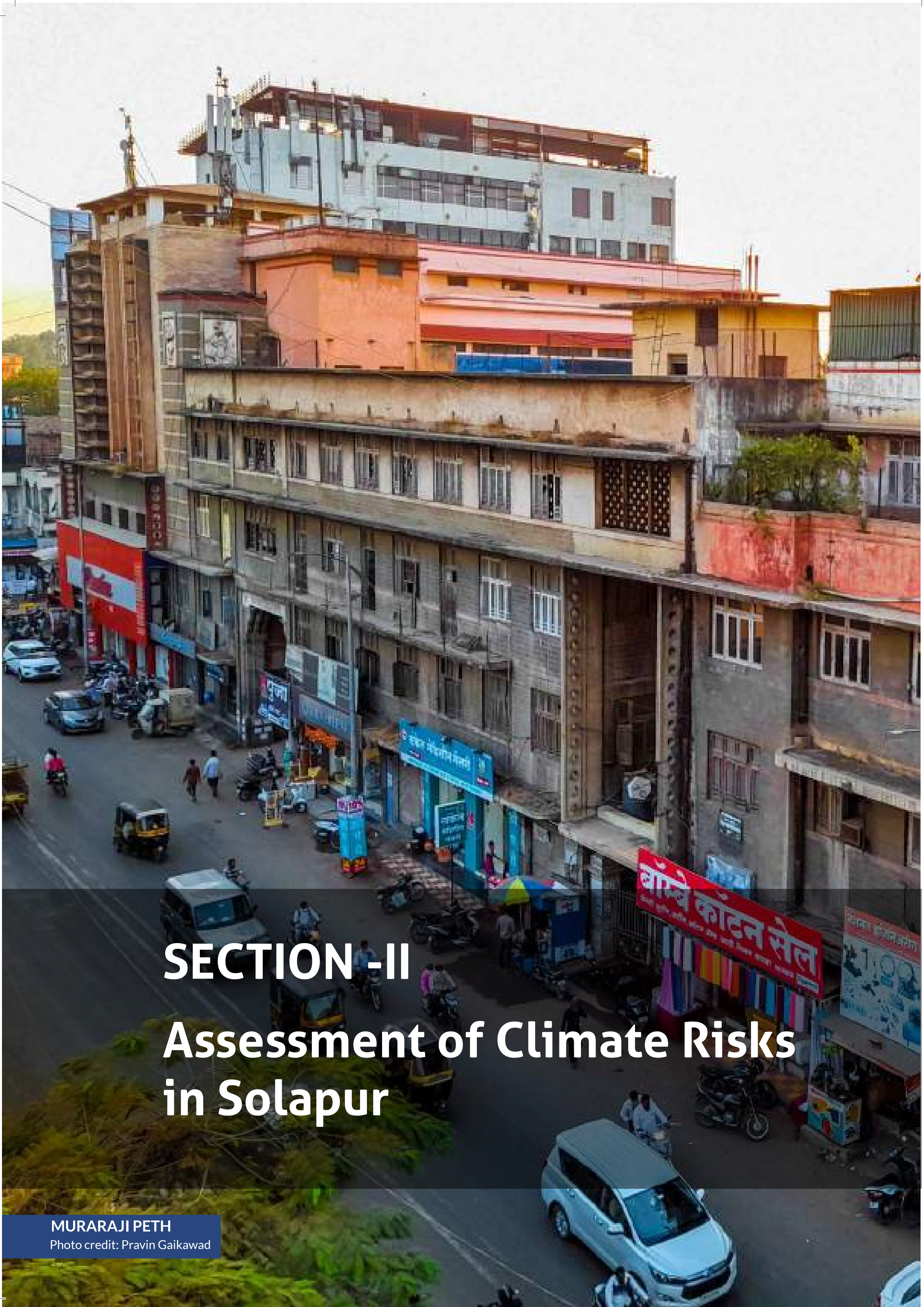
3.2.3 Key Climate Risks in Solapur

Solapur city faces three major climate challenges – heat risk, air pollution risk, drought, and groundwater depletion. On analysing rainfall variability as a part of the VA, urban flooding is not a key risk that Solapur faces. However, because the region and the district are prone to drought, the city might face drought-like situations in terms of its water resources availability, causing severe water stress.

Disaster management is mostly addressed at the level of state, district, and sub-division rather than city. The district disaster management plan[10] categorises the following as disasters: floods, droughts, lightning, hailstorms, earthquakes, road accidents, rail accidents, fire accidents, crowd disasters, communal violence, and industrial accidents. However, in the context of climate-induced disasters, this report focuses on heat, air pollution, rainfall variability and groundwater depletion. Although air pollution is an anthropogenic activity induced hazard, monitoring and reducing criteria air pollutants can significantly contribute to minimising short-lived climate pollutants (SLCPs), such as methane (CH_4), tropospheric ozone, hydrofluorocarbons (HFCs) and black carbon, which curb global warming. These GHG emissions remain in the atmosphere for a brief duration but are more potent than carbon dioxide, leading to multiple challenges for human development and well-being.

Figure 3-3: Key climate risks in Solapur





SECTION -II

Assessment of Climate Risks in Solapur

MURARAJI PETH
Photo credit: Pravin Gaikawad

4. URBAN HEAT RISK

4.1 ASSESSMENT

The assessment of urban heat risk has been done by analysing non-spatial and spatial parameters (Refer to Annex 1-1).

- Non-spatial parameters include air temperature using 1975-2021 data NCEI and night-time Land Surface Temperature (LST) from Moderate Resolution Imaging Spectroradiometer (MODIS). Annual, seasonal, and monthly variations of air temperature were analysed to demonstrate the overall trend of exposure to heat.

- Spatial analysis of heat risk uses MODIS night-time LST data at the district level to study LST difference between urban areas and the rural peripheries and day-time LST data from Landsat (USGS) that helps identify local areas more exposed to heat stress, also known as Heat Island Effect.

4.2 KEY FINDINGS

4.1.1 Temperature trend analysis

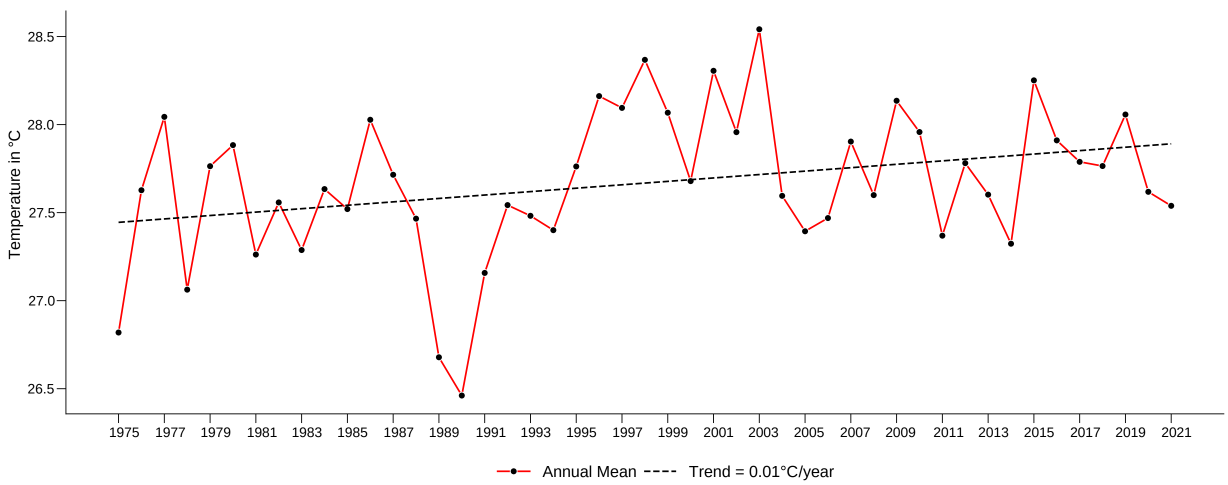
1. Annual Air Temperature trend

Annual mean temperatures were calculated for Solapur city from the year 1975 to 2021 using data from NCEI. The trend analysis shows that annual mean air temperatures are rising by 0.01°C per decade between 1975 and 2021 as seen in Figure 4-1.

2. Change Point Detection

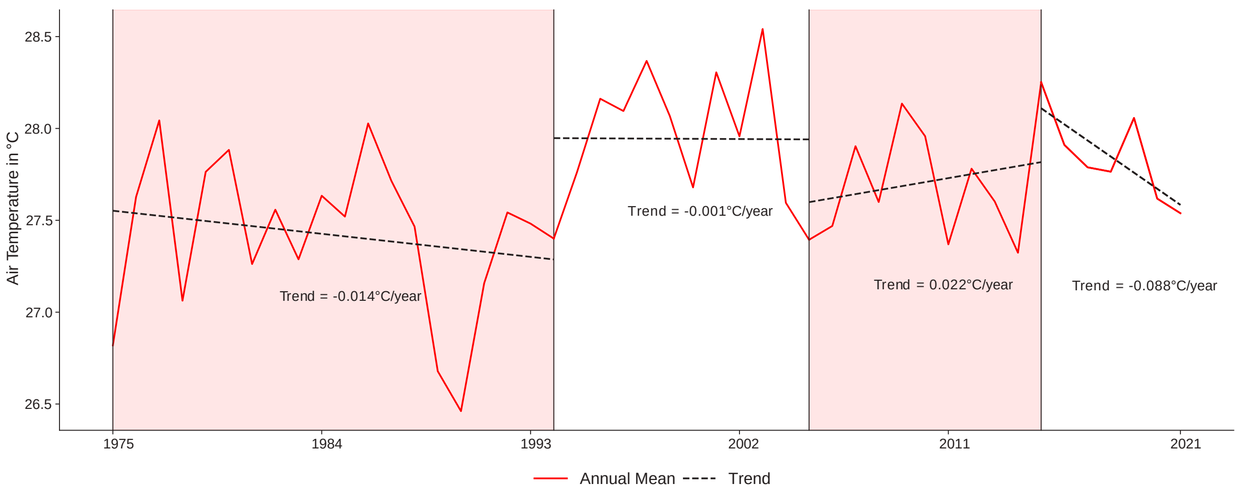
In addition to interpreting the annual average trend, it is insightful to study significant statistical shifts within the trend. The points in time at which the trend changes are referred to here as 'breakpoints'. Figure 4-2 shows three breakpoints that were identified using an established mathematical method. It divides the entire period into four sections, each with a different slope.

Figure 4-1: Long term trend of annual average air temperature between 1975 & 2021



Source: WRI India Analysis 2022, NCEI 1975-2021

Figure 4-2: Change points in the annual average air temperature trend between 1975 & 2021.



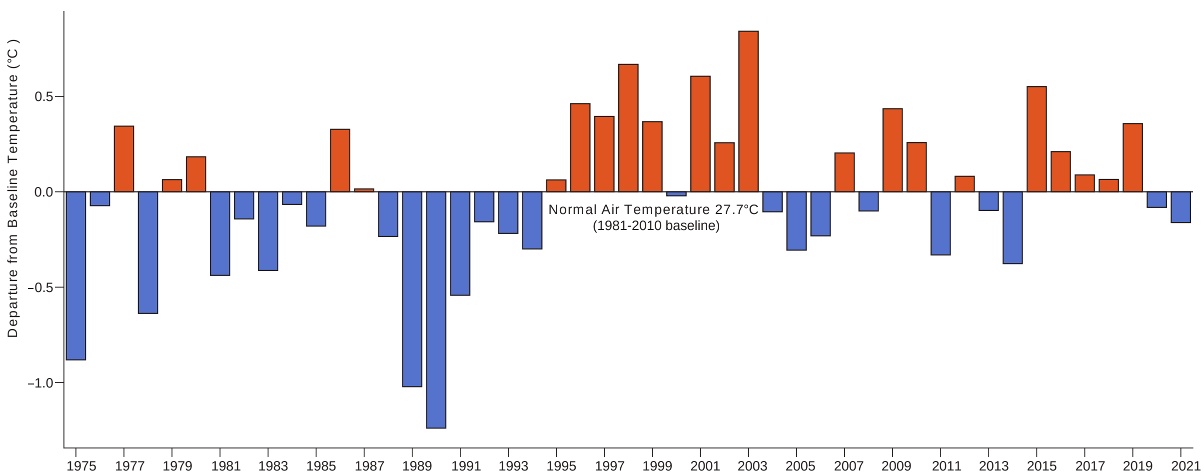
Source: WRI India Analysis 2022, NCEI 1975-2021

3. Annual Air Temperature Deviations

Figure 4-3 shows annual air temperature deviations in Solapur from 1975 to 2021. The baseline temperature for the city, 27.7° C, was calculated using IMD's definition. It is the annual average temperature of the period from 1981 to 2010. The anomalies were calculated by subtracting the baseline temperature from each year's annual average temperature.

In total, 22 years were warmer than the baseline average in this period. Positive anomalies are observed predominantly during the periods 1995-2003 and 2015-2019.

Figure 4-3: Deviations of annual average air temperatures from the baseline temperature in Solapur between 1975 & 2021

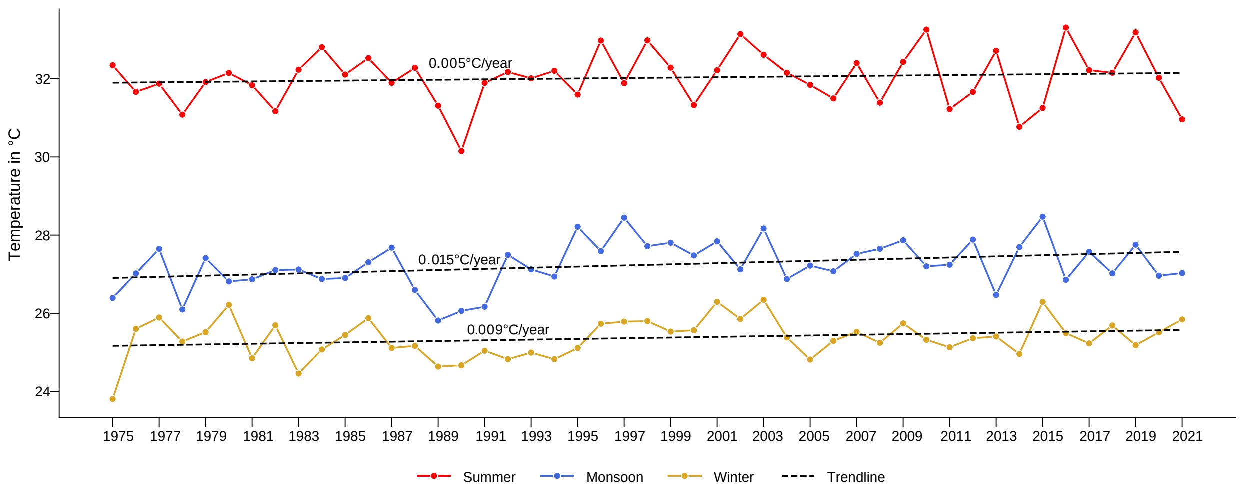


Source: WRI India Analysis 2022, NCEI 1975-2021

4. Seasonal Air Temperature Trend

The annual average temperatures can be broken up as per the three seasons to understand seasonal trends as referred to in Figure 4-4 . Relatively, the monsoon season shows the most rapid increase in temperatures, followed by winter and then summer, which implies that the monsoon season is witnessing a greater number of high temperature days than the other two seasons.

Figure 4-4: **Seasonal average air temperature trends in Solapur between 1975 & 2021.**



4.1.2 Extreme Heat events

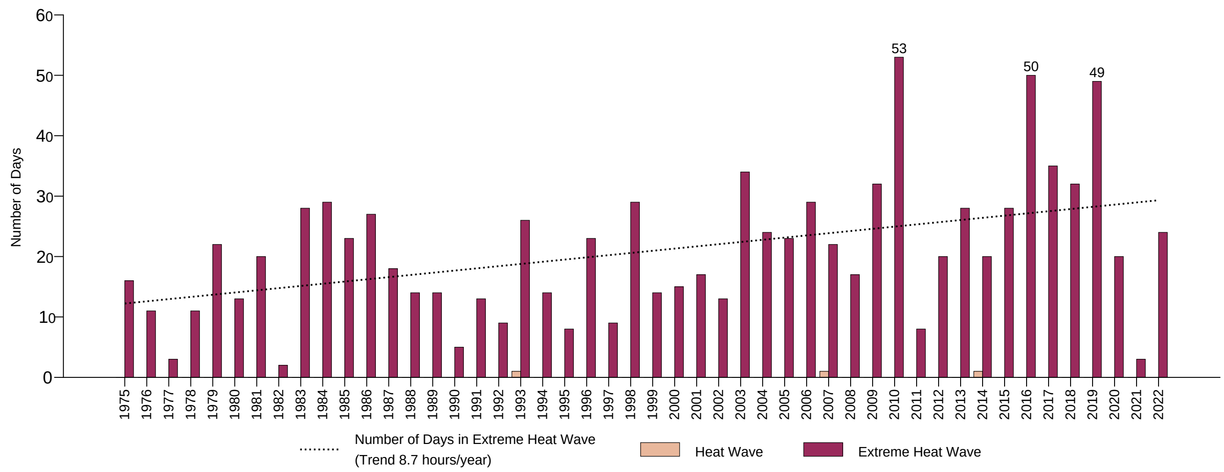
A heat wave is a period of high air temperature, which can be fatal for the human body based on the duration of exposure. Heat wave and extreme heat wave incidents in Solapur are analysed for the period 1975-2022.

1. Heat Waves

First, data was filtered only for those days where the maximum temperature was above 40°C as IMD requires plain areas to follow this threshold (a threshold of 30°C should be applied to areas in hilly regions). All those days where the deviation from the daily long-term average air temperature was between 4.5°C and 6.4°C were classified as 'heat wave' while those where the deviation was more than 6.4°C were classified as 'extreme heat wave'. Figure 4-5 shows the number of heat waves and extreme heat waves in Solapur.

An increasing trend is that every year, 8.7 hours are getting added to the time that the city spends in extreme heat waves. The years 2010, 2016, and 2019 were among the hottest years in this period, with 53, 50, and 49 days classified under extreme heat waves, respectively. (Refer Figure 4-5)

Figure 4-5: Extreme heat wave incidents in Solapur between 1975 & 2022



2. Heat index classification

Heat index classification considers both air temperature and relative humidity and, hence, provides an indication of the perceived temperature. As the moisture content in the air increases, the capacity of the human body to cool down decreases. The days were classified using the classification scheme of National Oceanic and Atmospheric Administration (NOAA).

According to this scheme, temperatures in the 26°C- 32°C range are classified as 'Caution' and 32°C-39°C as 'Extreme Caution'. Table 4-1 lists the health hazards associated with the different heat index categories.

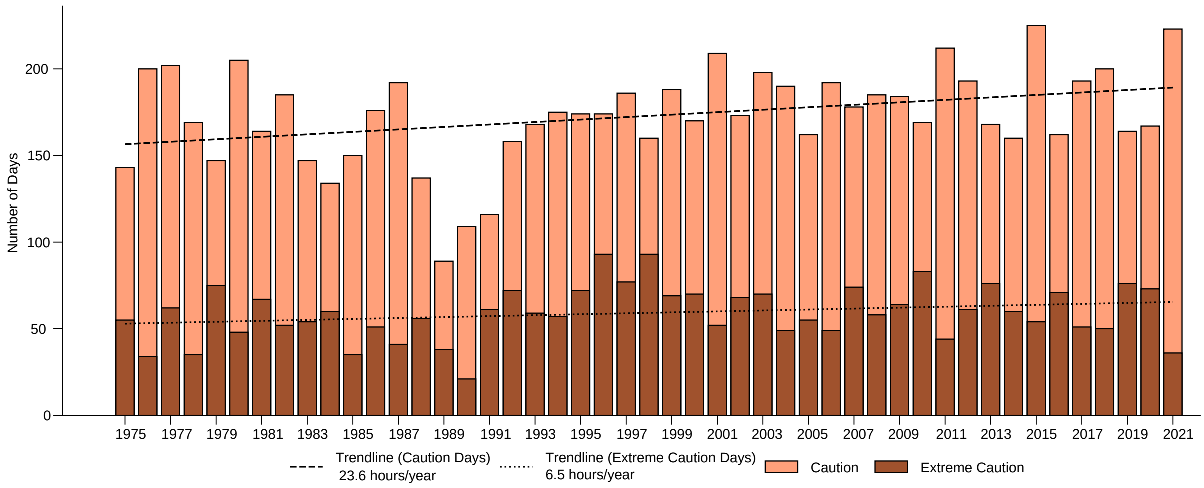
Table 4-1: Heat index classification of NOAA

Classification	Heat Index (°C)	Effect on the body
Caution	26–32	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	32-39	Heat stroke, heat cramps or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	39-51	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	Above 51	Heat stroke highly likely

Source: WRI India analysis

Figure 4-6 shows the number of caution and extreme caution days per year in Solapur. The combined number of days in both these categories are increasing at the rate of one day per year.

Figure 4-6: Heat Index Classification in Solapur between 1975 and 2021



Source: WRI India analysis; NCEI data between 1975 & 2022

A perceived temperature range of 26°C — 32°C or 32°C — 39°C is not unusual for the city of Solapur. It is the increasing trend that needs attention. It indicates that over the next few decades, the heat index values will continue to rise and cause problems to the micro-climate of the city. Therefore, prompt interventions must be implemented to restore the balance. The SMC initiated a process to record the suspected heat stroke cases for the first time since March 2022. A total of 125 cases were reported up until April.

4.1.3 Land Surface Temperature (LST) Analysis

Land surface temperature demonstrates the temperature of the Earth's surface. "Air temperatures are a direct UHI measure, but they are usually only available for single measurement stations or traverses through a city. Conversely, surface UHI can account for the temperature distribution within a large area, but it is only an indirect estimate of the UHI. "Therefore, the combination of both approaches provides added value for the description of UHIs" (Nina Schwarz et al, 2012). LST is the temperature of the surface of the earth and varies in natural and artificial landscapes and with land use. In this report, LST has been studied based on emissivity and radiative temperature sensed by satellite based thermal sensors.

1. Night-time temperature trends from LST

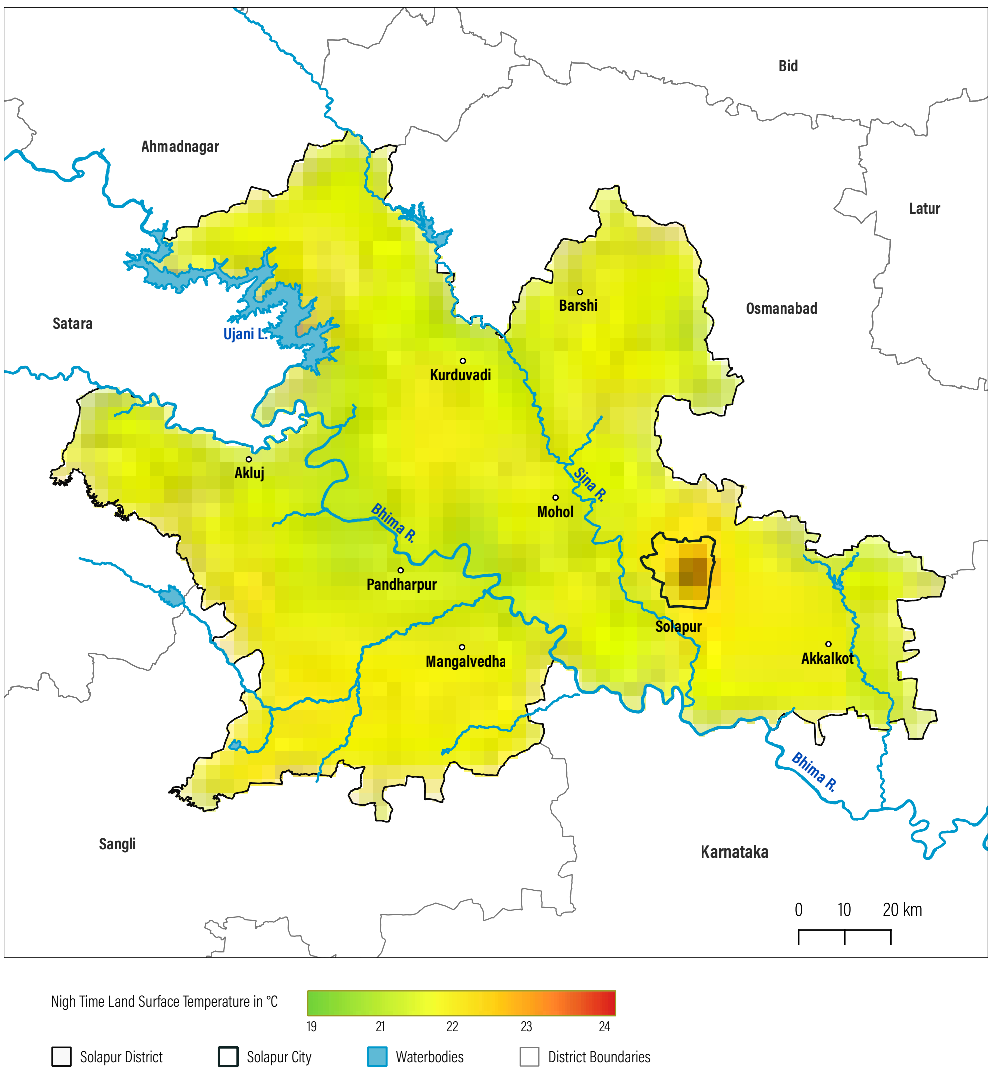
Urban built areas dissipate more heat at night-time as compared with the periphery. As a result, the human body does not get the opportunity to relieve itself from the day-long activity-based heat exhaustion. This phenomenon is largely known as Urban Heat Island (UHI) effect.

"A higher surface temperature is observed in the cities due to built-up impervious surfaces and high-rise buildings constructed through heavy use of metal as compared to surrounding rural landscapes characterized by forest–tree cover and pervious surfaces"[11] . The average night-time temperature was studied at the district level to understand the variation in night-time LST for rural, urban, and other landcover. Using Moderate Resolution Imaging Spectroradiometer (MODIS) for the period 2019-2021, images were used to study this area as seen in Figure 4-7.

The night-time LST within the city core with dense built-up is the highest within the district. This is due to the presence of paved surfaces, such as asphalt roads and concrete terraces, which are thermally conducive and lack vegetation cover. These surface store heat during the day, which is slowly released by night-time. Similar effects can also be seen in and around the smaller cities and towns of Pandharpur, Barshi, Mangalvedha within the district. This establishes the relation between urban areas and night-time LST.

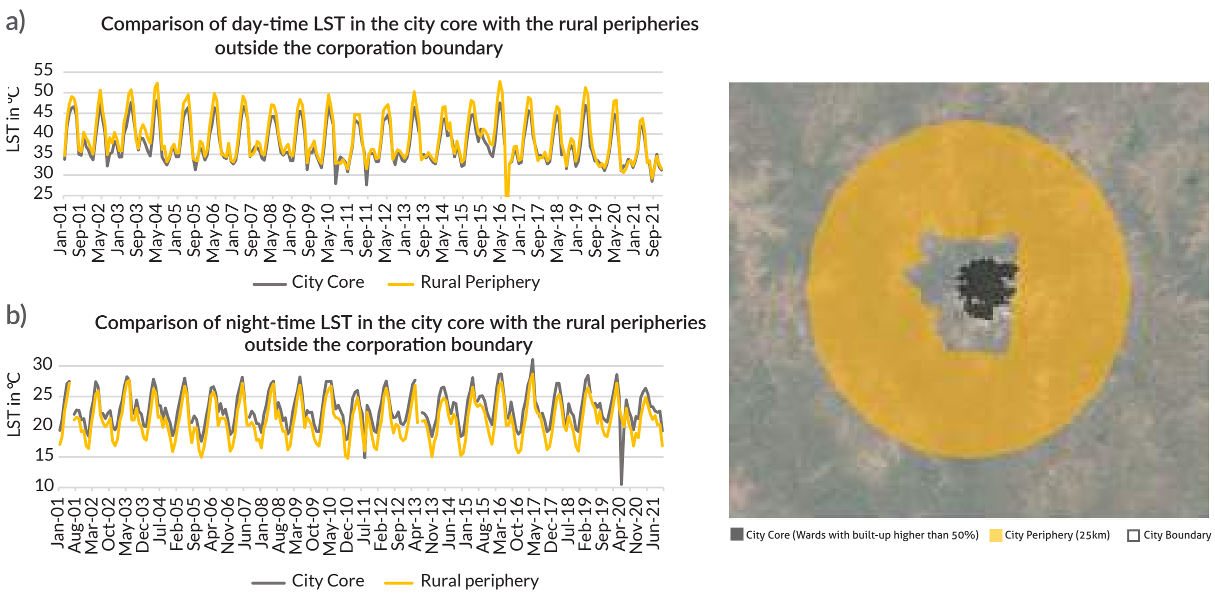
Figure 4-8 a) and b) shows the comparison between the yearly day-time and night-time temperatures of urban city core and surrounding areas within 25km buffer for the time period 2001-2021.

Figure 4-7: Land surface temperature in Solapur district for 2019 to 2021



Source: WRI India analysis; MODIS LST Product, 2019-2021

Figure 4-8: Comparing night-time and day-time LST outside Solapur city periphery



The day-time LST graph (a) shows the variation in the city core and rural periphery temperatures. The difference varies, depending on months and seasons. In graph (b), the night-time LST is higher within the city core as compared with the periphery, irrespective of months and seasons, further cementing the relation between night-time LST, urban areas with higher built density, and UHI effect.

Within the city corporation limits, the monthly average values were observed for the period 2001-2021. The trend shows an increase in night-time LST by 0.03°C per year. Refer to Annexure 1-4

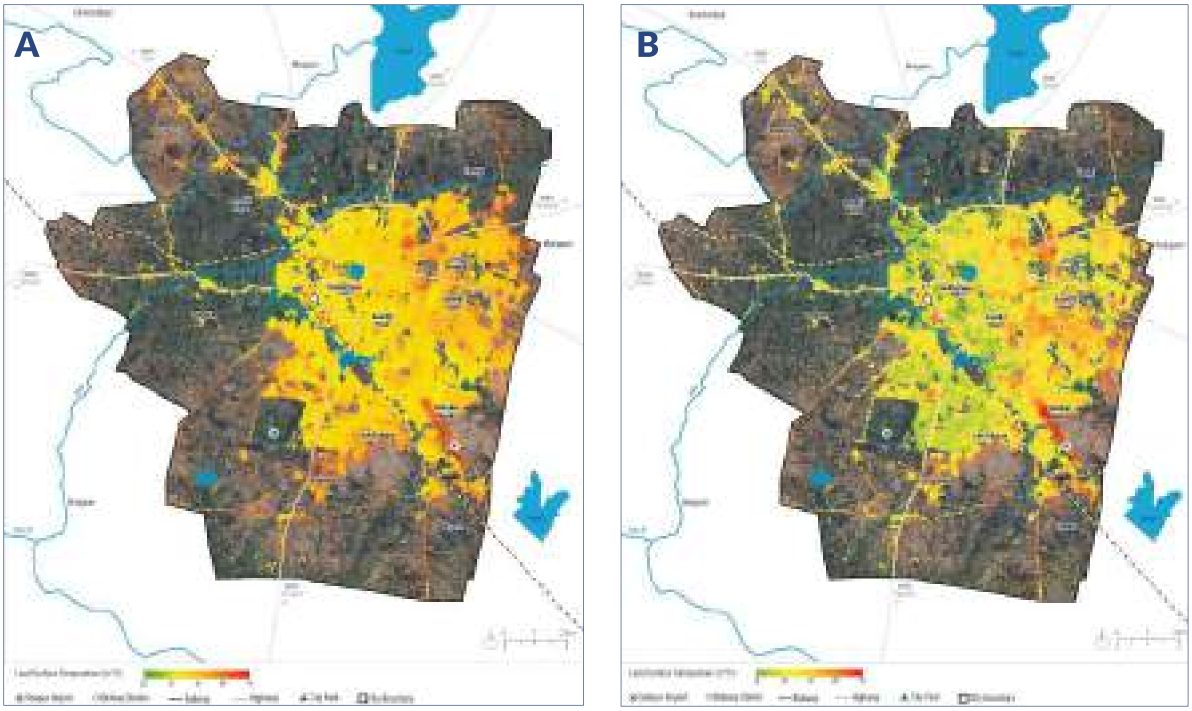
2. LST hotspots

Within the urban core, paved surfaces, such as concrete and asphalt roads, concrete terraces and metal and asbestos roofs get heated and create hotspots. The hotspot analysis was done using Landsat 8 data using the day-time LST values. For Solapur, LST was derived for two-time durations, pre-monsoon (April and May, 2019-2021), and post-monsoon (October, November, and December, 2019-2021), as shown in Figure 4-9.

For the pre-monsoon months, the average LST within the city built-up areas ranges between 33°C and 37°C, and during the post monsoon months, it ranges from 23°C to 31°C for the city, with evidence of greater spatial differentiability pushing some areas to higher LST than others.

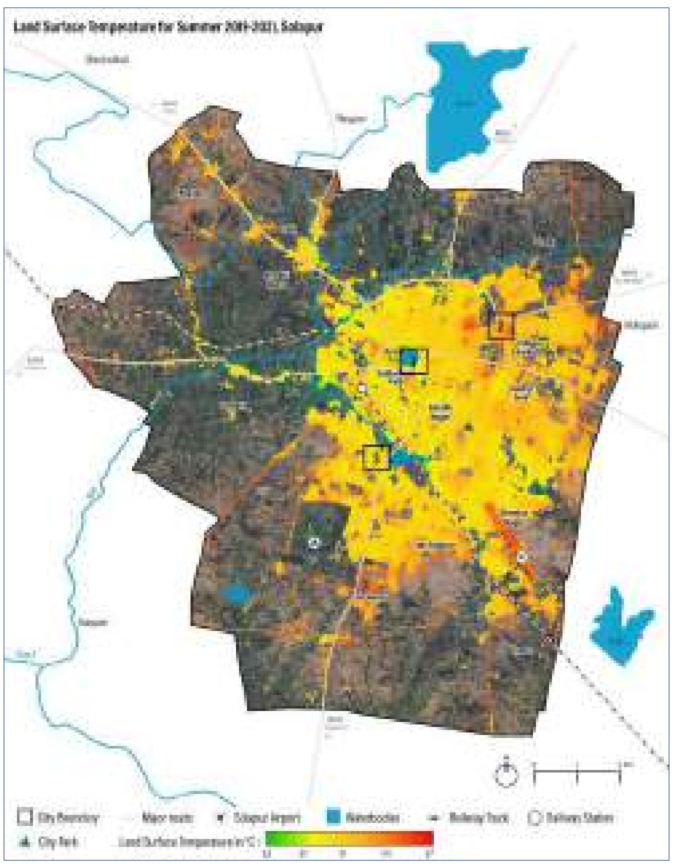
A few persistent examples of soaring LST include the Solapur airport – a typical example of high surface temperature that hosts a large area with bare soil and asphalt/concrete runways. During summers, LST in and around the airport can reach up to 45°C.

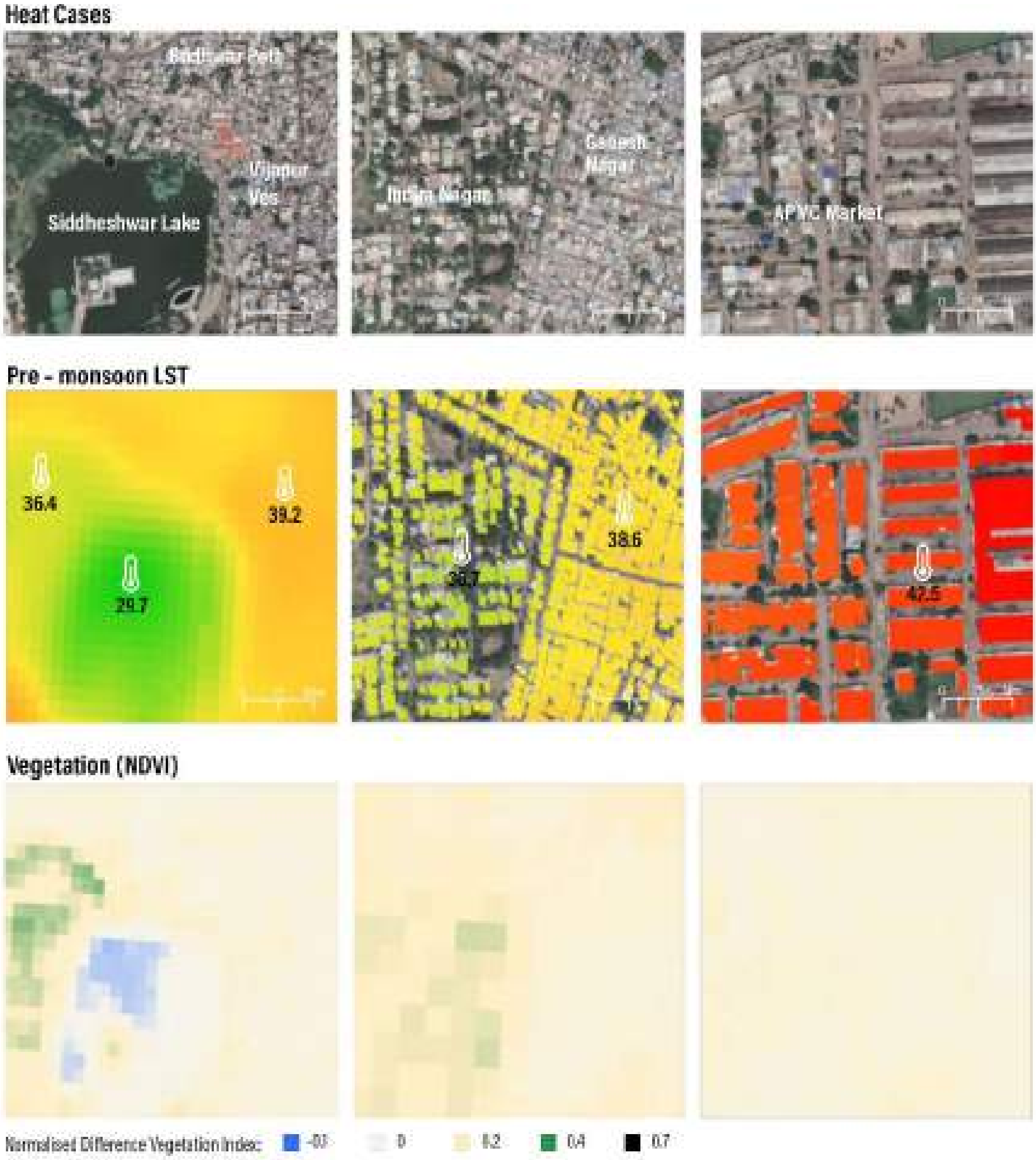
Figure 4-9: Mean Land Surface Temperature for pre and post monsoon (2019-2021): a) Pre-monsoon summer months (April & May), b) Post monsoon winter months (October – December)



Source: WRI India analysis using Landsat 8, USGS, 2022

Figure 4-10: Cases to study LST





1. The Siddheshwar lake area with a park is at a lower LST compared to the Laxmi market and Vijapur ves area. Budhwar peth is a commercial area within the city core which due to the anthropogenic activity can have temperature reaching 39°C while the LST in the lake is 32 °C and park area stays at 36 °C during pre-monsoon months.

2. Residential neighbourhood such as **Indira Nagar and slum in Ganesh Nagar** are closely situated. Indira nagar has LST 2-3 °C lower than the slum area. Ganesh Nagar can reach upto 38.5 °C during the pre-monsoon months. Slums or low income neighbourhoods have densely packed built-up and very less green area, which results in higher LST values.

3. Commercial areas such as **the APMC market** can have temperature reaching 39°C in the pre-monsoon months. The roofing material of such commercial and industrial areas are often constructed of metal or asbestos sheets which are high heat absorbing materials.

Source: WRI India analysis using Landsat 8, USGS, 2022

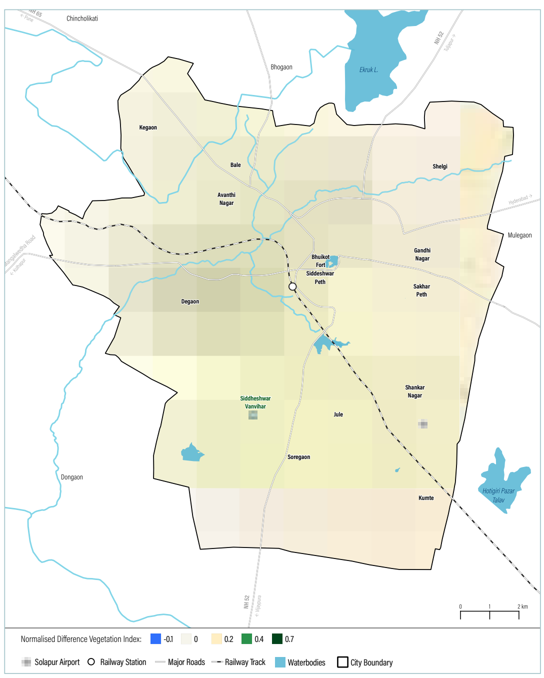
3. Correlation between LST and Vegetation

Vegetation affects LST, and the two are inversely correlated i.e. areas with lesser vegetation tend to have higher LST. This correlation depends on the type of vegetation and its distribution and seasonality. Trees that are present as a part of the built-up fabric or trees along the roads or avenues have higher effect on the microclimate of the area as compared with isolated artificial plantations. Similarly, seasonal plants can help in reducing the LST for a limited period. Ornamental species may not reduce LST but end up burdening the water supply. Open grounds that lack grass or similar vegetation during summer months also act as heat hotspots.

Solapur city has large agricultural land parcels within the corporation boundary, most of them concentrated along the two water streams flowing through the north and the west of the city as seen in Fig 4-11. Solapur has two main agricultural seasons, Rabi and Kharif, among which the effect of Kharif cannot be observed due to lack of satellite image availability during monsoon months. The Rabi crop sowing and greening phase in the months of October, November, and December was used to understand the effect of agricultural vegetation. Due to these seasonal crops, the areas with cropland showed higher vegetation and lower LST within the time duration, but these effects are seasonal and do not contribute towards lowering the LST throughout the year.

The core area of the city has fewer green areas. The maintained green areas, such as the areas near Bhuikot fort and Mahatma Gandhi Zoo, are at lower LST due to the higher vegetation than the surroundings but has a very less effect on the overall microclimate of the area as the anthropogenic activities has a higher impact on the LST (Refer to Annex 1-3).

Figure 4-11: **Mean NDVI for all months (2019-2021)**



Source: WRI India analysis, Landsat 8 data between 2019 – 2021

Figure 4-12: Comparison between ward wise mean LST and NDVI for pre monsoon months (April and May, 2019-2021)

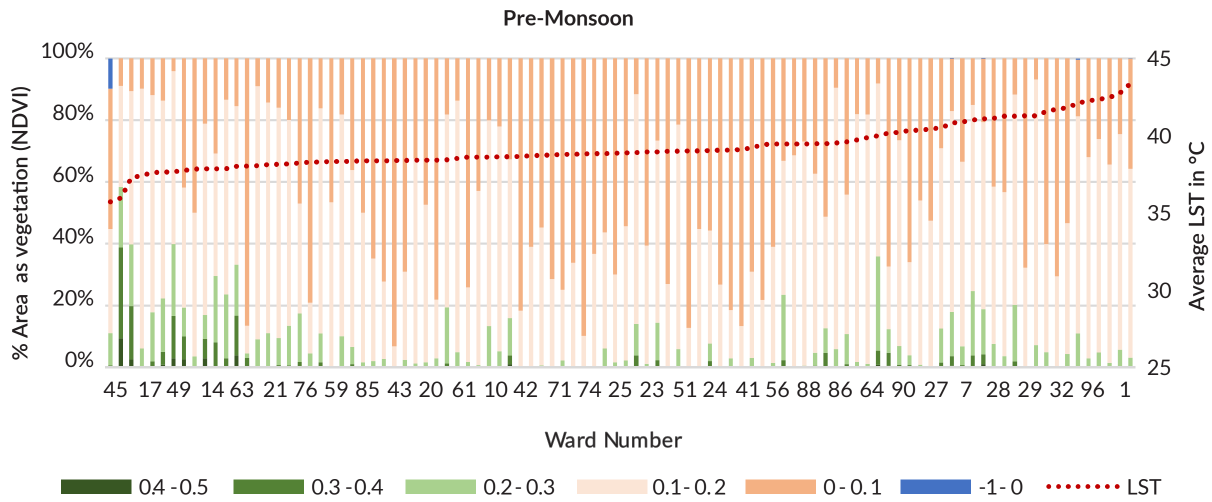
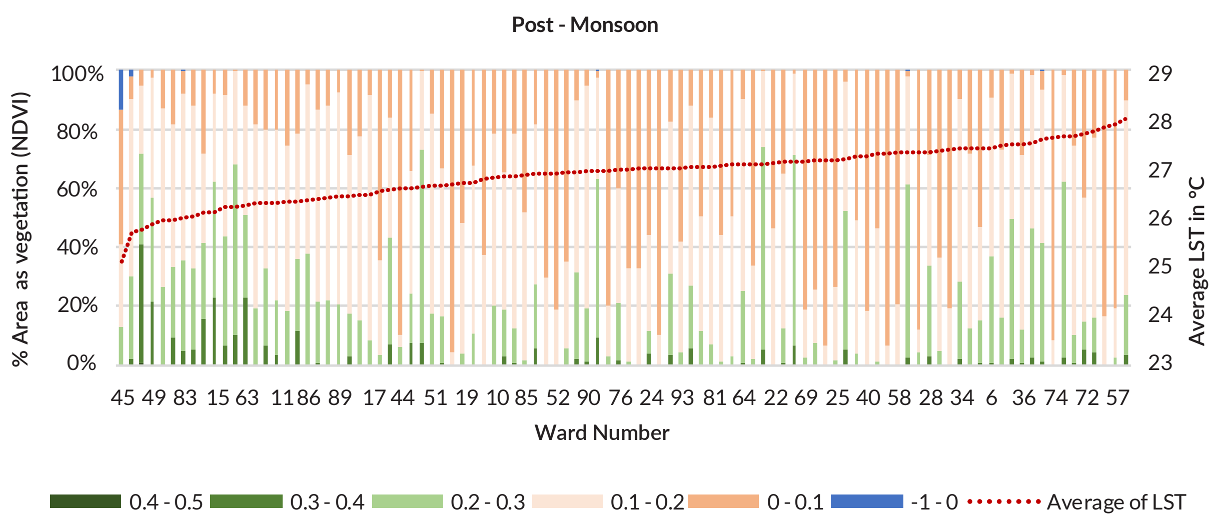


Figure 4-13: Comparison between ward wise mean LST and NDVI for post monsoon months (October, November, December, 2019-2021)



Source: WRI India analysis, Landsat 8 data between 2019 – 2021

Within the wards along the periphery of Solapur city, day-time LST is higher and is affected by the seasonal variation in the crop cycle within the area as seen in Fig 4-12 and 4-13 respectively. But however, due to low population density in these areas, the number of people getting affected due to higher LST levels is limited. Within the core area of the city, the population density is higher, with fewer green areas. The parks and gardens with a lot of vegetation concentrated within a small area, though beneficial for physical and mental health of the visitors, have minimal effect on the surrounding area LST and overall microclimate. Similarly, playgrounds and maidans with absence of trees and grass or presence of ornamental, seasonal vegetation can turn into high-temperature hotspots due to bare soil.

Areas such as *Siddheshwar vanavihar*, which is away from the city core, appears to have very less vegetation during the pre-monsoon months and also show higher LST at 44°C. It was observed that vegetation along the roads or periphery of the open grounds incorporated in built-up areas have higher impact on reducing overall temperature. These hotspots within the city core, which is a high population density area, along with the urban heat island effect elevate the severity of risk of exposure to high temperatures.

4.2. DISCUSSION AND CONCLUSIONS

The annual average air temperature in Solapur has been increasing from 1975 to 2021 at the rate of 0.1°C per decade. The number of extreme heat wave days experienced by the city is also on the rise. The years 2010, 2016, and 2019, on average, had 50 days of extreme heat wave. Moreover, the perceived temperature (heat index) analysis shows that the number of caution and extreme caution days are also increasing at the rate of almost one day per year.

The UHI effect is evident within the high built-up density city core. An increase in night-time LST by 0.3°C per decade was observed within the city corporation boundaries from 2001 to 2021. Within the city, areas such as *APMC market* and areas around *Laxmi market* appear as hotspots with less vegetation cover and high temperatures. In these areas, interventions could help lower temperatures.

PARK CHOWK
Photo credit: Pravin Gaikwad

5. AIR POLLUTION RISK

The interactions between urban climate, air pollution, and human health in cities need to be explored. Cities in developing nations such as India are facing high pressure due to air pollution and climate change. In India, studies on the combined effects of weather, climate variability, increased air pollution and health impacts are limited[12].

Climate plays a considerable role in spatial and temporal distribution of air pollutants. Greenhouse warming and ozone depletion in stratosphere are vital factors of climate change. Climate change can influence the air pollutant concentration and catalyse the formation of secondary pollutants. Also, the climatic conditions in addition to atmospheric parameters, topography, and urban settlements influence the dispersion, accumulation, and transformation of pollutants in the atmosphere. The dispersal of these air pollutants may cause respiratory disorders, such as emphysema and asthma, allergy problems, and chronic bronchitis[13].

Besides, the nexus between urbanisation, climate change, and air pollution is such that some of the atmospheric pollutants (aerosols) can enhance climate change because of their direct and indirect effects[14].

Anthropogenic emissions, such as Greenhouse Gas (GHG) emissions, trigger local climate changes, especially in the case of the risk of air pollution in cities. The correlation between air pollution, urbanisation, and climate change can be established based on increased pollutant emission and aerosol load in the atmosphere from urbanisation and increased vehicular traffic.

5.1 ASSESSMENT

Air pollution risk assessment includes temporal analysis using data from the Continuous Ambient Air Quality Monitoring Stations (CAAQMS) and manual stations established in the city and spatial analysis based on satellite imagery. Refer to Annexure 1-5.

- There are seven Central, state and city-led monitoring stations in Solapur maintained under different programmes. The locations and details of pollutants monitored at these stations are presented in Table 5-1 and mapped in Figure 5-1.
- The Indian Institute of Technology Bombay (IIT-B) and the National Environmental Engineering Research Institute (NEERI) conducted a source apportionment and emission inventory study in Solapur for MPCB.
- The city-specific air pollution micro action plan was created as a part of the NCAP programme, which included measures for mitigating the sources and strengthening air quality monitoring in the cities.

Air pollution monitoring includes the study of the concentrations of physical and chemical compounds.

- Chemical compounds include gases such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and carbon monoxide (CO), while the physical compounds include the dust particles PM_{10} and $PM_{2.5}$.

- For gaseous parameters, Solapur does not indicate non-attainment character. However, Respirable Suspended Particulate Matter (RSPM) levels were above the annual limit established by the Central Pollution Control Board (CPCB), which shows non-attainment.

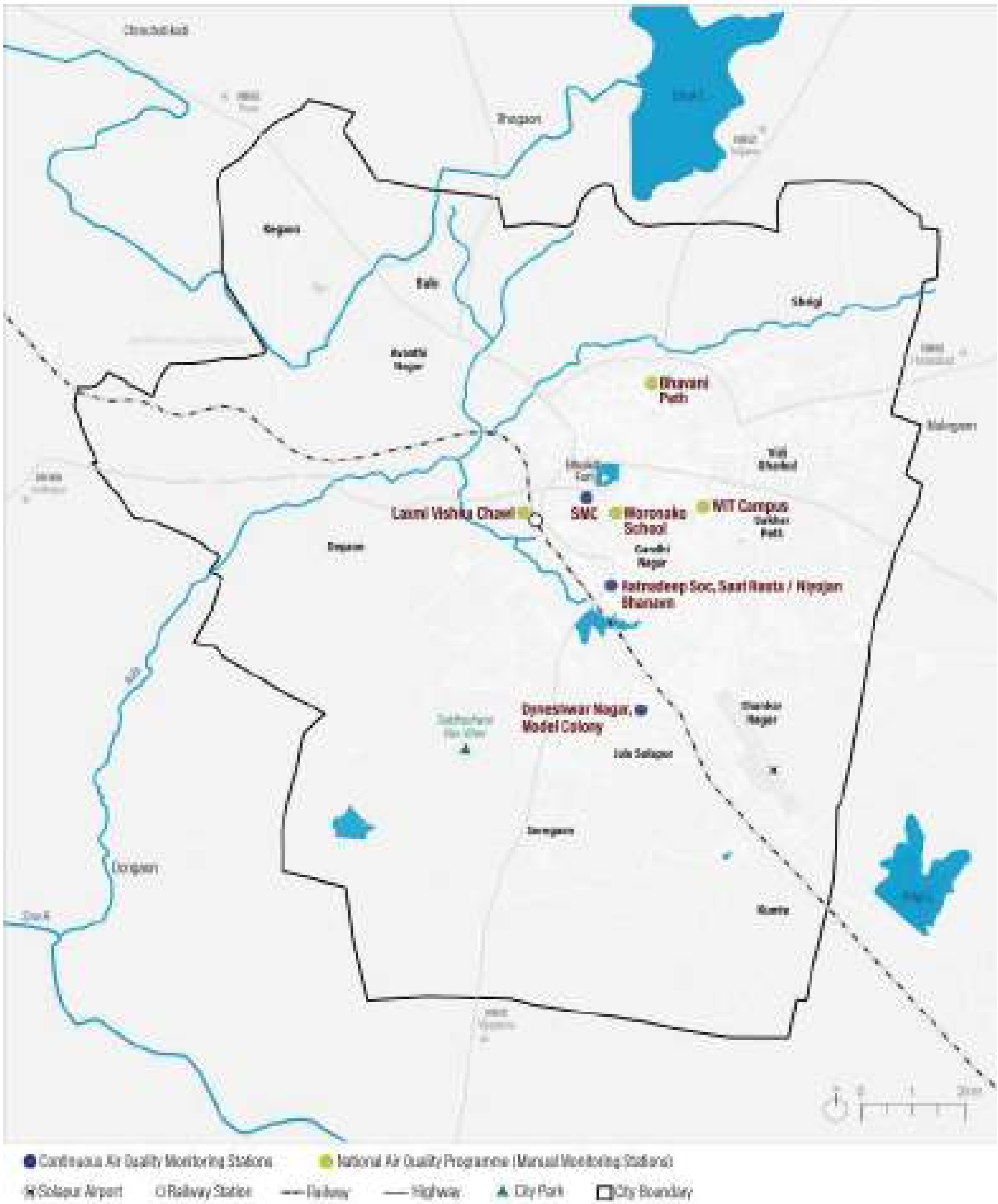
Table 5-1: Details of seven air quality monitoring stations within Solapur City

Monitoring station name, area	Pollutants	Data Range	Monitoring Frequency
Mcorp Premises, SMC Head office	SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, O_3	11/08/2016 to 22/06/2022	Hourly
Niyojan Bhawan, Saat rasta	SO_2, NO_x, RSPM, SPM	02/04/2004 to 29/03/2022	Two days a week
WIT Campus, WIT	SO_2, NO_x, RSPM, SPM	01/04/2004 to 31/03/2022	Two days a week
Rupabhawani chowk, Bhavani peth	SO_2, NO_x, PM_{10}, $PM_{2.5}$, SPM	01/02/2021 to 31/01/2022	4 and 8 Hourly
Indradhanu Degaon road, Laxmi Vishnu chawl	SO_2, NO_x, PM_{10}, $PM_{2.5}$, SPM	01/02/2021 to 31/01/2022	4 and 8 Hourly
Jule Police Chowk, Dhyaneshwar Nagar	PM_{10}, $PM_{2.5}$, SO_2, NO, NO_2, NO_X, NH_3, CO, O_3, BENZ	01/02/2022 to 31/05/2022	Hourly
Woronako School	Data Not available		

Source: SMC, MPCB website; http://cpcbenvis.nic.in/airpollution/finding.htm
Note: RSPM is the same as PM10

The lone Continuous Ambient Air Quality Monitoring Stations (CAAQMS) station is in the SMC premises where hourly data is available for the pollutants listed in Table 5-1. Moreover, MPCB has established two new monitoring stations, at Rupabhavani Chowk (Commercial) and Indradhanu – Degaon Road (Residential), data for which is available from 2021, while data from the monitoring station at Jule Police Chowk station (Dnyaneshwar Nagar) is available from 2022. Woronako School is the newest monitoring station, due to unavailability of data the station was not considered in the analysis .

Figure 5-1: **Locations of air quality monitoring stations in Solapur**



Source: WRI India using CPCB, MPCB, SMC, 2022

The CAAQMS near the SMC, is located on the road between two junctions, Babasaheb Ambedkar Chowk and Dufferin Chowk (also a traffic hotspot). The adjacent landuse is mostly institutional and recreational surrounding home, ground, park, stadium, etc. Niyojan Bhavan is located on Vijapur road, with a predominantly residential landuse. The station is located about 500 m away from the Saat Rasta Junction.

The WIT Campus monitoring station is located near the inner ring road area and is a mix of high density residential (including slums neighbourhoods) and institutional, with few retail/commercial activities in the vicinity.

The Indradhanu-Degaon road station is located very close to the Solapur railway station, where the landuse is mostly residential. Similar landuse is also observed near the Bhavani Peth station in the northern part of the city near the inner ring road and the Jule Police Chowk station towards the south near Model Colony. However, in the case of the latter, a small industrial area is located about 1 km to the north of it. Lastly, the station at Woronako school is located near the city center, with predominantly residential landuse and high traffic volume.

5.2 KEY FINDINGS

The pollution levels for particulate matter and gases with respect to their individual permissible limits as per National Ambient Air Quality (NAAQ) standards prescribed by CPCB were analysed for the monitoring stations. In addition, the spatial analysis of the concentrations was carried out using satellite observations. The key findings of this analyses are presented in this section.

5.2.1 Air pollution concentrations

The temporal analysis of different air pollutant levels (annual averages) for Solapur city has been carried out for the period from 2004 to assess the city-wide and station-wise variations using data from the three manual stations: Niyojan Bhawan, Walchand Institute of Technology (WIT) Campus, and Solapur Municipal Council (SMC) premises.

The two newly established stations, Indradhanu and Rupabhavani Chowk, monitor pollutant levels in 4-hour window periods — 2 am, 6 am, 10 am, 2 pm, 6 pm, and 10 pm — for 2-3 days per week. Since, at these two stations, the data was only available for the past eighteen months, drawing any concrete insights is difficult. Nonetheless, we have calculated monthly averages to identify trends, if any, over this relatively short time span.

Using the hourly data from the SMC station, hourly, weekly, monthly, seasonal, and annual scale analyses were carried out. However, for the same station and the remaining two stations, only annual averages were calculated using the limited data (1-2 data points per week) available on the MPCB website. These annual averages were compared with the NAAQ standards to determine when the concentrations were breaking above the threshold.

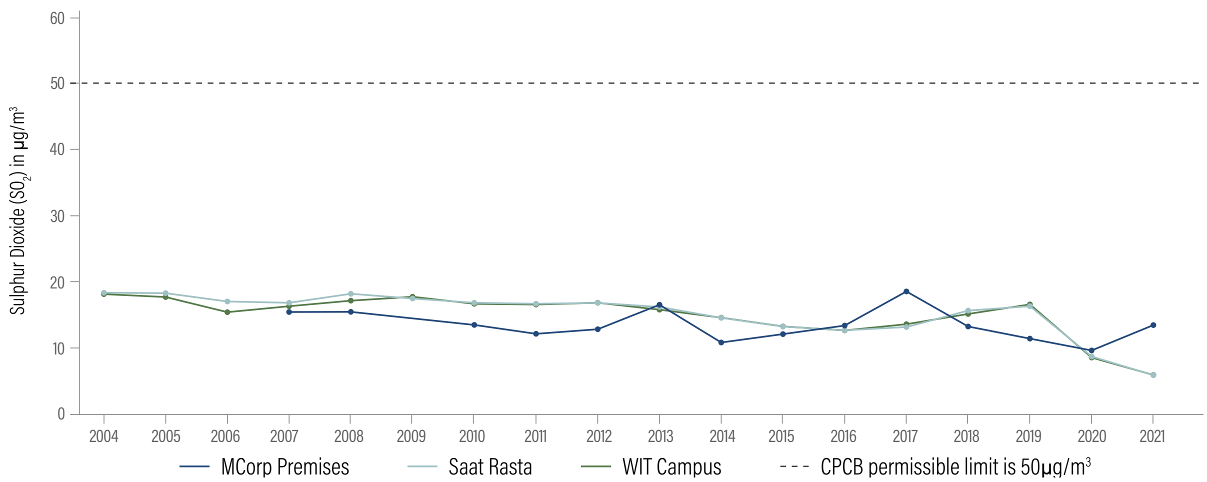
Spatial analysis includes the spread of each pollutant in the region of interest. It must be noted, however, that higher concentrations in a region, as seen in the spatial maps, do not indicate the presence of source(s) at that location as wind direction plays a key role in moving plumes of emissions to adjacent regions. Furthermore, the units of concentrations for all the pollutants in the sentinel data are different from those used in the temporal analysis, with no easy method of conversion between the two. Therefore, one should refrain from applying the NAAQ safety thresholds to the sentinel maps and utilise these maps to only understand the broader areas in the city where the concentrations of pollutants are relatively higher.

The maps presented in sections below were created using data from the Sentinel satellite mission for all the pollutants except $PM_{2.5}$ for which the data was provided by the Atmospheric Composition Analysis Group at the Washington University in St. Louis, USA. Also, note that the spatial data is not available for ozone and PM_{10} / RSPM.

1. Analysis of concentration of Sulphur Dioxide

Annual average sulphur dioxide (SO_2) concentrations are observed to be much lower than the stipulated regulatory limit (50 μg/m³), indicated by the black dashed line in Figure 5-2, since 2004. Therefore, the presence of SO_2 seems to have a minimalistic impact in Solapur. The monthly average concentrations of SO_2 at the two newest stations where seasonal variations are apparent with high concentrations in the winter and low concentrations in the monsoon. However, these values cannot be compared with any standard safety thresholds at monthly level as no such thresholds exist.

Figure 5-2: **Annual Average Concentrations of Sulphur Dioxide across all three air quality monitoring stations in Solapur between 2004 and 2021**



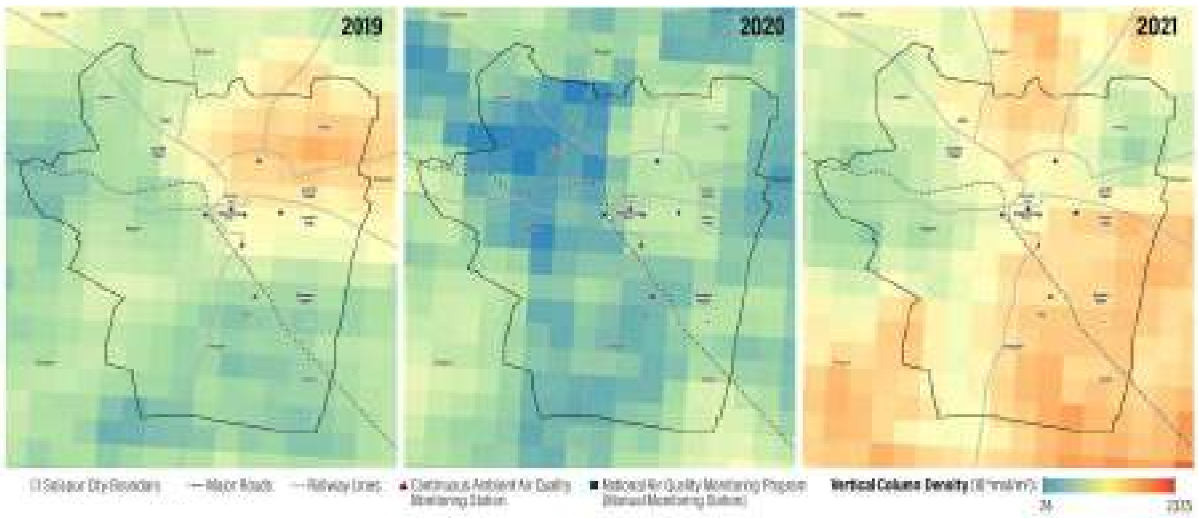
Source: Maharashtra Pollution Control Board

The spatial data shows more variability as compared with the other pollutants, as seen in Figure 5-3. In 2019, the area around Shelgi appears as a prominent hotspot. The APMC market located near Gandhi Nagar south of this hotspot could be one of the contributing sources. In 2021, the area between Sakhar Peth MIDC and the thermal power plant shows relatively higher concentrations. The years 2019 and 2021 also show high concentrations at the stone crushing site East of Bhogaon.

The monthly average concentrations of SO_2 from 2019 to 2021 show a pattern consistent with the observations from the temporal analysis with high concentrations in the winter and low concentrations in the monsoon (Refer to Annex 2-6).

In 2019, the hotspot near Shelgi discussed above is seen in January and March, while the hotspot in February and April seems to be concentrated over 'Solapur Bio Energy Systems' in the north-central portion of the city.

Figure 5-3: **Annual average concentrations of Sulfur Dioxide (SO_2) in Solapur from 2019-2021.**

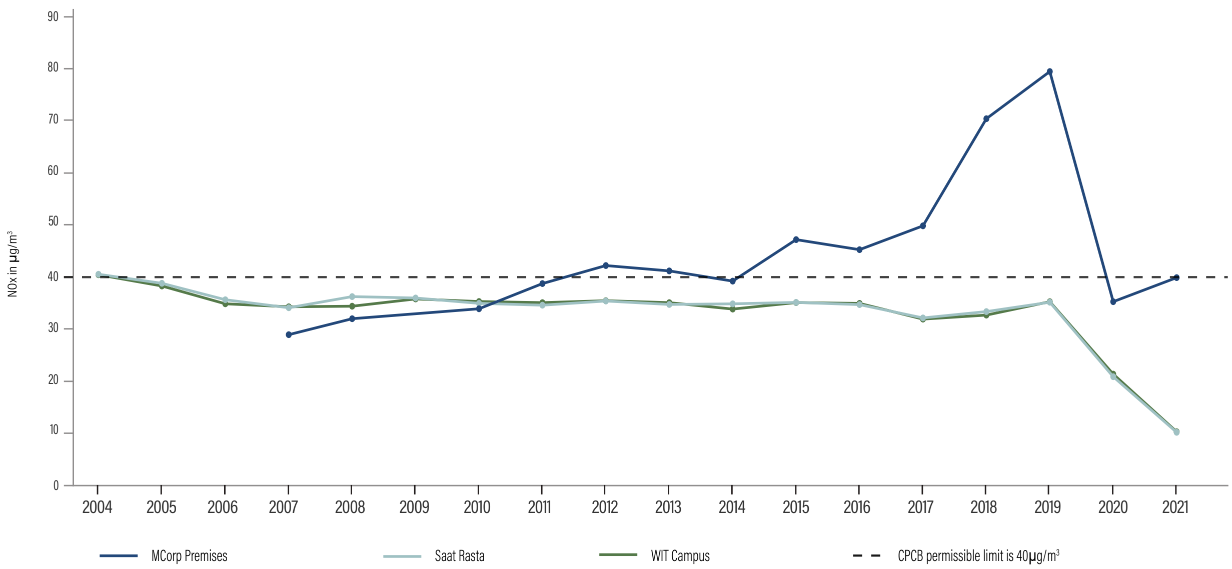


Source: WRI India using Sentinel data

2. Analysis of concentration of nitrogen oxides

Figure 5-4 shows annual nitrogen oxides (NOx) averages at the three stations and are observed to be reaching dangerously close to the safety threshold of 40 µg/m3, with the monitoring station at SMC crossing the threshold 7 times since 2012. These high concentrations could be attributed to emissions from vehicular traffic on the busy streets surrounding this station.

Figure 5-4: **Annual Mean Concentrations of Nitrogen Oxides (NO_x) across all the manual air quality monitoring stations in Solapur from 2004 to 2021**



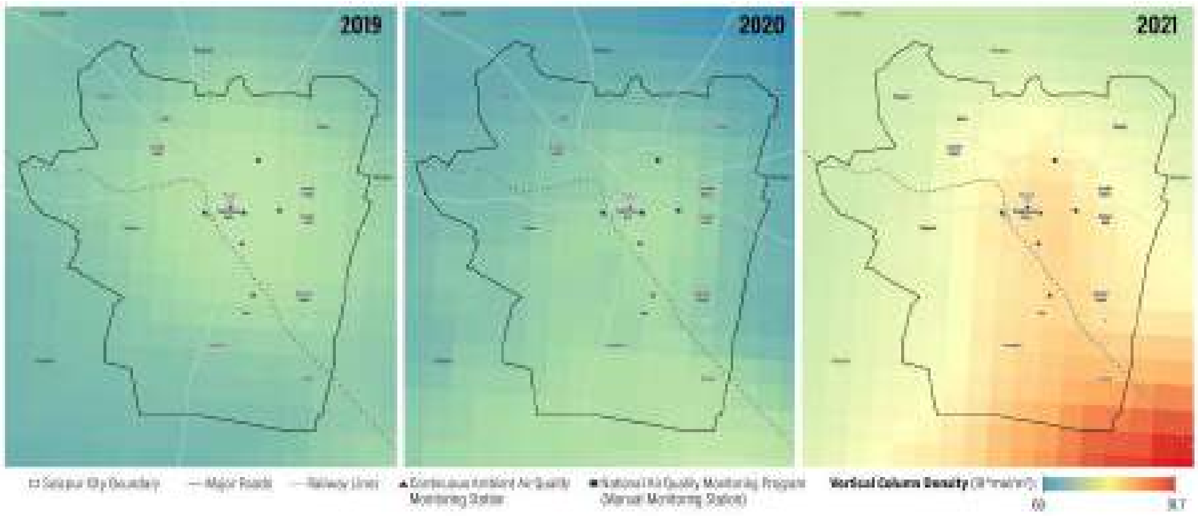
Source: Maharashtra Pollution Control Board

The monthly average concentrations of NO_2 at the two new stations show high values during winter (December – February) due to relatively low wind and higher inversion duration. NO_2 values start declining during summer due to higher ventilation and falls to lowest levels in the monsoon.

The analysis of hourly concentrations of NO_2 at the continuous monitoring station at the SMC premises show that the daily CPCB threshold was crossed on 347 days between mid-2018 and early 2020. This station is located between two major chowks on the busy VIP Road indicating high traffic volume in its vicinity, which explains the higher concentrations (Refer to Annex 2-7).

Vehicular emissions are the most important source of NO_2. As such, the maps show relatively high concentrations in the middle of the city in areas such as Siddheshwar Peth. Other areas such as Solapur thermal power plant just outside the SMC jurisdiction and Shri Siddheshwar sugar factory located east of the airport outside the city limit could also be contributing to these emissions. The effects of COVID-19 lockdowns are quite apparent in these maps, with a significant reduction in the concentrations and the spatial spread of NO_2 in this region during 2020 (Refer to Figure 5-5).

Figure 5-5: Annual average concentrations of Nitrogen Dioxide (NO_2) in Solapur from 2019-2021



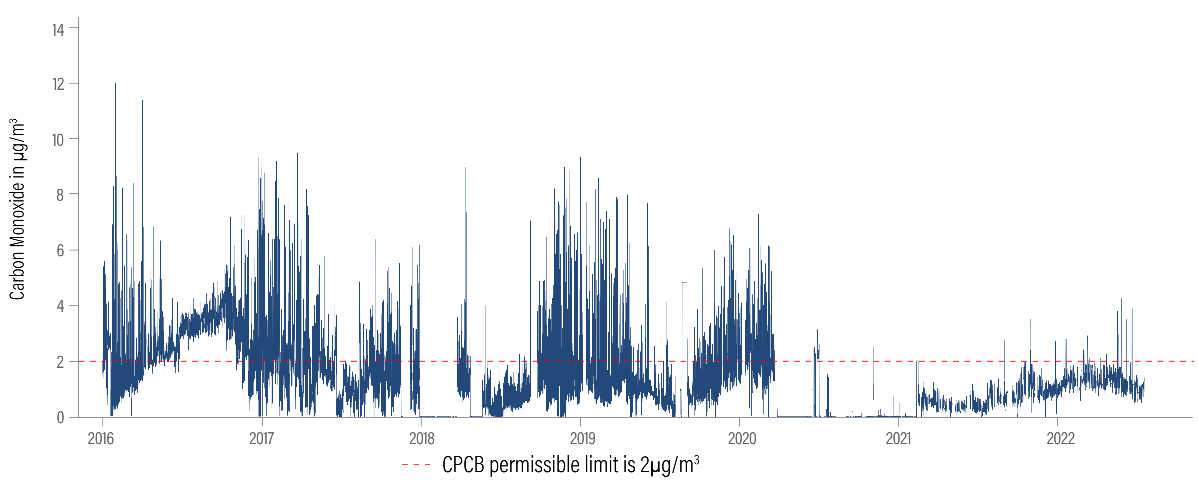
Source: WRI India using Sentinel data

The monthly average concentrations of NO_2 from 2019 to 2021 in the city indicated higher values consistently over the city center. Moreover, the seasonal variations are similar to the other pollutants, with high concentrations in the winter and low concentrations in the monsoon months (Refer to Annex 2-8).

3. Analysis of concentration of Carbon Monoxide (CO)

Figure 5-6 shows the measured hourly concentrations of CO at the SMC station. When aggregated to the daily scale, on 22% of the days, the daily averages in this entire period were above the threshold of 2 mg/m3. The winter months typically show spikes in CO values whereas concentrations are lowest during the monsoon season. A total 1039 days saw the daily CPCB threshold exceeding during this entire period.

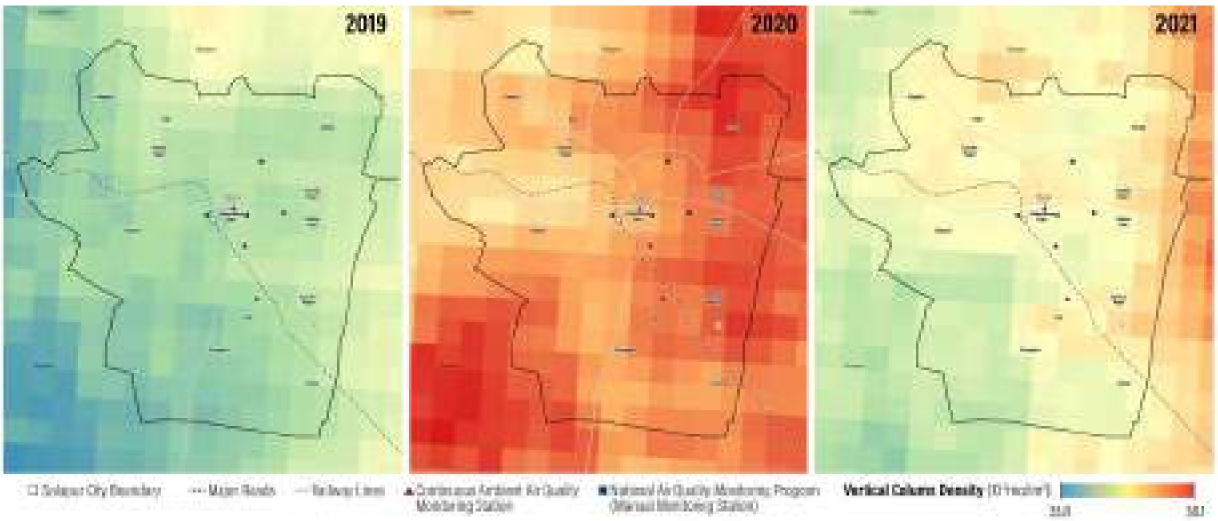
Figure 5-6: Hourly Carbon Monoxide (CO) concentrations at the SMC air quality monitoring station between January 2016 and July 2022



Source: Central Pollution Central Board

The annual average concentration of CO appear to have increased during the COVID-19 lockdown. (Refer to Figure 5-7). According to NASA's Fire Information for Resource Management System, there were a few incidences of fire (most likely stubble burning) outside the city boundary between March and April 2020, which may explain these elevated concentrations. This hypothesis is also backed by the study conducted by (Mohite & Sawant, 2022) which shows elevated CO concentrations in this year compared to 2019. Lastly, the lockdown may have pushed household dependency on diesel generator (DG) sets and the increased use of (polluting) cooking fuels could have added to the concentration levels. For the seasonal variations, refer to Annex 2-9.

Figure 5-7: Annual average concentration of Carbon Monoxide (CO) in Solapur from 2019-2021

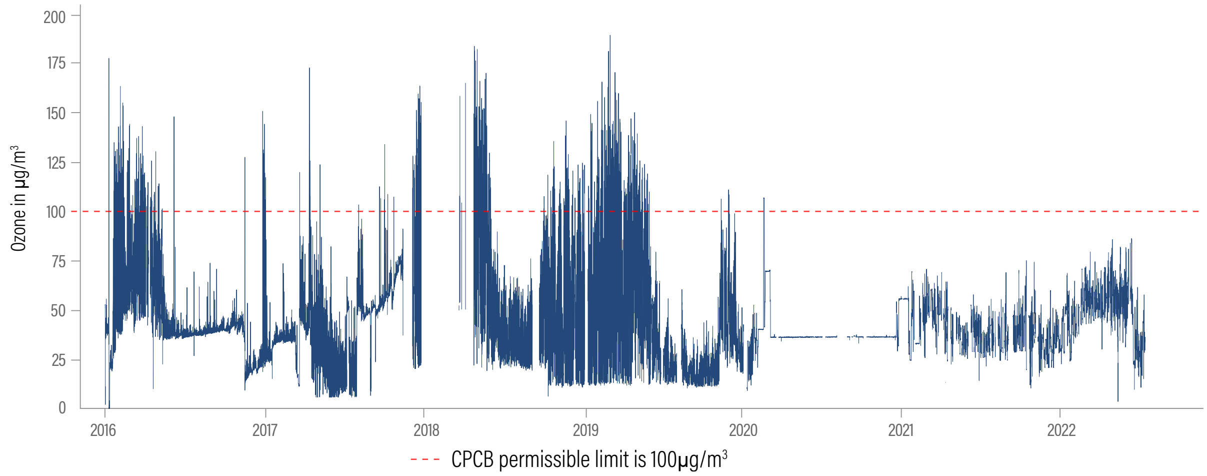


Source: WRI India using Sentinel data

4. Analysis of concentration of Ozone

Figure 5-8 shows the measured hourly concentrations of Ozone (O_3) at the SMC station. Unfortunately, this dataset contains a significant amount of noise. Similar to the other pollutants, winter months show higher concentrations (note the values around January for all the years). Throughout this period, the daily CPCB threshold was crossed on 317 days, with a majority of the crossings happening between November and May.

Figure 5-8: Hourly Ozone (O_3) concentrations at the Solapur Municipal Corporation air quality monitoring station between January 2016 and July 2022

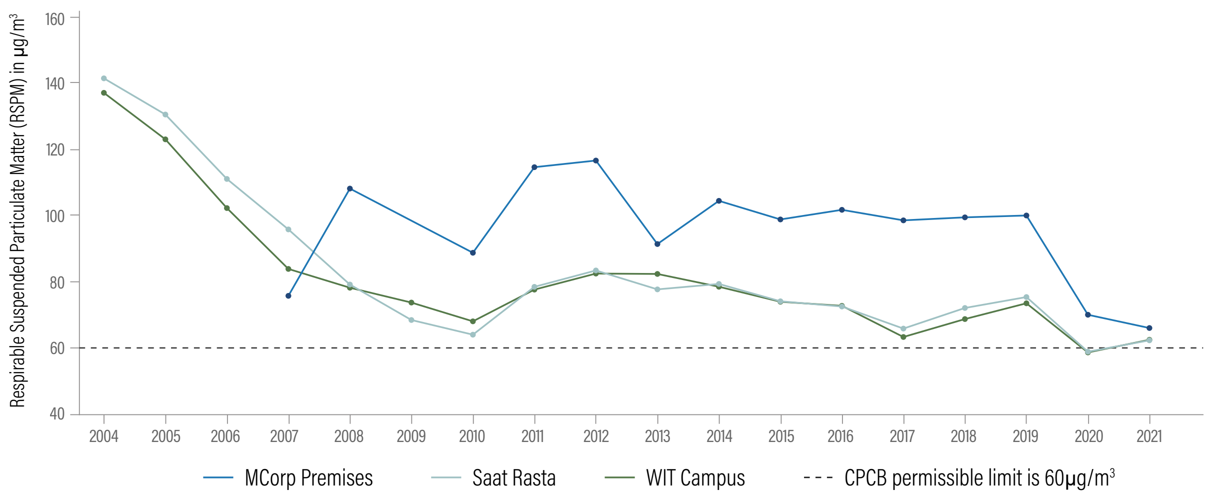


Source: Central Pollution Control Board

5. Analysis of concentration of RSPM (PM_{10})

Figure 5-9 shows annual average concentrations of RSPM at the three manual stations. The markedly high values crossing above the annual safety threshold of 60 µg/m3 (black dashed line) are observed at all the stations, indicating non-attainment. The most common source of RSPM/ PM_{10} emissions is suspended dust particles from road, construction sites etc. and, therefore, the phenomenon of non-attainment with respect to this pollutant is common across many Indian cities.

Figure 5-9: Annual average concentrations of RSPM/ PM_{10} across three air quality monitoring stations between 2004 and 2021



Source: Maharashtra Pollution Control Board

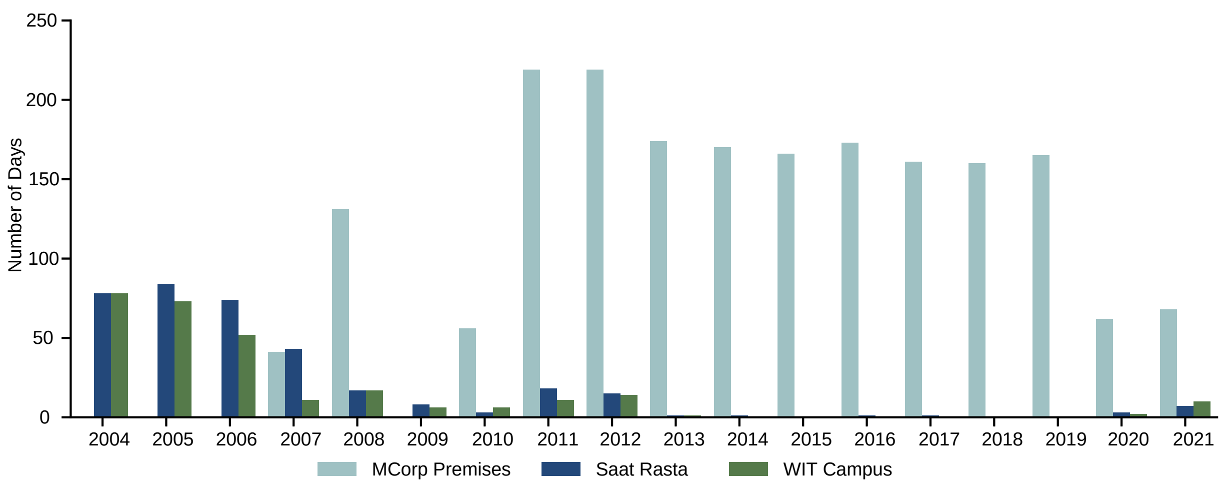
The station at MCorp Premises shows markedly high concentrations of RSPM during this period. This is most likely because it is located in the middle of the city and surrounded by residential landuse with plenty of vehicular traffic and footfall.

Figure 5-10 illustrates the number of days each year that the CPCB threshold limit of 100 μg/m^3 was crossed at each of the 3 stations. Since these are manual monitoring stations[15], the observations are recorded approximately twice a week. Therefore, each year, the ideal number of daily observations at the stations at Saat Rasta and WIT Campus should be around 105. The station at SMC (MCorp) premises has the most number of days when the RSPM threshold was crossed, which is most likely due to its location and the surrounding landuse.

Similarly, the analysis of hourly concentrations of PM_{10} at the SMC station shows the numerous instances of concentrations breaking above the stipulated daily safety limit of 100 μg/m^3 (Refer to Annex 2-10).

When aggregated to the daily scale, the daily averages were above the threshold on 38% of the days. This amounts to a total of 1,428 days, with a majority of these crossings observed between November and May.

Figure 5-10: Number of days of PM_{10} CPCB threshold limit crossed annually for Solapur from 2004-2021



Source: Maharashtra Pollution Control Board

6. Analysis of concentration of Particulate Matter (PM2.5)

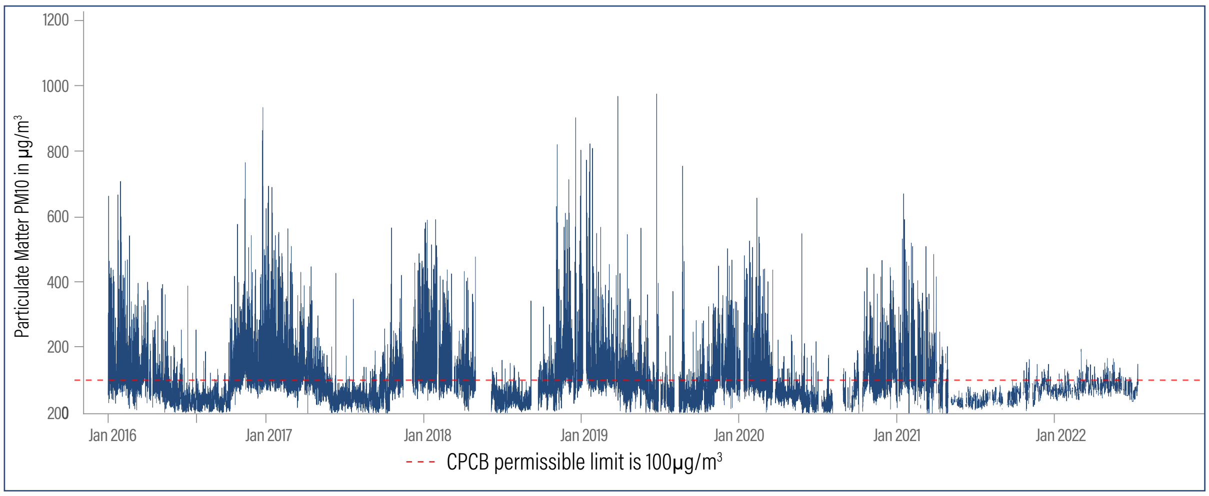
Particulate Matter 2.5 - fine fraction size up to 2.5 μm – contains airborne particles composed mainly of carbonaceous materials (organic and elemental), inorganic compounds (sulphate, nitrate and ammonium) and trace metal compounds (iron, aluminium, nickel, copper, zinc and lead) largely formed from combustion and vehicular emissions (CPCB, 2020). Due to the extremely small size, these are easily breathable and give rise to several health issues.

Figure 5-11 shows the measured hourly concentrations of $PM_{2.5}$ at the SMC station. Note the numerous instances of concentrations breaking well above the daily CPCB safety threshold (red dashed line). Also, the highest concentrations are observed in the winter season, around January each year.

A comparison of $PM_{2.5}$ for the years 2019 and 2020 shows that the number of days when $PM_{2.5}$ levels breached the annual limit was 180 in 2019 and 110 in 2020 (Refer to Annex 2-11). This decrease reflects the COVID-19 lockdown period in 2020. While the 2019 monsoons had numerous peaks, 2020 had a more conspicuous gap from April to October.

In Solapur, 10% of the daily average concentrations are above the daily threshold of 60 µg/m^3 in the duration considered (from January 2016 to July 2022). The total activity shutdown during the COVID-19 lockdown also led to a decrease in the concentrations in the middle of the year, between April and September . Specifically, based on the 3-D charts (Refer to Annex 2-12), winter months of November-February and the morning-evening hours of 6 AM and 6 PM show relatively higher concentrations of $PM_{2.5}$.

Figure 5-11: Hourly $PM_{2.5}$ concentrations at SMC Air Quality Monitoring Station between January 2016 and July 2022



Source:Central Pollution Control Board

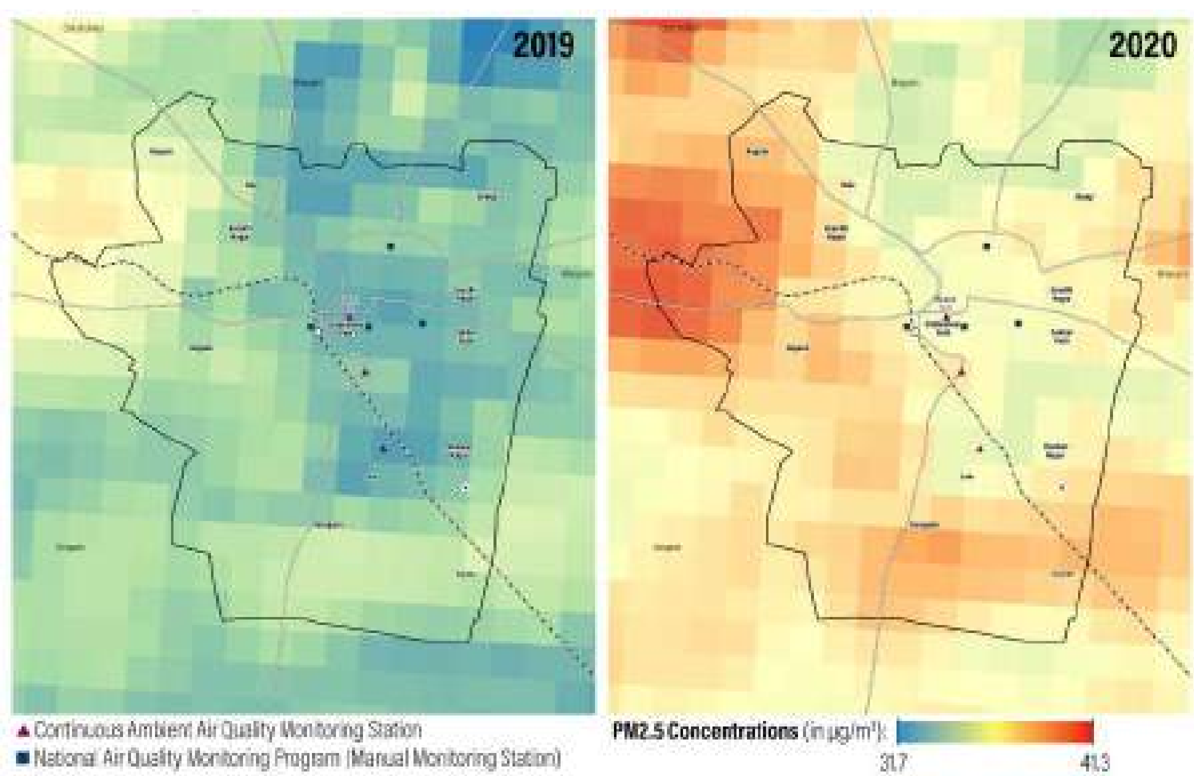
With regards to the spatial analysis, unlike other pollutants, $PM_{2.5}$ dataset is only available until December 2020, as shown in Figure 5-12. The prominent hotspot outside the western boundary is most likely the result of a plume whose source (a cluster of industries) is in the region where the Kolhapur Road exits the city boundary. This region hosts a stone crushing site (contributing to the highway maintenance work) and a waste material treatment plant. Similarly, the north-western hotspot near Chincholikati is also located over a small industrial area.

Furthermore, the hotspot east of the airport is located near the Shri Siddheshwar sugar factory, while the Degaon sewage treatment plant located in the west-central portion of the city could be the source of slightly elevated concentrations of $PM_{2.5}$ in this zone.

5.2.2 Source apportionment study – key findings

The source apportionment study carried out for the city of Solapur in 2017 by IIT-B and NEERI provides an emissions inventory to understand the sources and causes of the net-play of various pollutant concentrations analysed in the previous sections. The study categorises the pollutant type as point (industrial activities), line (vehicular emission), and area (domestic and commercial activities), along with a spatial representation of the pollutant concentration caused by all sources based on activity mapping and hotspot identification using visuals of 2x2 km grids.

Figure 5-12: **Annual average concentrations of $PM_{2.5}$ in Solapur between 2019-2020**



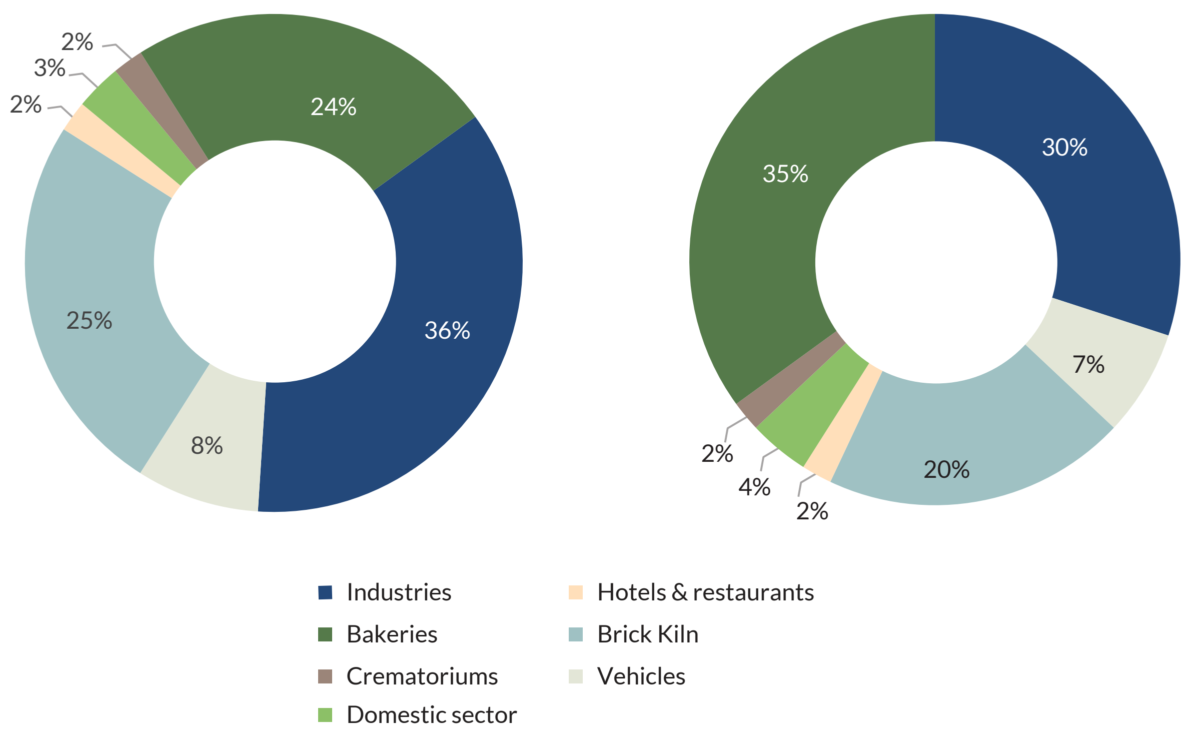
Source: WRI India using data from Atmospheric Composition Analysis Group, USA

1. Pollutant and sources

- $PM_{2.5}$ and PM_{10}: Under these pollutant categories, the major sources are industries (30-36%), bakeries (20-25%), open eat-outs (24- 35%), and vehicles (7-8%). The pollution levels also coincide with the type of fuel usage. The MIDC area is located towards the eastern side of the city, showcasing a higher concentration of $PM_{2.5}$ and $PM_{10.}$
- Subsequently, many bakeries that operate in the city use wood as their major source of fuel. Recently, due to the increase of cost of wood, bakeries began using diesel with DG sets as an alternative source. In the case of the transport sector, most operational buses ply on diesel.

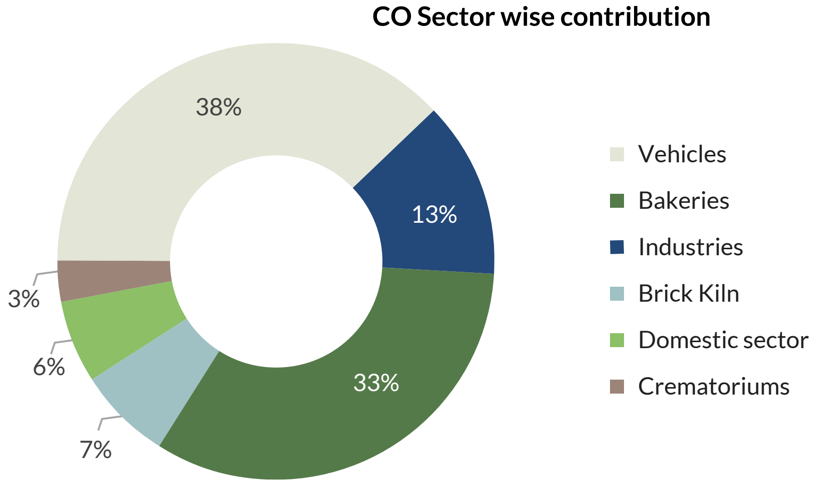
Correlating the pollutant source with the fuel usage provides better understanding in appropriating actions for bringing down pollution levels in the city.

Figure 5-13: Sector wise contribution of PM_{10} and $PM_{2.5}$ within Solapur City



Source: Source Apportionment Study[16]

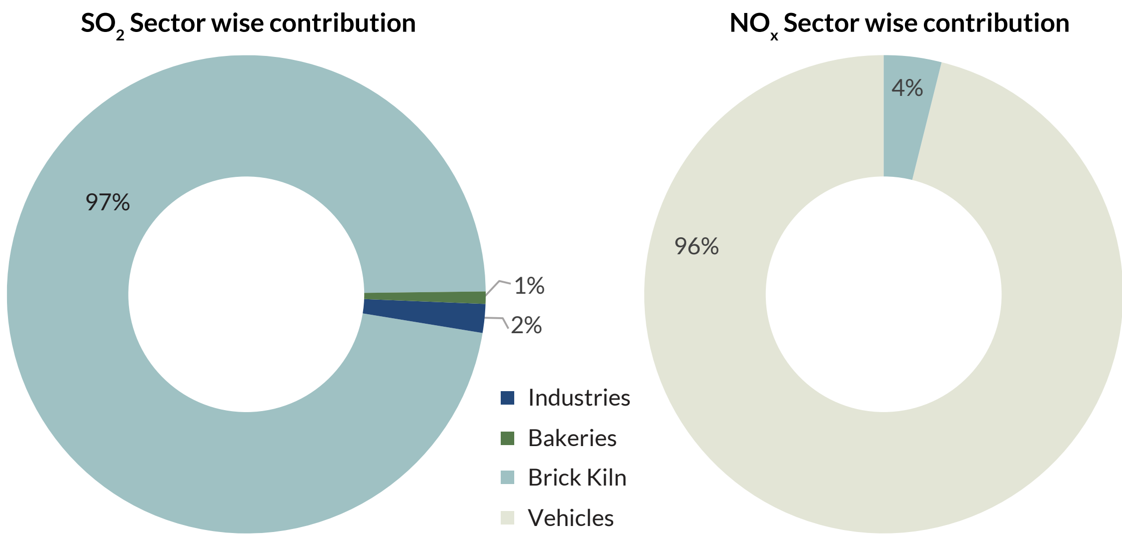
Figure 5-14: Sector wise contribution to CO emissions within Solapur City



Source: Source Apportionment Study

- CO, NO_x and SO_2: Vehicles (38%) categorised as line sources are the major contributors of CO emission caused from fossil fuel burning, followed by open eat-outs (33%) and industries (13%). The public transit services operate on buses that run on diesel. While NO_x and SO_2 are not considered major pollutants on the basis of the trend analysis presented in the previous section, the source apportionment study mentions the pollutant sources as vehicles being the major contributor to NOx.
- Subsequently, for SO_2 the major source is likely to be brick kilns. The number of brick kilns and their location i.e. within the city municipal boundary or in the city periphery need to be further verified.

Figure 5-15: Sector wise contribution for NO_x and SO_2 for Solapur City



Source: Source Apportionment Study

5.2.3 Indoor pollution analysis

$PM_{2.5}$ has numerous instances of concentrations breaking above the CPCB thresholds. Therefore, it is one of the major drivers for air pollution risk.

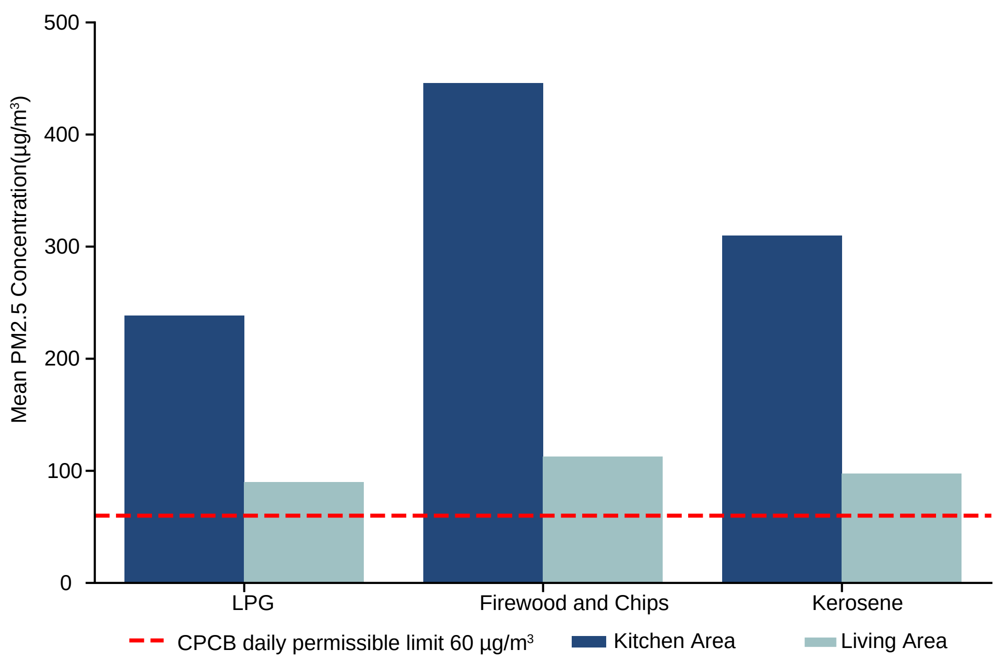
Indoor air pollution is often a forgotten aspect of air quality. However, various studies have shown that high concentrations of pollutants pervade Indian households. Of all the common domestic fuels, LPG, PNG, biogas, and electricity are considered as clean fuels while cow dung cakes, kerosene, coal/lignite/charcoal, and firewood are considered as polluting fuels for which the exposure is computed using the $PM_{2.5}$ concentrations.

Figure 5-16 shows the concentration of $PM_{2.5}$ in the kitchen and living area, categorised according to the fuel type and based on the methodology adopted from Balakrishnan et al., 2013. The effect of the polluting fuels on the indoor concentration of PM2.5 is clearly seen, with firewood and chips showing the highest PM2.5 levels due to their usage followed by kerosene.

As per Census 2011 data, in Solapur, about 65% of the households are observed to be using clean cooking fuel (LPG/PNG, biogas, electricity) as the daily cooking fuel. However, the city is yet to achieve the benefits of the Pradhan Mantri Ujwala Yojana, targeting 100% LPG prevalence.

About 21% of the households are observed to be using kerosene as the daily polluting cooking fuel, with households in wards 72 (Kurban Hussain Nagar), 70 (near Jawaharlal Housing Society), and 68 (north of Keshav Nagra) having the highest usage at 50%, 49%, and 46%, respectively.

Figure 5-16: Daily average concentration of $PM_{2.5}$ in kitchen and living room for different types of fuels



Source: WRI India using Census 2011 data

Firewood is the next most used polluting cooking fuel, with 12% of the city households using it daily. Wards 96 (Kumte), 98 (near Vidya Vikas Pratishthan Polytechnic), and 48 (between Aditya Nagar and Belati) have the highest consumption of firewood, at approximately 49%, 48%, and 42%, respectively.

5.2.4 Health risk

Air pollution can lead to serious short-term and long-term impacts, both on human health as well as on the regional climate. In 2019, approximately four million people died from exposure to fine particulate outdoor air pollution, with the highest death rates occurring in East Asia and Central Europe. Exposure to $PM_{2.5}$ reduced average global life expectancy by approximately one year in 2019[17]

The deadliest illnesses linked to $PM_{2.5}$ air pollution are stroke, heart disease, lung disease, lower respiratory diseases (such as pneumonia), and cancer. High levels of fine particles also contribute to illnesses such as diabetes, hinder cognitive development in children, and cause mental health conditions.

The short-term health effects are well known and include various lung- and heart-related diseases, such as cough, difficulty in breathing, and rapid buildup of calcium in the coronary artery, leading to stroke and heart attack[18]. Similarly, the short-term effects of declined air quality on the environment include increased apparent heat and pollution of waterbodies due to the dissolution of gaseous and physical particles. These conditions have impacts on humans inhabiting the environment.

5.3 DISCUSSION AND CONCLUSIONS

With increased population and urban expansion, the issue of air pollution has become critical in many Indian cities. As such, it is important to understand the key time periods as well as specific areas in the cities where pollution is the highest so that solutions can be implemented in the most efficient manner while ensuring economical use of resources.

In Solapur, CO, NO_2, and PM_{10} are the most critical pollutants that need attention. All these pollutants have either crossed or are close to the safety thresholds defined by CPCB. CO and NO_2 emissions primarily originate from vehicular traffic, while PM_{10} are dust particles sourced mainly from construction, suspended road dust, stone crushing sites etc. Furthermore, according to the source apportionment study, PM_{10} is also emitted by industries, open eat-outs, and bakeries in Solapur.

The temporal and spatial analysis shows that winter months have the worst air quality in terms of all the pollutants considered owing to the environmental effects. However, in the case of CO, stubble burning during the summer months appears to be a cause of increase in its level in the city.

RING ROAD KEGAON
Photo credit: Chetan Ligade

6. RAINFALL VARIABILITY AND WATER LOGGING

6.1 RAINFALL VARIABILITY

6.1.1 Regional Setting

Solapur lies at an elevation of 457 m asl within the Upper Bhima sub-basin, which is a part of the longest tributary of the Krishna River. It fulfills its water requirement from the Ujjani Dam, which lies 100 km west of the city. The land around the city and in its immediate vicinity is relatively plain. To understand the water availability risks for the city, analysis was carried out at a regional scale (refer sub-basin map in Figure 6-1). The surface and subsurface water dynamics directly impact Solapur's water security, surface, and subsurface water dynamics in the Upper Bhima basin and the numerous dams that contribute to its flow.

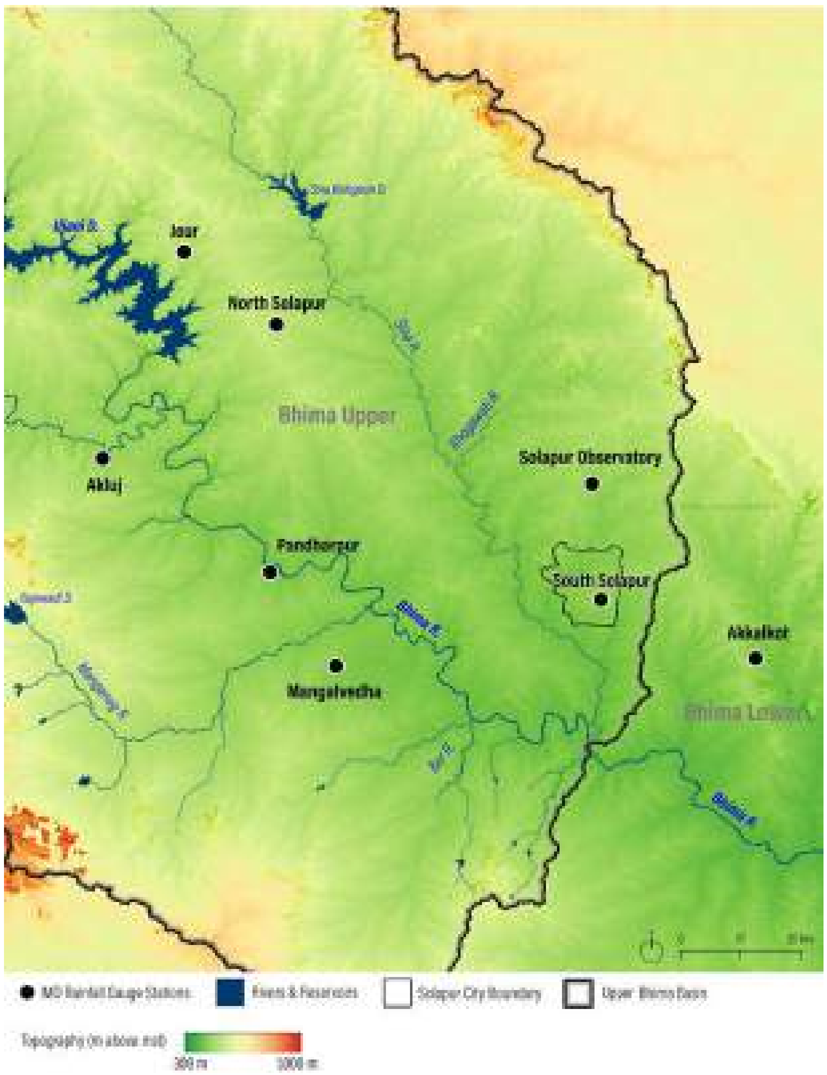
Figure 6-1: Regional setting of Solapur city located near the downstream reaches of the Upper Bhima river basin

Source: WRI India using SRTM(USGS), CWC Streams, HydroBASINS level 4, HydroLAKES

6.1.2 Assessment

The assessment of rainfall variability was based on an analysis of two parameters: extreme rainfall events and their impact on Solapur and the larger region. This analysis uses rainfall data from IMD rain gauges in and around Solapur to assess the long-term variation of rainfall patterns, including intensity, duration, and frequency. Data from one IMD station within the Solapur Municipal Corporation limit and seven IMD stations varying at 20-100 km in the region has been analysed. (Refer Figure 6-2).

Figure 6-2: Rainfall Gauge Network between Solapur and Ujani Dam (along the lower reaches of Bhima River)



Source: WRI India using IMD Station Rainfall data and SRTM topography CWC Streams, HydroRIVERS, HydroLAKES

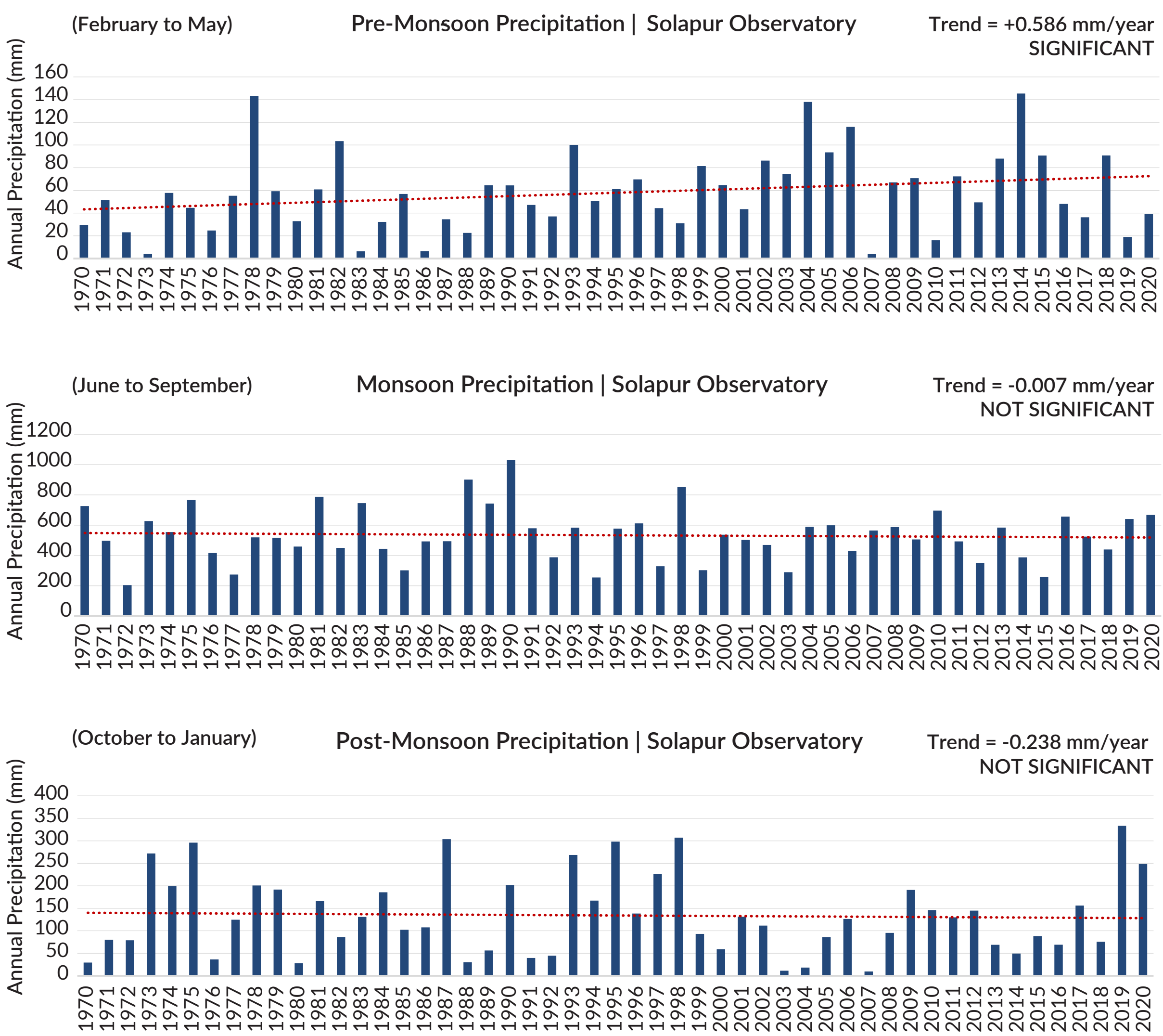
Climate trends are, in general, described as the average weather conditions of a particular place over a 30-year period. Therefore, analysis was carried out using daily rainfall data from Solapur Observatory (50 years) instead of South Solapur IMD station (22 years). The Solapur Observatory station is 23 km to the north of the South Solapur station. To note, both the stations have similar variation in daily rainfall patterns.

6.1.3 Key Findings

1. Long-term Rainfall Trends

The mean annual rainfall in Solapur is ~725 mm, indicating no significant trend. The variation of seasonal precipitation in pre-monsoon rainfall (February-May) has a significant increasing trend of 0.58 mm/year, as seen in Figure 6-3 (note that the vertical scale in each of the seasonal graphs are different).

Figure 6-3: Annual Accumulative Rainfall by seasons between 1970 and 2020, Solapur Observatory



Source: WRI India using meteorological data from IMD

2. Extreme Rainfall Events

The criteria used for classification of an extreme rainfall event (ERE) is based on the intensity of daily accumulated rainfall. Intensity is used to determine the probability of a single rainfall event that can overwhelm the drainage capability of hydraulic structures in a particular locality. IMD's classification scheme for 24-hour (daily) accumulated rainfall intensity is used to study ERE as follows — very light, light, moderate, rather heavy, very heavy, and extremely heavy rainfall events.

2(a) Frequency and Intensity of Extreme Rainfall Events

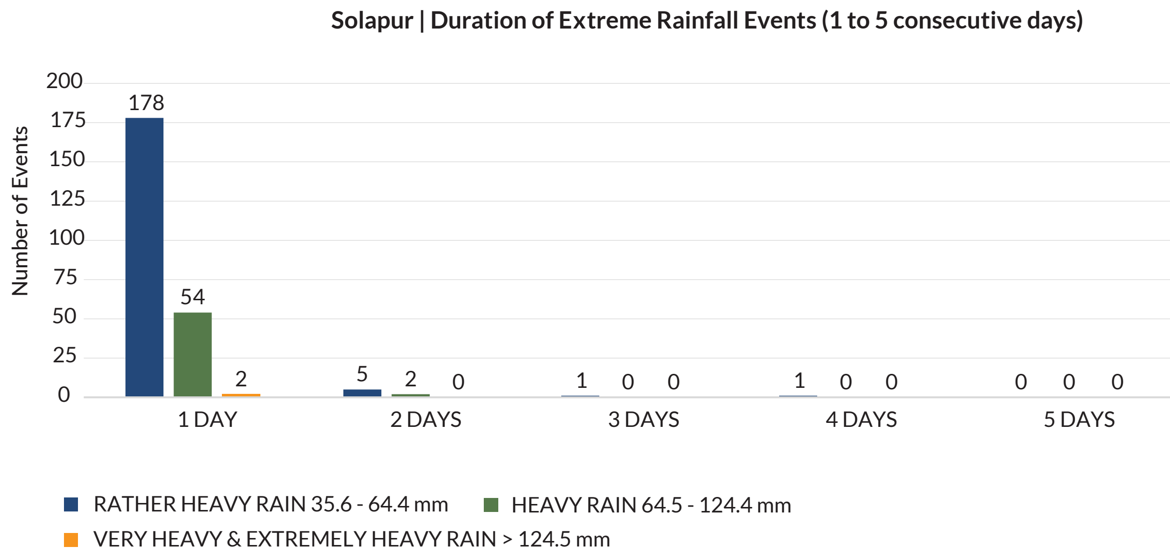
The number of EREs (rainfall more than 35 mm per day) in the last 20 years in Solapur has decreased to less than 3%. Solapur Observatory recorded 9 single extreme events of< 1% frequency of 'rather heavy rainfall' and 'heavy rainfall' in the past 51 years during the pre-monsoon months (from February to May). The frequency of rainfall is used synonymously with recurrence interval/return period. A frequency of 1% would correspond to an event with a 1-in-100 chance of being exceeded in any one year. A majority of the rainfall occurs during the monsoon months (from June to September). The number of extreme events with frequencies of 1 – 6 % during monsoon in the last two decades has decreased. The number of extreme events during post-monsoon (from October to January) has decreased and has frequencies of 1 – 3% in the last two decades (Refer to Annex 2-13).

With regard to the dependency of the city on water resources and climate change, it is important to understand the spatial variation of rainfall in the watershed where the city is located. The rainfall patterns of the three IMD stations in and around Solapur were analysed to observe the inter-annual variation of different frequencies of ERE (rainfall more than 35 mm per day) detailing the recurrence of different intensity rainfall events in the region. It is observed that the city receives light to heavy rainfall more frequently, while the frequency of very heavy and extremely heavy rainfall is less than 0.015%. The stations located along the Bhima River, such as Akluj, Pandharpur, and Mangalveda, have relatively higher frequency of very heavy and extremely heavy rainfall (Refer to Annex 2-14).

2(b) Duration of Extreme Rainfall Events

Analysis shows that the region receives rainfall that lasts for one or two days, with few to no occurrences where the rainfall continued for 3-5 days. Most ERE tend to last only a single day, as seen in Figure 6-4. 3.7% of all rather heavy ERE in the last five decades were not one-off events. Similarly, 3.5% of heavy and none of the extremely heavy ERE lasted more than a day as seen in Figure 6-4.

Figure 6-4: Duration of Extreme Rainfall Events based on Intensity and Number of Events (1970 – 2020)



Source: WRI India using meteorological data from IMD

Annex 1-7 presents details of cumulative counts of ERE reported at Solapur Observatory between 1970 and 2020 by duration i.e. how long the single event lasted.

6.2 URBAN WATERLOGGING RISK

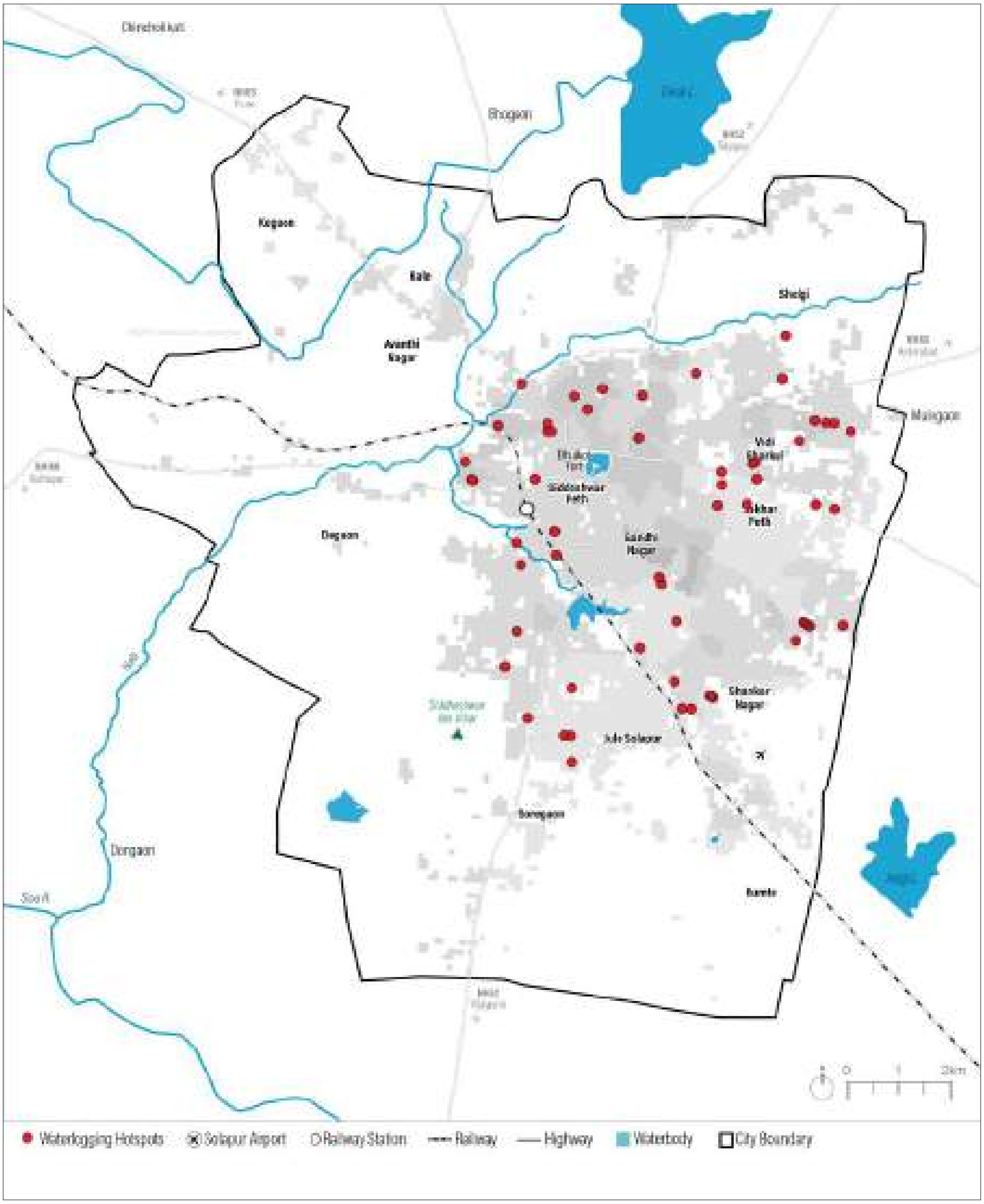
6.2.1 Waterlogging hotspots and built-up area

The waterlogging hotspots were identified manually by city officials from the Municipal Department. A total of 62 locations that were frequently waterlogged are mapped in Figure 6-5. The dense population in the urbanised area where the storm water drains and sewage network become overwhelmed even after moderate rainfall is the cause of waterlogging. The locations indicate the extent to which water logging may impact the population.

Based on the rainfall analysis, it is concluded that the probability of a flood-like situation for Solapur city is unlikely. However, during the rainy months, the city experiences waterlogging issues, the extent of which lasts for a day or two.

There are about 62 waterlogging hotspots in SMC split across the 8 zones in the city: Zone 1(10), Zone 2 (13), Zone 3 (10), Zone 4 (18), Zone 6 (7), Zone 7 (3), and Zone 8 (1)[19] . The reasons for waterlogging are mostly associated with the clogging of open and closed sewage pipelines and drainage (which have a coverage of 47.24 kms) and not excess rainfall. The number of households impacted by waterlogging issue is 1445 .

Figure 6-5: Waterlogging hotspots identified and ear-marked by officials in Solapur



Source: Solapur Municipal Corporation, WRI India

KILLA ROAD
Photo credit: Chetan Ligade

7. DROUGHT RISK

A drought occurs when it rains less than usual in one place for a long time, resulting in a decrease in the amount of water availability. As there is less water in the soil, more water is drawn from the ground and less water flows through streams. As compared with other risks, it is harder to know when a drought will start and end. Depending on the duration of water scarcity, droughts happen in this order: meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. Drought is a gradual process that occurs in stages, which are characterised by changes in precipitation, soil moisture, stream flow, and other indicators of water availability. The stages of drought typically include:

1. Meteorological drought: This is the initial stage of drought, characterised by a prolonged period of below-normal precipitation. This can lead to lower-than-normal stream flow and reservoir levels.
2. Hydrological drought: This stage occurs when the lack of precipitation leads to lower-than-normal surface and groundwater levels. This can result in reduced availability of water for various uses, such as irrigation and drinking.
3. Agricultural drought: This stage occurs when the lack of water affects the growth and yield of crops. This can lead to reduced crop production and income for farmers.
4. Socio-economic drought: This is the final stage of drought, characterised by the social and economic impacts of the previous stages. This can include food and water shortages, loss of livelihoods, and increased poverty and migration.

It is important to note that the stages can occur in succession, one leading to the next, but also that not all droughts progress through all the stages. Additionally, the time frame for each stage can vary, depending on the severity of the drought and the climate of the region. Droughts can be long-term or short-term and irregular and unpredictable. So, it is important to be prepared to face these.

7.1 ASSESSMENT

The assessment of drought risk is based on analysing the probability of drought at a sub-basin scale. This analysis is carried out by using rainfall data from IMD gridded rainfall data. First, the percentage of each grid's annual deficit for each year is worked out. There are three classifications of meteorological drought: normal (25%), moderate (26–50%), and severe (>50%). The probability of drought is obtained by finding the frequency of drought that exceeds 25% during the duration of 70 years (1951-2020) considered for the analysis. Refer to Annex 1-8.

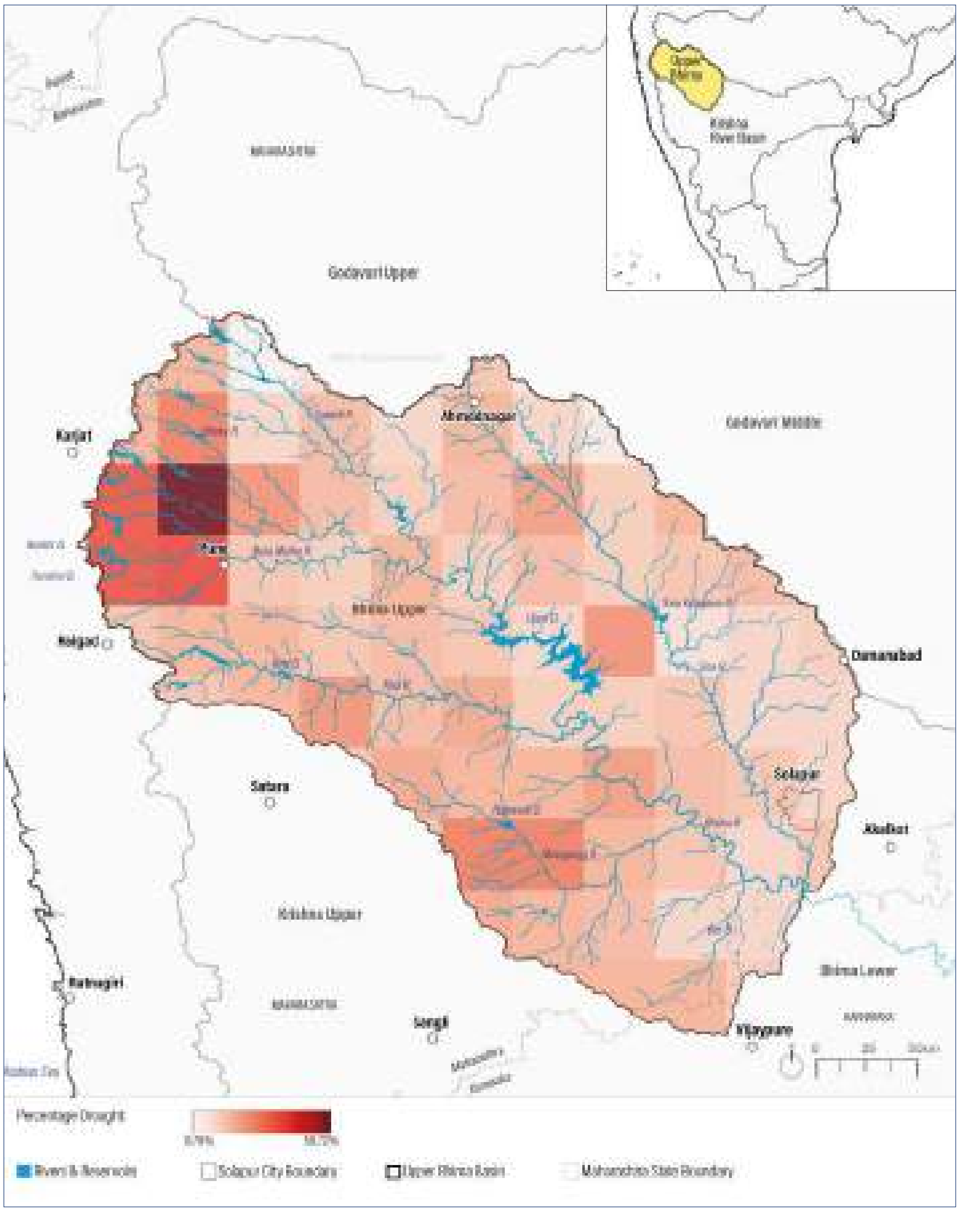
7.2 PROBABILITY OF METEOROLOGICAL DROUGHT

The probability (expressed as a percentage) of meteorological drought is calculated for each grid in the Krishna River basin's Upper-Bhima catchment.

- For the catchment, the chance of drought is between 8% and 50%.

- Solapur is located near the outlet of the Upper Bhima. The city has four IMD grids across its extent. The probability of meteorological drought is obtained by calculating the mean of the values for the four grids, which is 16.5%.
- Since the probability of drought is less than 25%, the city falls within the 'normal' condition. The region in the upper stretches of the Bhima River, near Pune is at a greater risk of meteorological drought with the grids falling within the classification of severe drought. The several reservoirs that impound water in the higher reaches of the Bhima River and feed the Ujani Dam exacerbate the risk to the city's water availability (Refer Figure 7-1).

Figure 7-1: Probability of Meteorological Drought using historical rainfall for the period 1951 - 2020



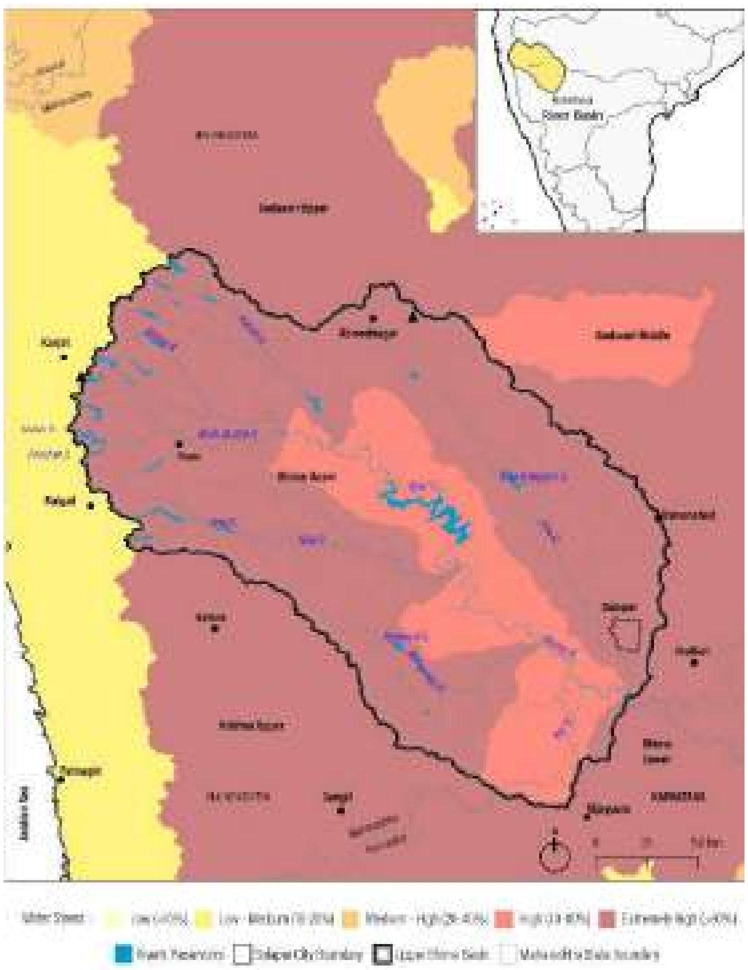
Source: WRI India using IMD Gridded Rainfall, SRTM Topography, CWC Streams, HydroBASINS and HydroLAKES

7.2.1 Water Stress

According to WRI Aqueduct, Solapur district has a high baseline water stress, which means that the district is already using or overusing a significant portion of its available water resources. Additionally, the city of Solapur has a high (40-80%) to extremely high (>80%) level of water stress, which indicates that the city is facing a significant amount of competition for its water resources from various sectors, such as agriculture, industry, and households. This can lead to a shortage of water for various uses and may also cause conflicts between different users of the water.

The state of Maharashtra, including Solapur, is facing severe drought conditions. The Upper-Bhima sub-basin, in which Solapur city is located has a high (0.8 – 1.0) drought risk. Drought risk identifies where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate a higher risk of drought (WRI Aqueduct 2019), the reasons for which can be attributed to the decrease in rainfall and over-extraction of groundwater. Drought conditions can lead to crop failures, changes in crop patterns, and loss of livelihoods for farmers, water scarcity for drinking and other

Figure 7-2: Water Stress analysis in Solapur

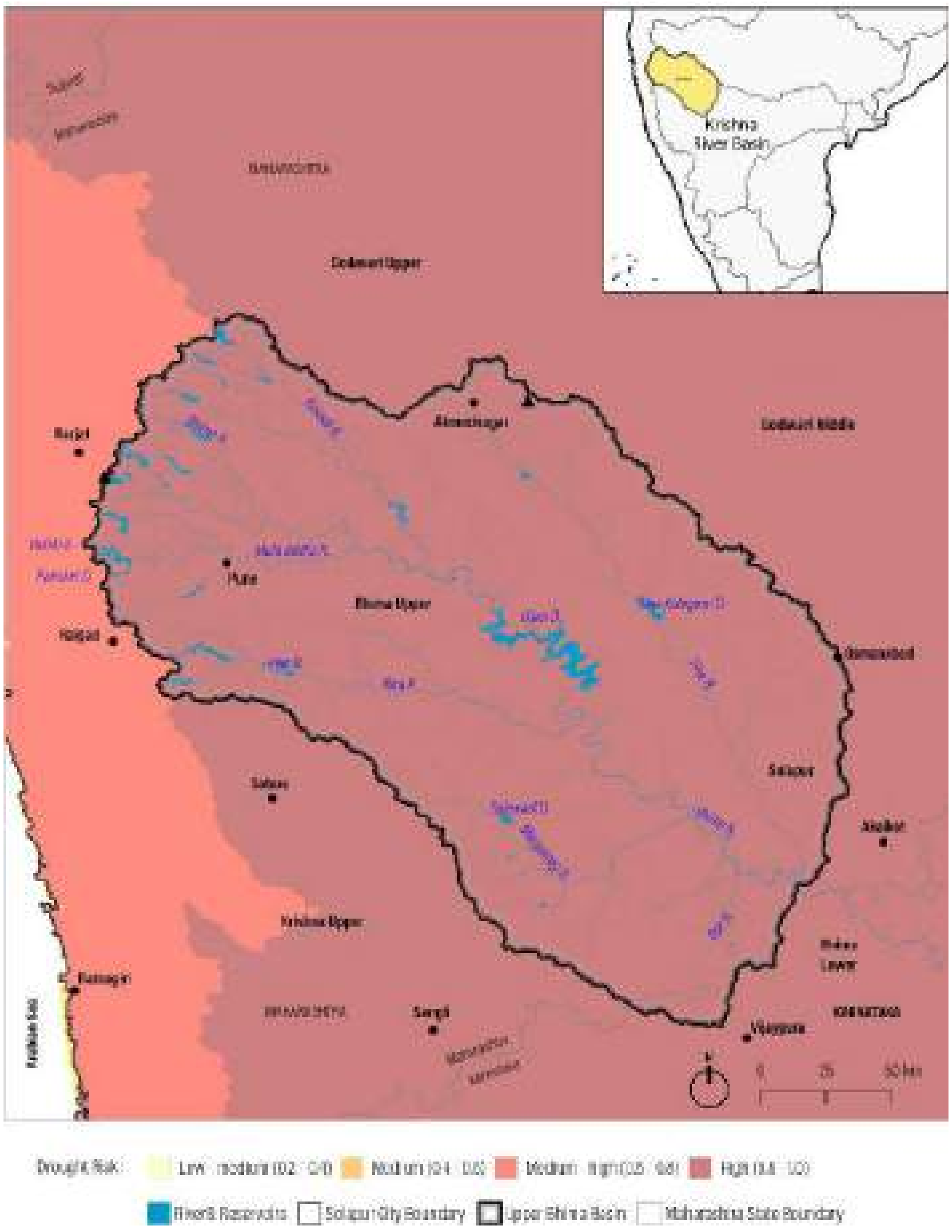


Source: WRI India using WRI Aqueduct

daily uses, as well as exacerbate poverty and food insecurity in the region.

The over-extraction of groundwater from underground aquifers leads to land subsidence. When the pumping is done at a rate that is faster than the rate of replenishment, the underground spaces that were once filled with water can collapse, causing the land above it to either sink or subside. This can lead to several problems, such as damage to buildings and infrastructure, flooding, and changes in the local hydrology. It is important for the local government and other organisations to take steps to manage groundwater resources sustainably in order to prevent or mitigate land subsidence.

Figure 7-3: **Drought Risk analysis in Solapur**



Source: WRI India using WRI Aqueduct

7.3 GROUNDWATER MANAGEMENT

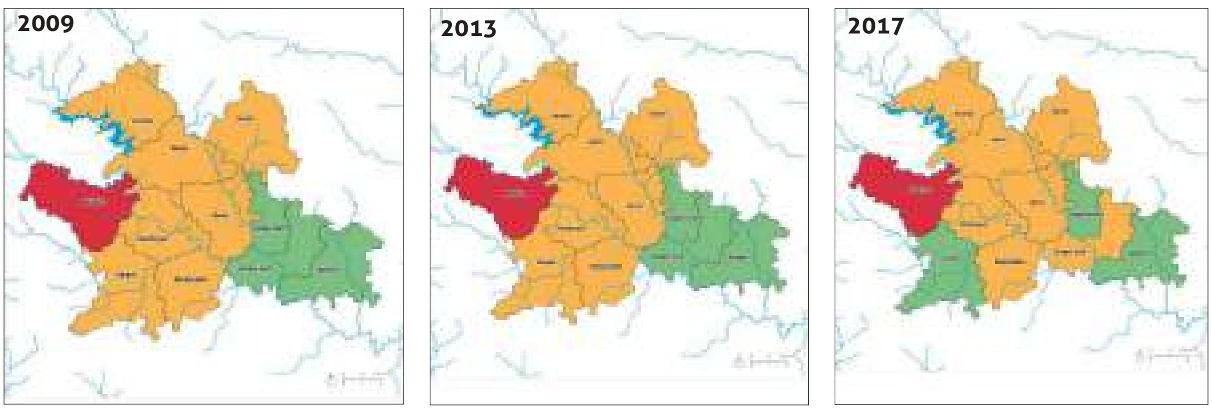
7.3.1 Stage of Groundwater Development

The stage of groundwater development is the ratio of the annual groundwater draft to the net annual groundwater availability, expressed as a percentage. Simply put, it is the ratio of the actual groundwater extraction to the permitted groundwater extraction as a percentage.
The stages of groundwater development are categorised as safe (<70%), semi-critical (70-90%), critical (90-100%), and over-exploited (>100%).

1. Variation in Stage of GW Development for Solapur District

The stages of groundwater development was obtained from various CGWB reports. The districts of Solapur exhibit a gradient, from overexploited to critical to semi-critical to safe. *Malshiras*, which lies to the west, is over-exploited while seven districts that lie in the middle are semi-critical. Solapur city, which lies in the northern part of the district, has been reported as safe (average stage of groundwater development is 65%) for the past two decades. Since it borders the district *Mohol*, which is currently semi-critical, and given stream connectivity and aquifer characteristics, there could be a possibility in the future where Solapur city would lie in the semi-critical zone. Annex 1-9 shows the variation in the stages of groundwater development for three years – 2009, 2013 and 2017. The percentages do not vary much, except for one district – Sangola – which wavers between 'semi-critical' and 'safe'. The same numbers have been represented as a map in Figure 7-4, the gradation between each of the talukas can be seen from left to right in decreasing order of concern.

Figure 7-4: Stage of Ground Water Development for Solapur District



Stage of Groundwater Development (%):
- Safe (<70%)
- Semi - Critical (70-90%)
- Critical (90-100%)
- Over-Exploited (>100%)
- Waterbody
- Solapur City
- Solapur District

Source: WRI India using data published in various CGWB reports

7.3.2 Groundwater Recharge Potential

One of the major problems faced by Solapur is that there isn't enough water. To begin with, the city is in a rain shadow region, so it receives very little rainfall. Secondly, most of the water resources available from the Ujani Dam are used for sugarcane farming, which is a water-intensive crop. Understanding the dynamics of surface water infiltration into the ground will aid in the identification of places at imminent danger of decreased groundwater availability, which could then alter the quality of groundwater in aquifers.

1. Contributing Parameters

The groundwater recharge potential (GWRP) is estimated using three parameters – average annual rainfall (using IMD gridded daily rainfall), slope of the terrain (obtained from topography/DEM), and the conditions of the vegetation, soil, and land-use (represented by NDVI). Depending on the rainfall, slope, and NDVI classification, a weighted mean is used to calculate the GWRP on a scale of 0 to 5, where 0 represents no recharge, 1 is low recharge potential, and 5 corresponds to high recharge potential. The GWRP for Solapur city was obtained for two years – 2000 and 2020. These two GWRP timestamps were compared to find the percentage change in the recharge potential at each grid (resolution of 30m).

Table 7-1: Drought Risk-Assessment Parameters and Attributes

Parameter	Vulnerability	Method Used	Data Source
Groundwater Recharge Potential	Positive Relation	Villholth et al., 2013	Indian Meteorological Department, SRTM Topography/DEM, LANDSAT 7 NDVI Composite

Table 7-2: Datasets used and its spatial and temporal details

Dataset	Description	Resolution	Reference Period
Historical Rainfall	Long-term mean annual rainfall	0.25 degree	1951 - 2020
Vegetation	Mean NDVI for two-time stamps	30 m	1999 – 2000 & 2019 – 2020
Terrain slope	SRTM DEM	30 m	2014

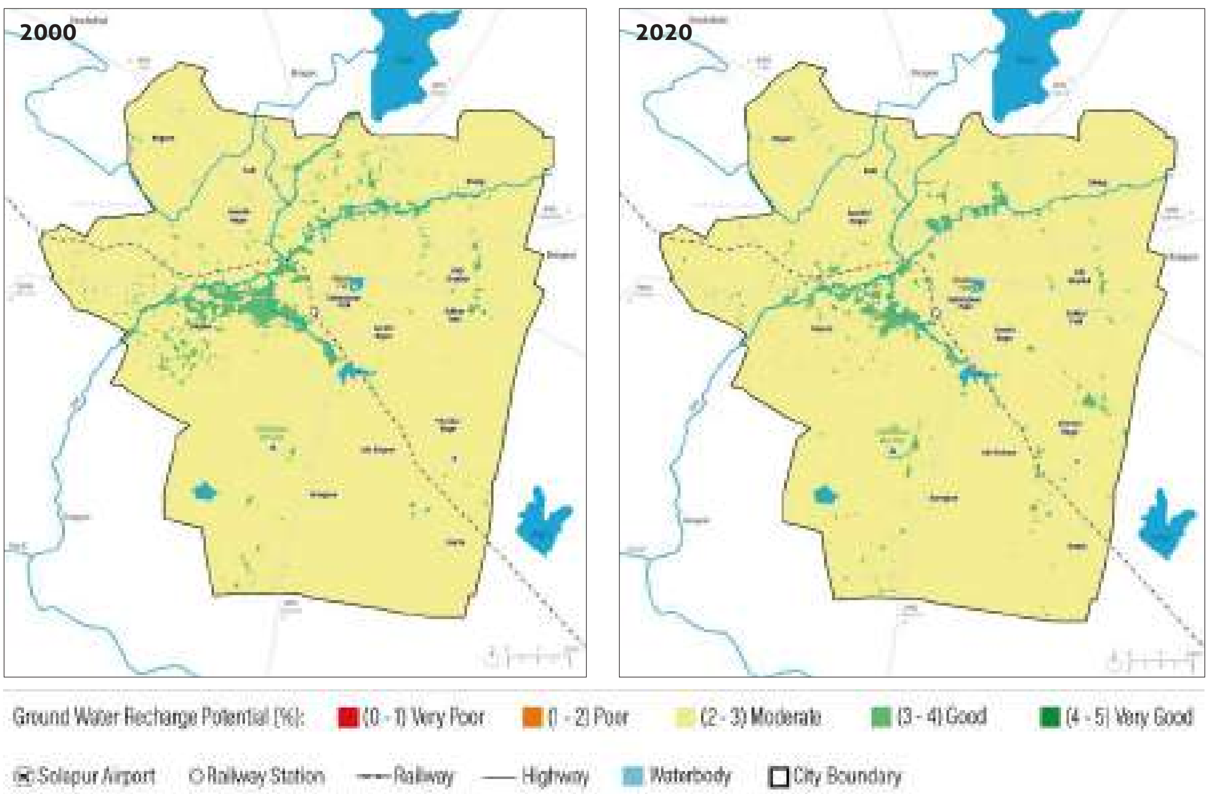
2. Groundwater Recharge Potential for years 2000 and 2020

The city exhibits a moderate GWRP throughout its limits while the recharge potential improves to good around the waterbodies. The extent of the good recharge potential has decreased in the western part of the city as many new developments have cropped up in the land that was used for agriculture in the year 2000. It can also be seen that as compared with the year 2000, the areas towards the south of the city have shown good recharge potential in 2020. This is attributed to the increase in farming activities in the periphery of the city, which, in turn, led to an increase in groundwater extraction as a source of irrigation. In certain cases, there has also been a change in cropping cycles, affecting the overall availability of water (Refer Figure 7-5).

3. Change in Groundwater Recharge Potential

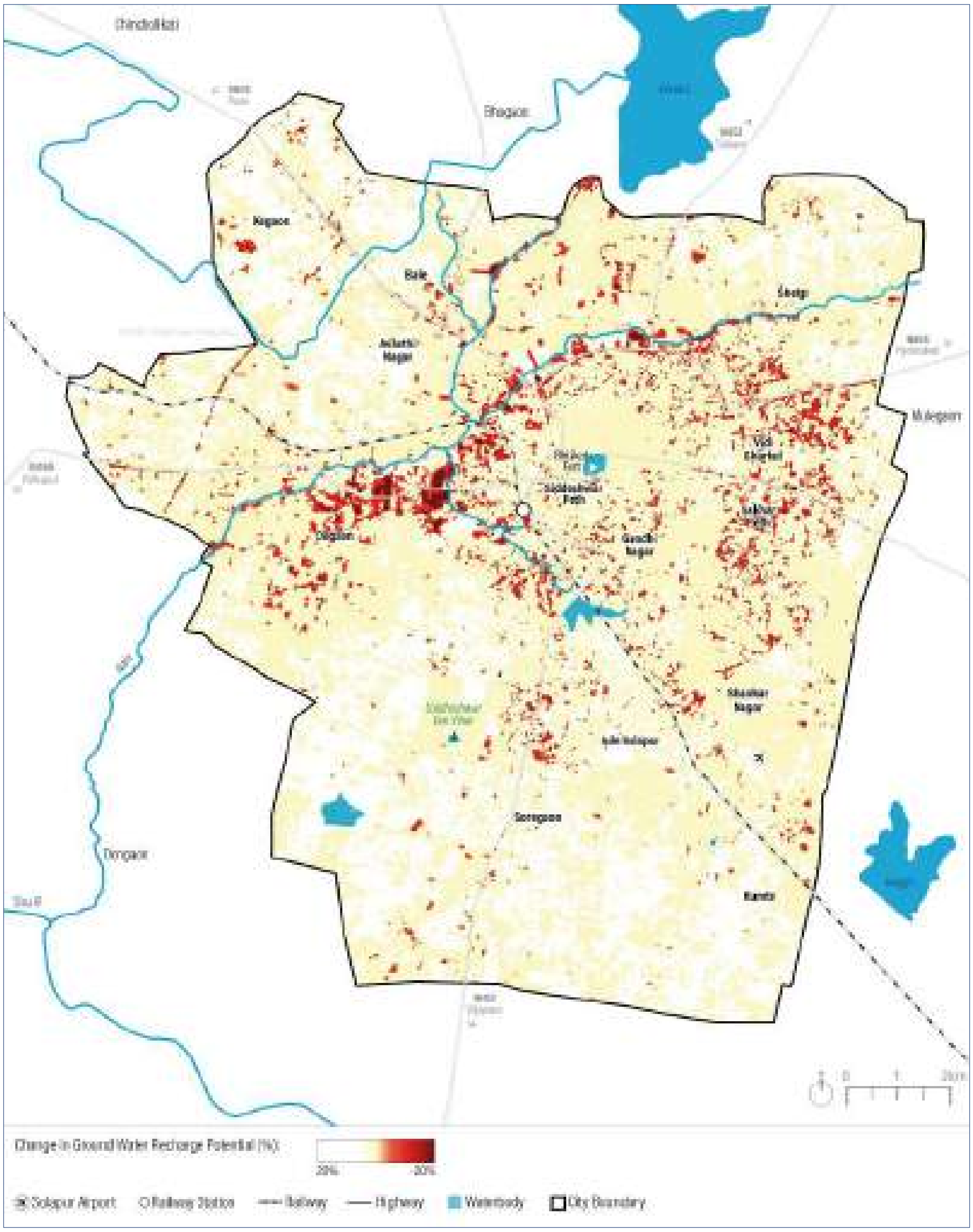
The change in GWRP is calculated as the ratio of the change between 2000 and 2020 to the conditions of the year 2000 and is expressed as a percentage. Figure 7-6 focuses on the areas that have a negative change in GWRP (shown in varying shades of red) i.e. the excess water on the ground that no longer infiltrates into the ground water table due to the impervious nature of the

Figure 7-5: Ground Water Recharge Potential for two time-periods – 2000 and 2020



Source: WRI India using IMD Gridded Rainfall, SRTM Topography, Landsat 7 8-day NDVI composite recently developed areas. Nearly 11% of the population residing in the city live in areas with decreased GWRP. Apart from the newly built areas, the agricultural land that was thriving with vegetation and is now devoid of it has also been captured as decreased GWRP. Such areas are mainly found scattered along the outskirts of the city.

Figure 7-6: **Percentage Decrease in Ground Water Recharge Potential**



Source: WRI India using IMD Gridded Rainfall, SRTM Topography, Landsat 7 8-day NDVI composite

8. MULTI-HAZARD ANALYSIS

Certain zones of the city are vulnerable to more than one climate-related risk. We have analysed using spatial and non-spatial information to identify vulnerable zones where the city authorities can isolate at-risk populations/ industries on priority so that the necessary mitigation strategies can be deployed.

Contributing parameters, such as air temperature trends, heat events, LST, concentrations of physical and chemical pollutants, long-term and extreme rainfall events, and the probability of meteorological droughts, has been included in the analysis to understand the vulnerabilities of the city.

8.1 CONTEXT

The city of Solapur and its surrounding regions are experiencing higher night-time LST along with an increasing trend of 0.1°C every year. The direct impact of groundwater depletion and LST may impact more in future as it is already impacting jobs, public transport, and the population living in the informal settlements and exposed to recurrent flooding.

8.2 METHODOLOGY

The layers listed in Table 8-1 are overlaid for multi-hazard analysis where the city's average LST is 32°C.

8.2.1 Key Findings

The analysis shows that 33.4% of Solapur's population is exposed to LST levels above 33°C. A majority of this population resides on the eastern side of the city, which is densely populated and has sparse vegetation. The areas around the major roads have also recorded LST greater than 33°C. Nearly, 10.94% of Solapur's population resides within the areas with decreased GWRP. Most of this population reside in the periphery of the city where either agricultural land is converted into new establishments or developments are On-going. The decrease in GWRP is seen mostly in the western part of the city, along the Solapur-Mangalvedha Road, although increase in LST is not observed here yet.

Approximately 3.4% of Solapur's population is vulnerable to both above average LST and decreased GWRP, a majority of which is in the eastern part of the city. A majority of the multi-hazard regions in the western section of the city lie in recently developed neighbourhoods. 19 schools

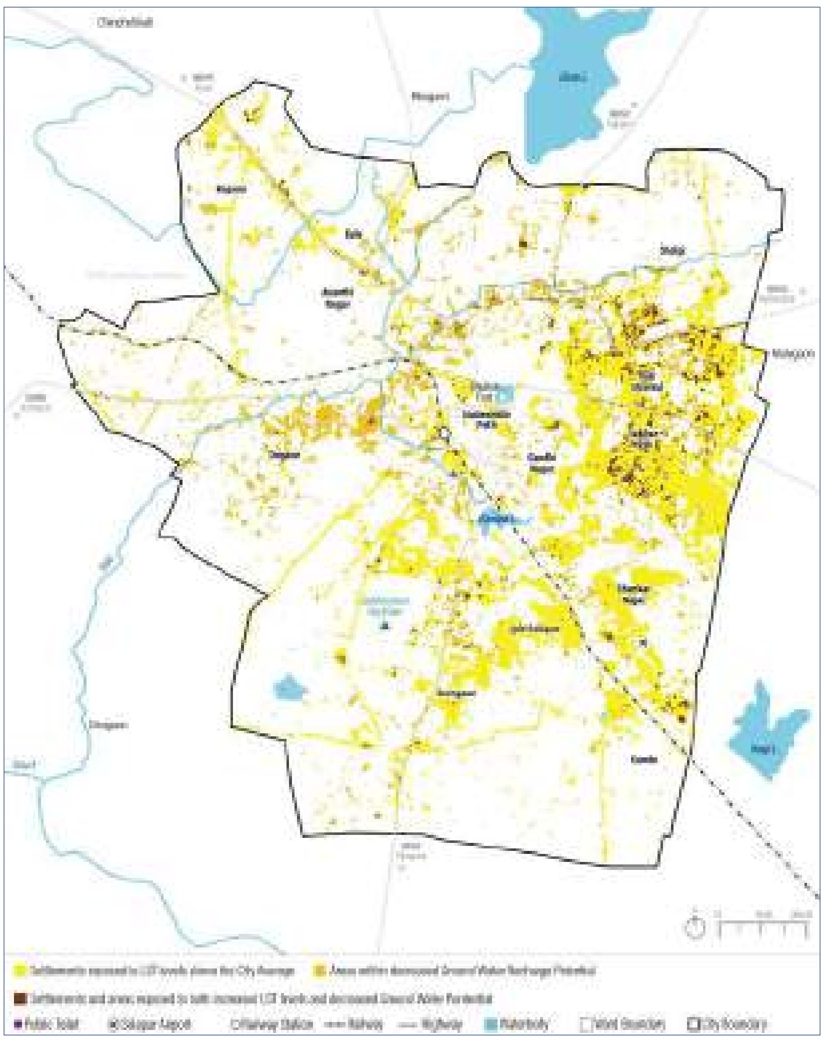
Table 8-1: Datasets used for multi-hazard analysis

Layer	Source	Method Used
Land Surface Temperature	Landsat 8 (30m)	The pixels from the population layer falling in areas exposed to LST greater than 32°C are extracted.
Ground water	p[20]	
Traffic congestion Hotspots	SMC, Environment Dept.	Hotspots listed under Solapur DP and NCAP

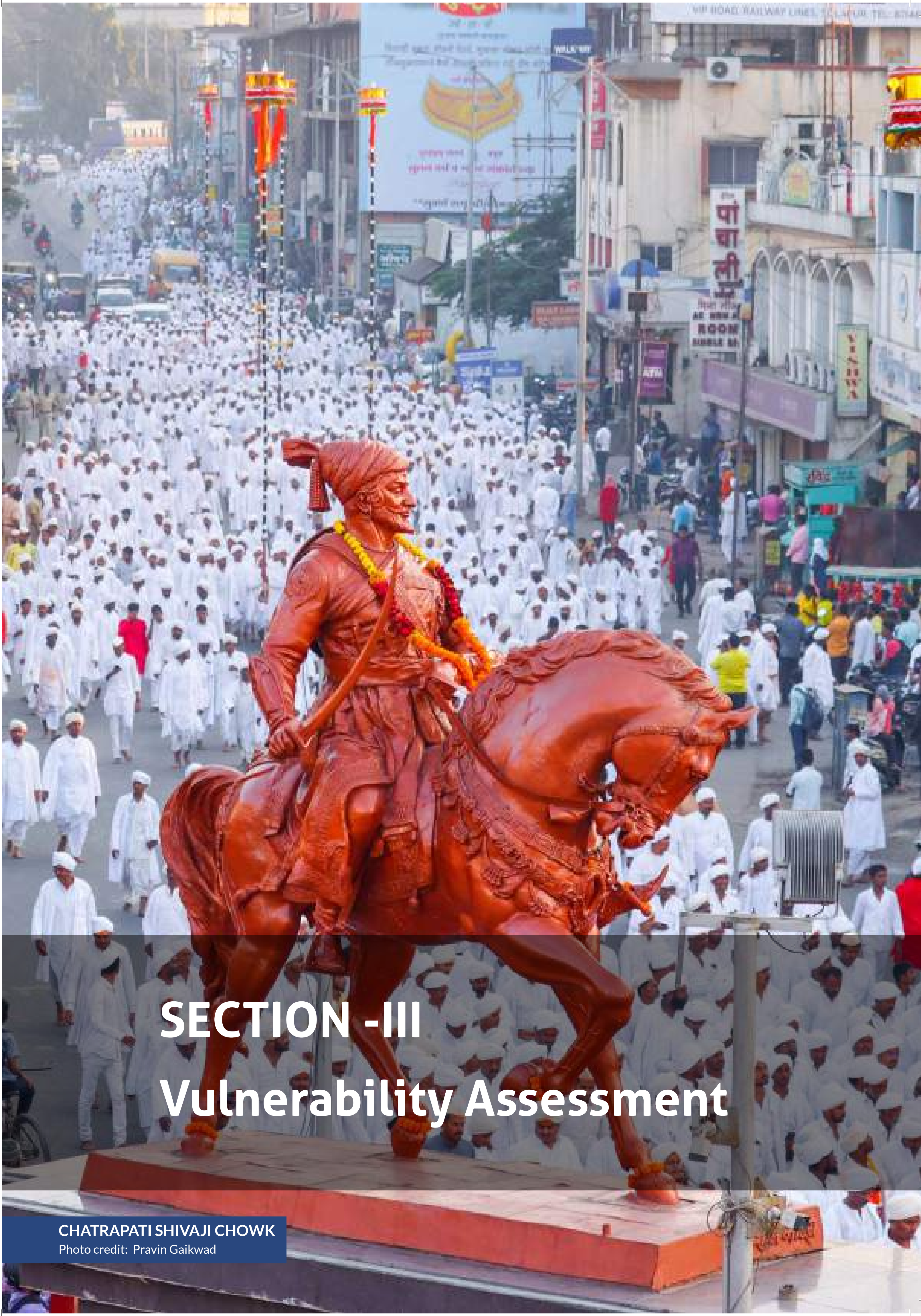
and 2 hospitals are at the risk of a combined LST and GWRP multi-hazard. The service area analysis carried out by excluding these 19 schools showed no reduction in the access of schools within 10 minutes of walkable distance. Approximately 2% of slum areas and 10.3% of industrial areas (mostly in *Sakhar Peth* and *Asha Nagar)* are prone to multi-hazards (Refer Figure 8-1).

The population that is at risk from above average LST and a decrease in GWRP is primarily dispersed throughout the densely populated region. The combined effect of greater surface temperatures and a rise in the percentage of impermeable surfaces would induce increased surface evaporation and, at the same time, a decrease in the water infiltrating to the groundwater table, which would lead to an increase in water stress. To combat the heat, there would be an increase in energy use for cooling means across all sectors, including residential and industrial, which would have the effect of raising the temperature even higher.

Figure 8-1: Multi hazard map for settlements and areas with decreased Ground Water Recharge Potential and LST above city average



Source: LST – Landsat 8 processed in GEE, Historical Rainfall – IMD; Vegetation – Landsat 7, Terrain Slope – SRTM Plus v3, Census 2011, WSF 2019; OSM; WRI India 2022



SECTION -III

Vulnerability Assessment

CHATRAPATI SHIVAJI CHOWK
Photo credit: Pravin Gaikwad

9. VULNERABILITY ASSESSMENT: DEMOGRAPHIC CONTEXT

This section presents an analysis of demographic aspects using Census of India 2011 data. Acknowledging that the data may be outdated, it is the only and most recent spatially available dataset that captures socio-economic indicators in depth. This analysis will help understand the potential effects of climate change on different socio-economic groups, the sensitivity of population and its variation, based on demographic diversity, such as age, sex, education, etc. and how it manifests spatially in the city. This will further help in identifying the priority areas for actions.

9.1 ASSESSMENT

The framework consists of a wide range of indicators related to demographic characteristics to represent complex dimensions of socio-economic vulnerability in Solapur as seen in Annex 1-11. Using Census of India 2011 population series data, from Primary Cenus Abstract[21] ward-level assessment (98 Census wards in the case of Solapur)[22] and mapping are carried out to evaluate the dynamics of literacy, gender, and social composition in the city.

Table 9-1: Key findings- Demographic context

Indicator	Vulnerability Analysis
Literacy (Refer to Annex 1-11)	The overall effective literacy rate of Solapur is 82.8% (Annex 2-3) However, the effective female literacy rate is lesser, at 75.87%. Areas near South Sadar Bazar (ward no. 68), Keshav Nagar (ward no. 69), Jawahar housing society (ward no. 70), and Nilam Sramjivi Nagar (ward no. 77) perform poorly, with an effective overall literacy rate of less than 76% along with a high population density. Keshav Nagar (ward no. 69) and Nilam Sramjivi Nagar (ward no. 77) also perform poorly in terms of effective female literacy rate, which is less than 67% (Annex 2-4).
Access to Schools (Refer Annex 1-11)	This includes all the public and private schools in the city. It was seen that 95% of population have ease of access (within 10 minutes walkable distance) to schools. Areas such as Avanthi Nagar, Kegaon towards Northwest, and Shelgi in the northeast lie beyond the ease of access (10 minutes walkable distance) (Annex 2-15). Kegaon (ward no. 1) is the most vulnerable, with only 43.92 % of the population having ease of access to schools.
Access to Municipal Schools	This includes only the municipal schools (those run by the urban local body). Approximately 82% population has ease of access (within 10 minutes walkable distance) to municipal schools. Areas such as Murarji Peth, Avanthi Nagar, Kegaon towards the northwest, Shelgi in northeast, around Siddeshwar Vanvihar, and Shankar Nagar lack ease of access (within 10 minutes walkable distance) to municipal schools (Annex 2-16). Patil Nagar (ward no. 79) has the least ease of access, with only 14.46% of the population having access to municipal schools within 10 minutes walking distance.

Indicator	Vulnerability Analysis
Gender Profile (Refer Annex 1-11)	The trend in the sex ratio of SMC shows that the average sex ratio (number of females per 1000 males) of the city has improved, from 962 in 2001 to 979 in 2011. When compared with Maharashtra, the sex ratio of Solapur is higher than the state-level ratio of 925. Kegaon (ward no.1) in the extreme north-western periphery and near the Siddeshwar Temple area (ward no. 46) in the core city are wards with less than 870 women per 1000 males (Annex 2-2).
Social Composition (Refer Annex 1-11)	Data shows that overall, the population belonging to the Scheduled Castes and Scheduled Tribes community in the city is 16.26%. Jamna Wasti (ward no. 10), parts of Mane Vasti, New Budhwar Peth (ward no. 11), Mahesh Nagar (ward no. 12), and Keshav Nagar (ward no. 69) have more than 52% of population belonging to SC and ST communities and a higher population density (Annex 2-5).

10. VULNERABILITY ASSESSMENT: ACCESSIBILITY ANALYSIS

The overall demographic context provides a background to evaluate how vulnerabilities are experienced differentially across the city depending on age, sex, education, etc. Even within a neighbourhood (having the same geographical location) or within a single household, such differential experiences exist, based on different demographic parameters. Incorporating these differences with the vulnerability assessment will further help in identifying areas that need immediate attention.

The vulnerability assessment investigates key three main aspects, namely socio-economic, physical environment and infrastructural aspects to be able to co-relate the spatial determinants of the city to pertinent climate risks, such as air pollution, heat, and waterlogging.

10.1 ASSESSMENT

The availability of various services, such as information (broadcast media and telephone), drinking water, sanitation, and electricity, at the household level using Census of India 2011 ward-level data and pedestrian access to services such as bus stops, schools, and parks and playgrounds in the city based on road network analysis have been evaluated for the accessibility indicators. Vehicular access to emergency infrastructural facilities, such as hospitals and fire stations, has been calculated using their respective standard response times. This will help to identify the specific areas that lack ease of access to these facilities and might be more vulnerable during disaster events.

For road network analysis, Census of India 2011 population has been appropriated to the recent built-up pixels (gridded population) extracted from World Settlement Footprint Evolution 2019 dataset and estimated to arrive at pixel-wise population density. It is then further divided into population having access and with lack of ease of access per 1000 sq. metres to a particular infrastructure.

In the impact section, to understand and quantify the extent of climate risk – both spatially and numerically – an overlay analysis has been done, which superimposes the spatial layers of areas with climate risks on the areas that have ease of access to different infrastructures, such as hospitals, fire station, and schools. Based on the results from Climate Risk Context Section, it is analysed that urban heat[23] poses maximum threat to the population living in Solapur over other hazards. This gives a quantifiable-spatially located figure, either by the percentage of persons or households at risk, at a city or wards level, which lack access to facilities and is also under the risk of heat stress, thus enabling evidence-based mitigation and adaptation measures.

10.2 SOCIO-ECONOMIC ASPECTS

In this section of socio-economic aspects, access to information and house ownership are included that spatializes such areas that are at risk of intensified climate disaster impact. Refer to Annex 1-12, 1-13 & 1-14)

Table 10-1: Key findings- Socio-economic aspects

Indicator	Vulnerability Analysis
Access to Information (Refer Annex 1-13)	Based on Census 2011 analysis, Kurban Hussain Nagar (ward no .72 - 40.4%) and in and around Degaon (ward no. 16 - 1.3%) have the lowest percentage of households owning mobiles and households owning landlines where the city-wide average is 61% and 6.1%, respectively. Similarly, Damini Nagar, Deshmukh Patil Wasti (ward no. 15 - 0.7%) has the lowest percentage of households owning both mobiles and landlines, which falls much below the average in Solapur city of 7.7% (Refer Annex 2-17) In the case of access to broadcast media, Keshav Nagar (ward no. 69 - 52.4%) has the least percentage of households having access to television while the average in Solapur is 71.5%. The lowest percentage is achieved in parts of Jawahar Housing Society and Moulai Chowk (ward no. 70), with only 9.8% of households owning radio/transistor, while the citywide average is 24.6%. Lastly, Sunil Nagar (ward no 35- 0.5%) has the least percentage of households having access to computers with Internet while the average in Solapur is 4.6% (Refer Annex 2-18).
Home ownership (Refer Annex 1-14)	On average, 69.8 % of Solapur's population live in houses owned by them i.e. 'own' house. Bhavani Peth (ward no. 25), parts of Joshi Galli, Raviwar Peth (ward no. 27), and parts of Bapuji Nagar (ward no. 58) have less than 56% of households living in 'own' house. The area around South Sadar Bazar (ward no. 68) and Keshav Nagar (ward no. 69) have the highest percentage of households, at more than 79%, living in 'own' house (Refer Annex 2-19). These wards also overlap with the areas of high population density in the city, with a higher concentration of slum settlements.

10.3 PHYSICAL ENVIRONMENT ASPECTS

Poor living conditions, such as dilapidated housing condition/ temporary material for roofs and limited ease of access to amenities, such as that of public green spaces is a reason for mental stress and anxiety among many, especially those who live in potentially unserviced areas and informal settlements in the city. These are covered in the physical environment aspect. The population living in these areas become more vulnerable to climatic risks because of their inability to recover from extreme events as quickly as others. The following section deals with the physical environment aspects of house condition and access to public recreational spaces.

Table 10-2: Key findings- Physical environment aspects

Indicator	Vulnerability Analysis
House Condition (Refer to Annex 1-15)	On average, 59.6% of Solapur's households live in houses with temporary roofing material. Parts of South Sadar Bazar, Keshav Nagra, Jawahar Housing Society (wards no. 68, 69, 70) and Indira Nagar (ward no. 73) have more than 71% of households with temporary roofing material, with a high population density making them more vulnerable (Refer Annex 2-20). Kurban Hussain Chowk area (ward no. 71) with 98.35% settlements being slums has 92% of households living in houses with temporary roofing materials and, at the same time, having 64.07% population at risk due to heat.

Indicator	Vulnerability Analysis
Access to Public Recreational Spaces (Refer to Annex 1-18, 1-19)	While 65.1% of Solapur's population has access to public recreational spaces within the threshold values distance of 1 km within 10 minutes walkable distance, 34.9% does not have access to any parks, gardens, playgrounds, maidans within 1km. Higher density areas in and around Sakhar Peth, Rajiv Nagar, Old Rangraj Nagar, Ashanagar, Shankar Nagar, and Dyaneshwar Peth lack ease of access to such facilities (within 10-minute walkable distance or 1 km service radius). (Refer Annex 2-21) Nilam Shramjivi Nagar (ward no. 77) and Shivganga Nagar (ward no. 92) have no population having ease of access to recreational spaces within 1km walkable distance, making them more exposed to extreme events such as extreme heat stress in spite of having a higher population density of 35 persons per 1000 sq.metres. Of these, Nilam Shramjivi Nagar (ward no. 77) has 13.27% of population with limited ease of access to public recreational spaces and, at the same time, are potentially at risk due to extreme heat (> 33°C), making it more vulnerable during extreme heat events.

10.4 INFRASTRUCTURE AND SERVICE ASPECTS

The infrastructure and service aspect section helps identify the neighbourhoods that lack access to amenities/ services at a household-level (from Census of India 2011) and that too within a standard time or distance, which enhances the quality of living, thereby making a city more resilient. Physical access to essential services is potentially compromised during a disaster event. This section essentially deals with access to essential infrastructure and how it gets impacted during extreme heat event. (Refer to Annex 1-22)

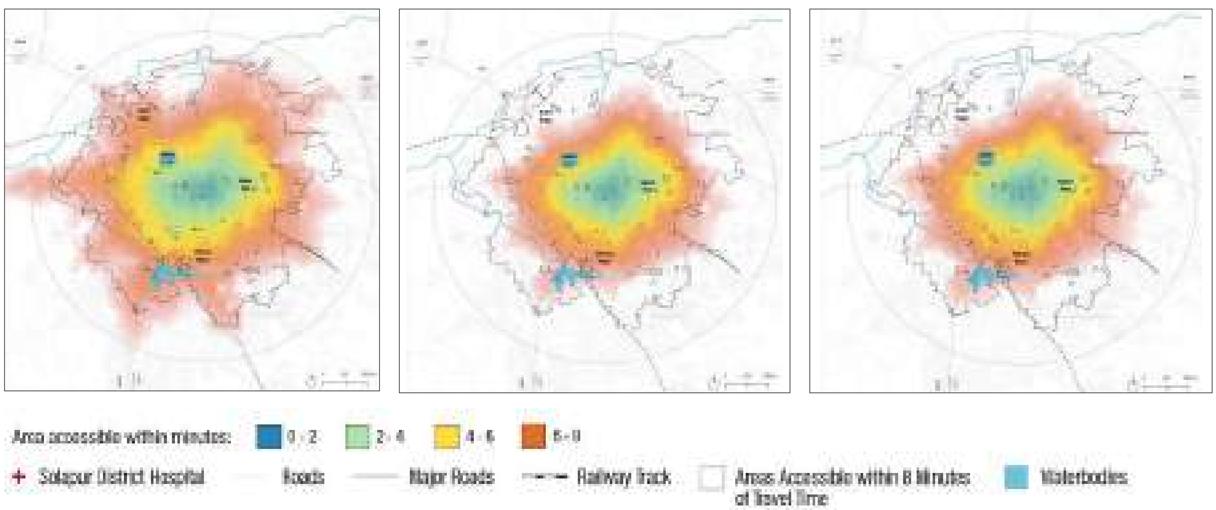
Table 10-3: Key findings- Infrastructure and Service aspects

Indicator	Vulnerability Analysis
Access to drinking water (Annex 1-21)	With regard to the source of drinking water, 8.93% of households in Solapur do not have the provision of treated drinking water (Refer Annex 2-23). Parts of Telngi Paccha Peth, Padgaji Nagar (ward no. 34) and Shanti Nagar (ward no. 79) are the most vulnerable, since more than 45% of households do not have treated water facility. (Refer Annex 2-23) Evaluating the proximity of drinking water source, 32.48% of households lack access to drinking water source inside their premises (Refer Annex 2-22). Kumta Naka (ward no. 60), Keshav Nagra, Jawahar Housing Society (ward no. 69, 70) and Mahesh Nagar (ward no.12) have more 56% households with non-availability of drinking water within premises, along with higher population density (Refer Annex 2-22). Amongst them, Padgaji Nagrar (ward no. 34) has 64.4% and 74.2% of households without access to treated drinking water and without drinking water inside premises, respectively, and, at the same time, having, 80.17% population at risk due to heat. This area has a potentially higher risk of heat stress vulnerability, which pose a serious health hazard, thereby reducing productivity and income of households.

Indicator	Vulnerability Analysis
Access to Clean Cooking fuel (Refer Annex 1-23)	Overall, 34.67% of households do not have access to clean cooking fuel. The inner-city areas of Keshav Nagra and in and around South Sadar Bazar (wards no. 68, 69, 70) and Indira Nagar (ward no. 73), with a high population density, have more than 60% households without access to clean cooking fuel (LPG/PNG, biogas, and electricity). These areas also have a higher population density and at least 30% households with household size of more than 6, making them more vulnerable to deteriorating indoor air conditions (Refer Annex 2-24).
Access to Sanitation (Refer Annex 1-24)	Assessing the proximity of latrines, it was found 35.4% of households do not have a latrine inside premises (Refer Annex 2-25). In terms of access to public toilets, approximately, 86.97% of the slum area is within 5 minutes walkable distance of public toilets while 13.21% of the area lacks ease of access to it (Refer Annex 2-26). A total of 3.44% of households have lack of access to treated sewage disposal methods (Refer Annex 2-27), while 39.11% of households dispose wastewater in an untreated manner (Refer Annex 2-28). Parts of South Sadar bazar area, Keshav nagar, and Jawahar Housing Society (wards no. 68, 69, 70, 71) have the maximum percentage of households (more than 64%) without latrine inside the premises (Refer Annex 2-25) and a high population density. 7.53% of the slums in Solapur lack ease of access to public toilets within 5 minutes walkable distance, which are mainly located in the periphery of the city (Refer Annex 2-26). Sakhar Peth (ward no. 40) and Budhwar Peth (ward no. 40) in the inner city have the maximum percentage (more than 24%) of households lacking access to treated sewage disposal methods (Refer Annex 2-27). Anand Nagar and Shivaganga Nagar (ward no. 80, 91, 92, 93) have more than 74% of households disposing wastewater in an untreated manner, along with a higher population density (Refer Annex 2-28).
Access to Electricity Grid (Refer Annex 1-25)	Overall, 6.16% of households do not have access to electricity as main source of lighting. Peripheral areas of Kumte (ward no 96) and Safalya Nagar (ward no 98) have more than 20% of households without access to electricity grid. (Refer Annex 2-29).
Access to Public Transit (Refer Annex 1-26)	Around 48.46% of Solapur's population lives within 5 minutes access radius of each bus stop in the city. Areas namely Vidi Gharkul, MIDC, Murarji Peth to the east of core city, Shankar Nagar are the higher density areas that are outside the ease of access (within 5 minutes walkable distance) (Refer Annex 2-30). Damini Nagar (ward no. 15) and Laxmi Peth (ward no. 17) having a population density of more than 20 persons per 1000 sq. metres have the least ease of access to bus stops, with no population having access to one within 5 minutes walkable distance.
Access to Emergency Healthcare Services (Refer Annex 1-29)	Approximately 97.56% of population has the ease of access (within 8 minutes response time) to hospitals. Majority of the areas have ease of access (within 8 minutes response time), except Shelgi in the northeast, along the Mangalwedha road and others (Refer Annex 2-31). The areas in and around Degaon (ward no. 16) have the least ease of access to emergency hospital services, with only 51.20% population having access to it within 8 minutes response time. It also has 33.86% of population with limited ease of access to hospitals and, at the same time, are potentially at risk due to extreme heat (> 33°C). The level of access also varies temporally throughout the day based on traffic and road conditions. Based on a sample temporal analysis[24], the area that lies within the accessible radius from which Shri Chhatrapati Shivaji Maharaj Sarvopchar Rugnalay (Solapur District Hospital) and can be reached within 8 minutes by a vehicle reduces from 10 sq. km at 3 am to 7.3 sq. km at 11.30 am and to 7.7 sq. km at 6.45 pm (Refer Figure 10-1). There is a 25% [25] reduction in terms of service area in peak hours, thereby increasing the potential risk.

Indicator	Vulnerability Analysis
Access to emergency fire services (Refer Annex 1-30)	Only 22.9% of the population has access to fire stations within five minutes of walking. Solapur has only one fire station, which is the reason why some of the high-density areas such as core city, Vidi Gharkul, and MIDC remained beyond five-minute serviceable response time. (Refer Annex 2-32). Areas of Keshav Nagra, Jawahar Housing Society (wards no. 68, 69, 70) do not have ease of access to emergency fire services, with no population that can be accessed within 5 minutes response time despite having a higher population density in the city (more than 85 persons in 1000 sq. metres). 51%[26] of wards do not have any ease of access. The Akkalkot MIDC area in the east, which can be potential source of fire hazard in the city, also remains beyond the service radius of the fire station. However, 97.62% of population living in areas in and around Sai Baba Chowk (ward no. 57) have limited ease of access to fire stations and, at the same time, are potentially at risk due to extreme heat (> 33°C). 45.16% of the slums in Solapur have limited access to fire station and are at potential heat risk.

Figure 10-1: Temporal Analysis showing Change in Serviced Area under Different Traffic Conditions during a Day



Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

11. VULNERABILITY ASSESSMENT – IMPACT ANALYSIS

11.1 IMPACT DUE TO HEAT

Solapur city experiences high temperatures and is at heat risk. The annual average LST within the city is between 25°C and 39°C. In the pre-monsoon months, the LST can reach up to 46°C within the built-up area. Some of the areas in the city are at higher heat risk than the rest of the city. These vulnerable areas are identified as the areas that have LST higher than the city heat threshold, which is considered at 33°C for Solapur. Certain zones of the city are at a higher risk, especially the overlap of urban neighbourhoods that are especially at danger from more than one climate-related threats. This analysis helps in identifying vulnerable zones where the city authorities can isolate at-risk populations/industries on priority so that the necessary mitigation strategies (optimised to fit all the hazards) are deployed by the city authorities.

11.1.1 Impact of heat on the population

Solapur has the total population of 9,51,558 (2011 Census). 33% of the total city population is at a higher risk due to heat. The top five wards (57, 28, 36, 32, 34) have more than 80% of the population that faces heat above the threshold. The population in these wards have high exposure to heat due to closer proximity to landuse types, which are higher contributors to UHI effect.

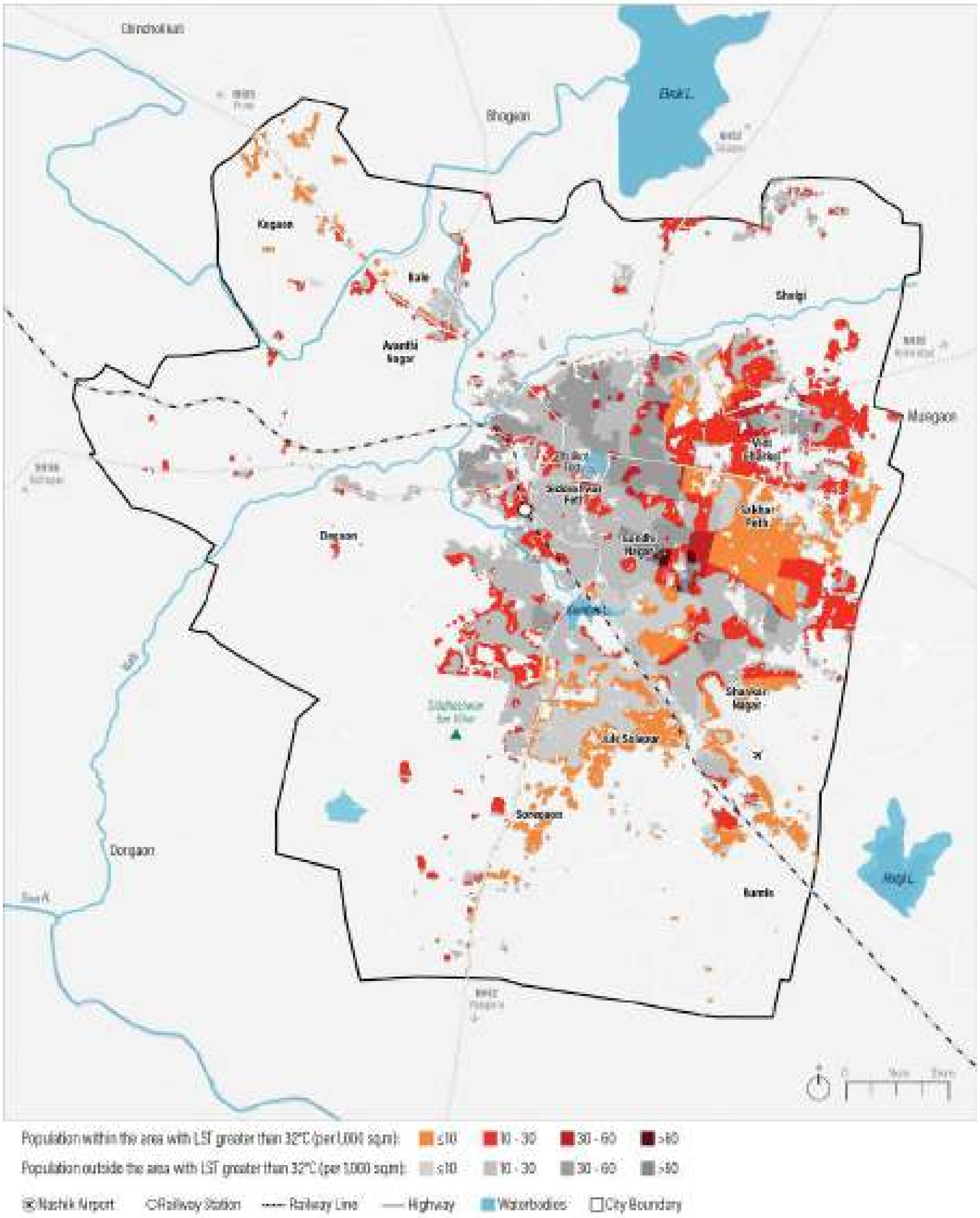
The map shows the population distribution within the vulnerable areas due to heat. Areas such as Shastri Nagar near inner ring road and Vijay Nagar are a few of the areas that are vulnerable and have a higher population density.

Table 11-1: Wards with highest heat impact in terms of percentage population

Ward no.	Population facing excessive heat (LST>=city annual avg.)	Percentage of population facing excessive heat (LST>= city annual avg.)
57	7287	97.62
28	7335	88.18
36	8914	83.62
32	13153	80.99
34	10274	80.17

Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

Figure 11-1: **Areas within the city above city annual average LST**



Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

The map shows the population distribution within the areas vulnerable to heat. Areas such as Shastri Nagar near inner ring road and Vijay Nagar are a few of the areas that are vulnerable and have a higher population density.

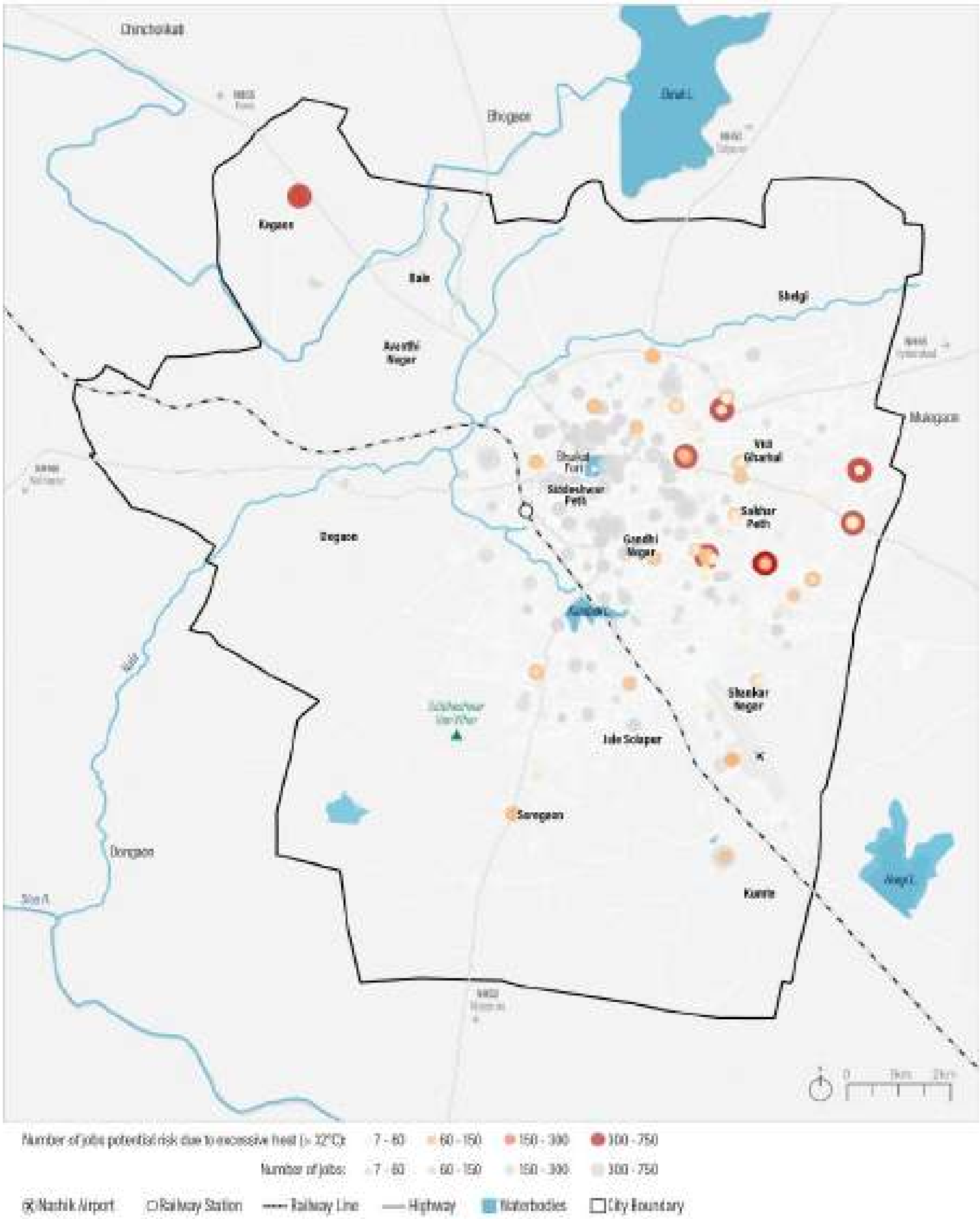
11.1.2 Impact on the Livelihood

The vulnerability due to heat can impact the livelihood of the people through heat exposure at workplace. It has been already established that the commercial and industrial areas can be hotter than the residential and other land uses. The working population in such commercial hubs are at a higher risk due to heat. To understand the opportunities available and the spatial distribution of these job opportunities within Solapur city, the Directorate of Establishments (DoE) sample Census from Economic Census 2015 was used, with the caveat that since the data for informal employment is unavailable, it was not possible to understand the risks faced by these categories of workers. However, the informal workers in the manufacturing sector are more likely to be impacted due to their employment type, working hours during the day, etc. The manufacturing category provides the maximum number of jobs within the city, which is 49.03%. 17 wards have more than 80% of jobs where the heat experienced is above the threshold. In the jobs in these wards, there is high exposure to heat, and most of the wards have high exposure to heat due to closer proximity to landuse types that are higher contributors to UHI effect.

58.1% of formal jobs within the city are at risk due to heat. 70.9% of establishments are in the manufacturing category that has 68.47% of the job share within the high heat risk area. Figure 11-2shows the areas with locations of employment and the areas that are at heat risk. Sakhar Peth is one of these highly vulnerable areas owing to commercial activities.

Vidi Gharkul area is located towards the east of the city and is has low-income housing for women workers of the *beedi* industry. These women make *beedi*s at home and deposit the daily production at the collection centres. This area is one of the high heat risk prone areas due to the unavailability of open green spaces. It experiences 39.3°C during the pre-monsoon months. Along with the heat threat, the nature of work exposes the workers and their families to tobacco dust.

Figure 11-2: Impact on jobs due to heat



Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, DoE,2015

Figure 11-3: Areas with higher UHI Case of Vidi Gharkul

11.1.3 Impact on slums

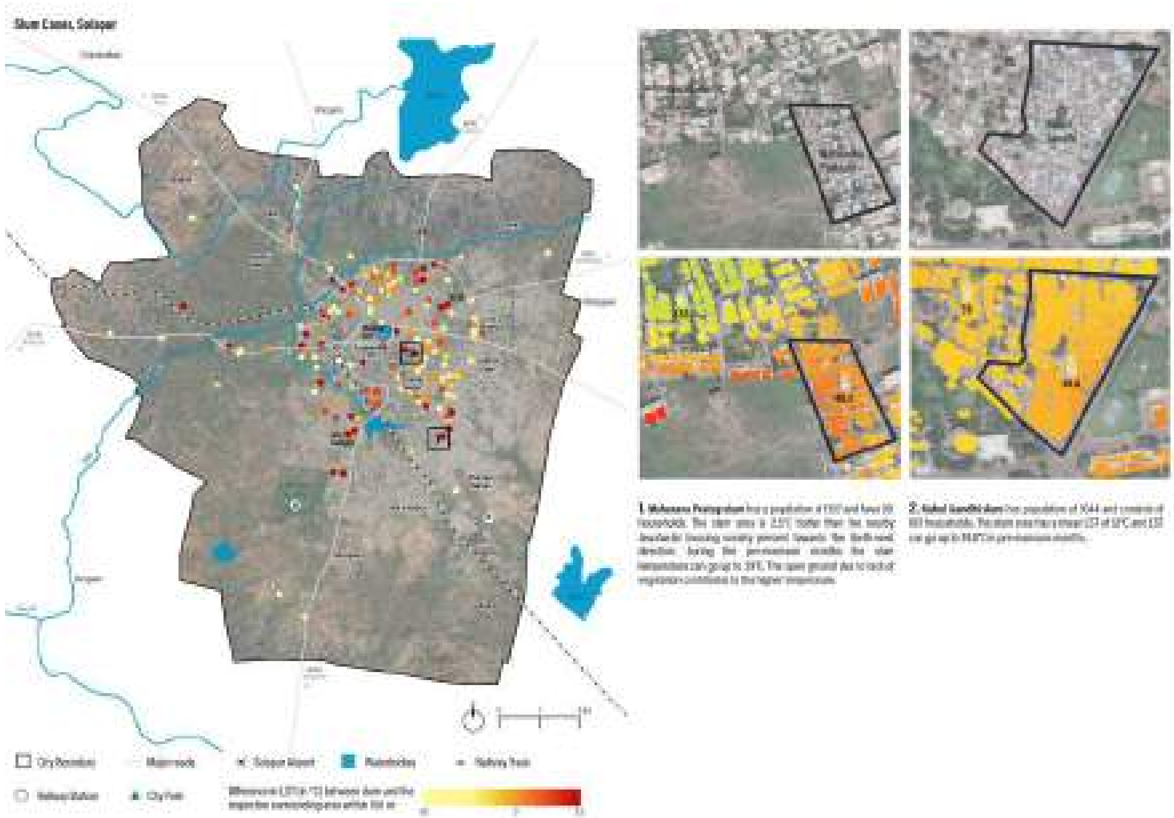
Slum areas experience higher temperatures and are more susceptible to heat. Slums are densely packed built units in which materials such as metal or asbestos sheets are used for roofing. Usually, there is very less number of trees or other vegetation in slums. These factors cause heat hotspots within the slum areas. Hence, slums usually have higher temperatures than the surroundings. Slums also usually have high population density, which increases the impact of heat within these areas.

Solapur has a total of 220 slums, out of which 159 are notified. The total slum population is 2,18,905 (Census of India 2001).

- These slums are represented by 186 polygons within the Municipal Corporation boundaries. Most of these are scattered around the city as small slum parcels, with two big clusters in the south-west and south.
- To study the impact of heat on slums, the average LST within the slum area was compared with the average LST of the surrounding area within 150m buffer.
- To calculate the average value cloud-free images available for all months from 2019 to 2021 was used . 108 of the slums appear as clear hotspots.

The average LST within these 108 slums was higher than the surrounding areas of 150 meters buffer. However, for the remaining slum pockets the avg. LST was lower than the surrounding region. This might be because the surrounding built use are Industrial or commercial which emit more heat compared to residential areas.

Figure 11-4: Impact on slums due to heat



Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019

Here is an example of Gandhinagar No. 6. Where the mean LST within the slum area appears to be around 34°C. The APMC market in the north of the slum area, shows avg. LST as high as 36°C. However, it should be noted that the LST within this slum can also reach upto 40°C during the summer months, which is still very high compared to any residential area.

Figure 11-5: Impact of built up in LST

A few slums have changed in terms of landuse over time and now consists of better housing, more open space, or vegetation.

11.1.4 Conclusion and discussion

Solapur city experiences high temperatures. This directly affects ~33% of its population and 58% of the formal job sector. It also affects the population in the slums.

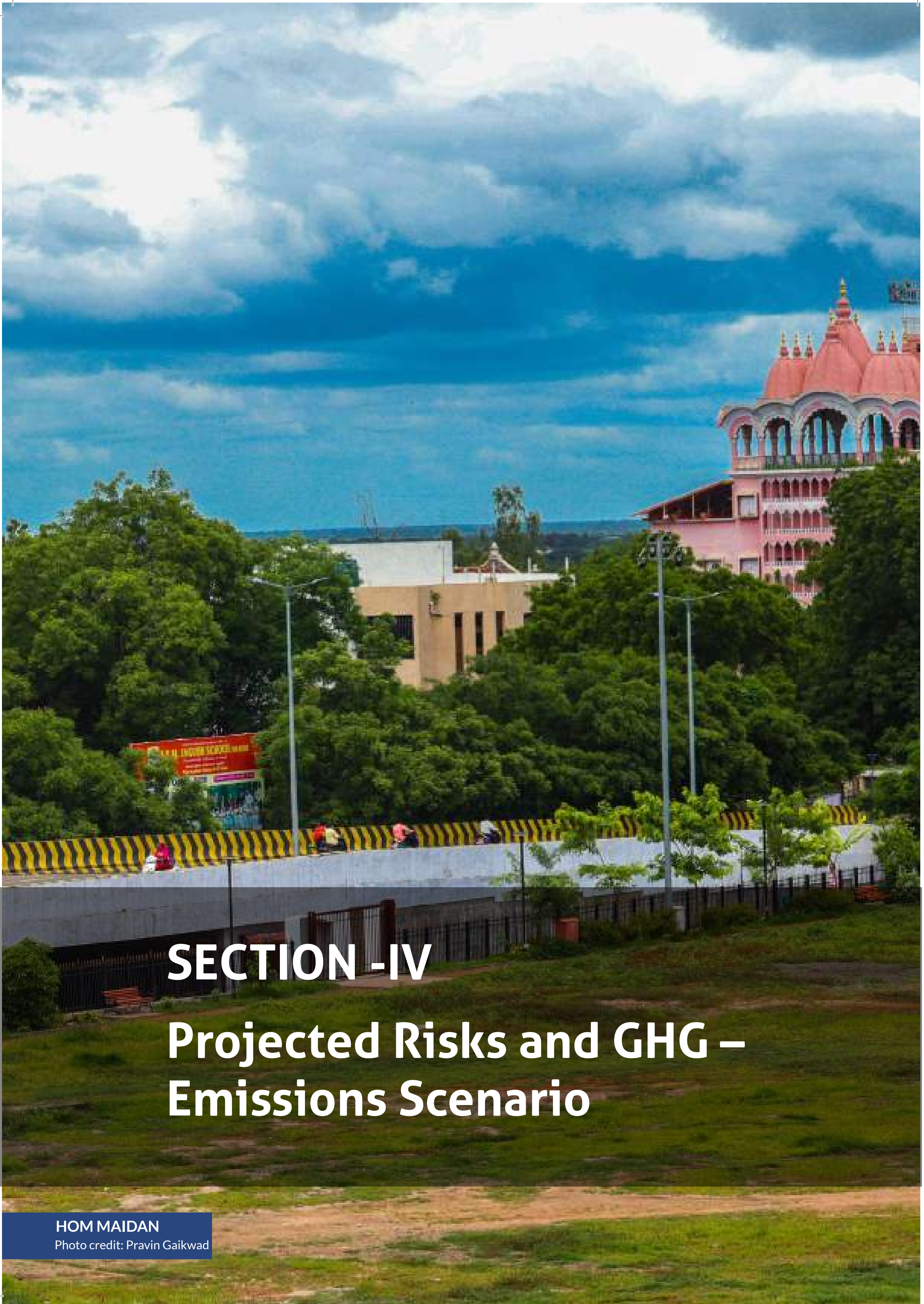
11.2 IMPACT ON SERVICES

Extreme heat stress affects the population of the city, thereby creating serious health hazards. Hence, the presence of emergency healthcare facility, especially with in-patient facilities, are of outmost importance. Although 33% of Solapur's population is impacted by heat, only 1.06% is outside the serviceable radius of 8-10 minutes drivetime distance of hospitals. However, with regard to fire services, Solapur lags behind as excessive heat can cause fire hazards, especially in closely packed neighbourhoods. There is only one operational fire station in the city, in Bhavani Peth. This means 29.14% of the population lives outside the serviceable radius of 5-7 minutes and is at heat risk, making them more vulnerable due to potential fire hazards.

In terms of informal settlements, 45.16% (83 out of 186) of informal settlements in Solapur have limited access to a fire station and face potential heat risk. However, from the perspective of accessibility to hospitals, only 12 of 83 informal settlements have limited ease of access to them. Amongst these, seven are in the inner city, such as Joshi Gali wasti, Madhukar Ulap wasti, and Bhagwan Nagar wasti.

Table 11-2: Summary of Service Indicators

Indicator	Population having access on a normal day	Unserviced Population also exposed due to risk of heat
Access to emergency healthcare facility	97.56%	1.03%
Access to emergency fire services	22.93%	29.14%
Access to public recreational spaces	65.10%	18.11%
Access to All Schools	94.73%	2.36
Access to Municipal Schools	81.69%	8.51%



SECTION -IV

Projected Risks and GHG – Emissions Scenario

HOM MAIDAN
Photo credit: Pravin Gaikwad

12. PROJECTED CLIMATE SCENARIOS

There is a distinct difference between a projected trend and the observed variability. In climate sciences, these projections are in general fit for informing the long-term mitigation plans while the temporally and spatially nuanced observed variability amongst the decadal, inter-annual, and seasonal variations are of the biggest need for adaptation savvy decisions. This chapter details the projected climate change scenarios, their implications, and the observed variations in the climate and environmental characteristics.

12.1 TAKEAWAYS FROM MSAAPC AND SOLAPUR GHG INVENTORY

To ensure a sustainable development pathway, the Maharashtra State Adaptation Action Plan on Climate Change[27] (MSAAPCC) outlines sector-specific adaptation recommendations and the concerned departments. The city would have to implement and enhance these recommendations in various sectors, such as agriculture, water resources, ecosystems, and health, to safeguard the city against any potential climate hazards. Enhancing the resilience of farming systems, groundwater recharge, and water-use efficiency are a few suggestions that would help build a climate-resilient future for the city and, in turn, for the state.

12.2 SCOPE OF ANALYSIS

1. **Analytical**

The current assessment studies the minimum and maximum temperatures and precipitation changes for two climate scenarios[28] – RCP 4.5 and RCP 6[29]– up to the year 2100 with intervals of short-term (the period 2023-2050) and long-term (the period 2071-2100) to align with targeted strategies under Solapur CAP. Each scenario plots a different emissions trajectory (called pathways) and the resultant cumulative CO_2 equivalent emissions concentration by the year 2100. The goal of working with scenarios is not to predict the future but to better understand uncertainties and alternative futures to consider the robustness of different decisions or options under a wide range of possible futures (IPCC, 2014).

2. **Geographical**

Solapur lies at an elevation of 457 metres above sea level, within the Upper Bhima sub-basin, as a part of the longest tributary to the Krishna River. The city fulfils its water demands from the Ujjani Dam lying 100 km west of the city. The land around the city and in its immediate vicinity is relatively flat . The city continues to face the risk of water availability. Hence, projections for temperature and precipitation change are analysed at a regional scale (refer to the sub-basin map in Figure 6-1).

12.3 ASSESSMENT

The historical baseline temperature and precipitation averages (considering the years 2006-2022) is estimated using the modelled data for RCP 4.5 and 6, respectively. The historical baseline averages are compared with the projected scenarios of both RCP 4.5 and 6, respectively, for the climatic parameters of precipitation and minimum and maximum air temperatures. Variations from the historical baseline are recorded and presented in the following sections for the three sub-domains of the study region that includes the Solapur Municipal Corporation (SMC) limits, the upstream watershed area of Ujani Dam, and the rest of the upper Bhima basin for the short term (2023-2050) and long-term (2071-2100) periods.

12.4 CONTRIBUTING PARAMETERS

Table 12-1: RCP scenarios: methods and sources used for analysis

Parameter	Method used	Data Source
Minimum Temperature	*For RCP 4.5:* Temporal Variations in minimum air temperature from the baseline (Magnitude of change based on 21 models[30])	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) for RCP 4.5 CMIP5 daily data for RCP 6
	For RCP 6: Temporal Variations in minimum air temperature from the baseline (Magnitude of change based on 13 models[31])	
Maximum Temperature	*For RCP 4.5:* Temporal Variations in maximum air temperature from the baseline (Magnitude of change based on 21 models[32])	
	For RCP 6: Temporal Variations in maximum air temperature from the baseline (Magnitude of change based on 13 models[33])	
Precipitation	*For RCP 4.5:* Temporal Variations in precipitation from the baseline (Magnitude of change based on 21 models[34]); including Spatio-temporal variations' examples using selected GCMs.	
	For RCP 6: Temporal Variations in precipitation from the baseline (Magnitude of change based on 13 models[35]);	

12.4.1 Baseline estimation

Temperature: As per NCEI data, minimum and maximum air temperature for SMC limits between the year 2006 and 2022, average at 23 to 34°C (Refer to Chapter 4, Section II for further detail). The NEX GDDP data estimates Upstream to Ujjani and rest of the upper Bhima basin nearly at 19-33°C for their minimum-maximum air temperature.

Precipitation: As per IMD, Solapur South station within SMC is said to receive 580 mm rainfall per year on an average between the period of 2006-2022 (Refer to Chapter 6, Section II for further detail). The NEX GDDP data estimates Upstream to Ujjani and rest of the upper Bhima basin to have received 59M and 22M annual accumulative rainfall aggregated for the respective study domains between the period of 2006-2022.

Upstream receives nearly 37% of the sub-basin's overall annual rainfall thereby supplying SMC and neighbouring region with their water needs.

12.5 KEY FINDINGS FOR PROJECTED SCENARIOS

12.5.1 Minimum Air Temperature

Minimum air temperature is a concept associated with the night-time, early in the day or winter season temperature. It is a critical parameter for the physical and psychological health of humans. A dramatic rise in minimum air temperature can also be deadly for plants and the functioning of the overall ecosystem. An increase in seasonal temperature post-monsoon affects thermal comfort during winters and worsens thermal endurance during summers.

Rising minimum air temperature trends are directly proportional to energy demand, further fueling the climate change woes if dependency on fossil-fuel consumption is not regulated. For a tier-2 city like Solapur, with a significant share of the industrial economy, this can also lead to a hike in water demand. Both RCP 4.5 and RCP 6 simulations, predominantly, project an increasing minimum temperature trend across the study region. Scenario-wise details are as follow:

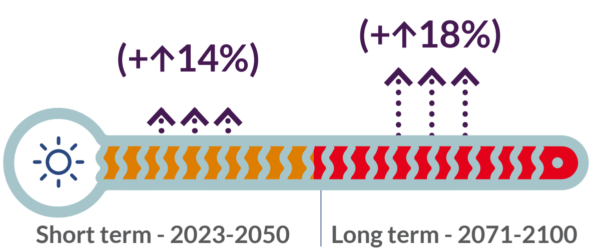
1. RCP 4.5

The 'intermediate scenario' shows the average temperature rise by +↑14% for the short-term epoch and +↑18% for the long-term epoch in the Upstream to Ujani Dam study domain. Solapur, being in a dry (arid and semi-arid) climate zone (Köppen, 2011) may continue to face the brunt of heat with warmer nights heightening Urban Heat Island effect. The energy and water demand in the region may also grow as the temperature is observed to increase at a similar for the upstream catchment and the rest of the sub-basin.

2. RCP 6

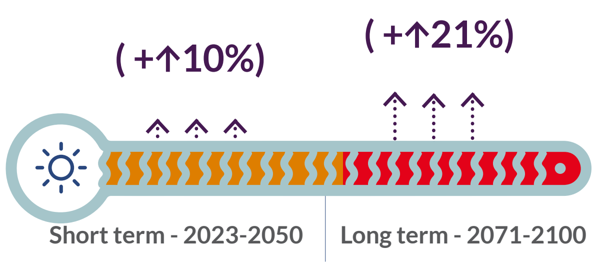
The 'high greenhouse gas emission scenario' is projected to soar as high as +↑10% for the short-term epoch and +↑21% for the long-term epoch for upstream to Ujani dam study domain. The plausible trend of a comparably hotter region (outside of the city) is very likely the result of

Minimum Air Temperature- RCP 4.5



Upstream to Ujani Dam

Minimum Air Temperature- RCP 6



Upstream to Ujani Dam

the continued rise in temperatures altering the precipitation, soil moisture, and vegetation patterns throughout the study area along with the perceived economic development in the region.

Most models project the precipitation in the upstream area of the Bhima Upper sub-basin to decrease.

Table 12-2: **Range of temporal variations observed in Minimum Air Temperature based on RCP 4.5 and 6 across the study area and domains between 2023-2100**

Study domain	Short-term *(2023-2050)*		Long-term *(2071-2100)*		78-year long period *(2023-2100)*		Projected Average		
	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Short-term	Long-term	78-year long period *(2023-2100)*
RCP 4.5									
Bhima Upper	3%	14%	2%	17%	3%	17%	3%	8%	6%
Upstream to Ujani Dam	3%	14%	2%	18%	3%	18%	3%	8%	6%
SMC	3%	13%	1%	15%	3%	15%	3%	7%	5%
RCP 6									
Bhima Upper	4%	10%	0%	20%	4%	20%	2%	6%	4%
Upstream to Ujani Dam	3%	10%	1%	21%	3%	21%	1%	6%	4%
SMC	5%	13%	0%	21%	5%	21%	2%	7%	4%

12.5.2 Maximum Air Temperature

Maximum air temperature is applicable for the relatively active part of the day, especially increasing the heat risk for outdoor workers. A fatal maximum temperature above 35°C (Sherwood & Huber, 2010) within SMC is observed for three months (March-May) every year on average, as per the NCEI data. Resonating with MSAPCC, for both RCP 4.5 and 6, most models project the high likelihood of a rise in temperature by 2°C **(~+↑7%)** to 4°C **(+↑13%)** for the city. This rise, as accounted for in the state action plan, can lead to prolonged heat waves, especially a hike in the extreme heat wave days and very strong to extreme heat stress (TERI, 2014).

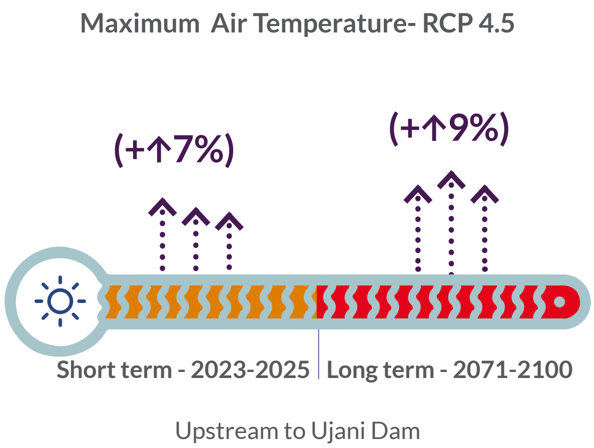
Unbearable heat succession can temper the community-economy-environment nexus, pushing people to migrate from the unbearably hot environment, leading to an increase in socio-political, cultural, and financial vulnerabilities. In continuation of the impact of rise in minimum air temperature, maximum air temperature increase can additionally lead to intense and frequent forest/ bush fires in the region, which can also hamper the air and water quality. Scenario-wise maximum air temperature changes are as follows:

1. RCP 4.5

For the short-term epoch, all the study extents which are Bhima Upper, Upstream to Ujani Dam and SMC limits project a maximum increase of +↑7%. While for Upstream to Ujani Dam, the maximum air temperature is projected to rise at most by +↑9% during the long-term epoch.

2. RCP 6

Most of the model's projects accelerated increase by +↑13% in the maximum air temperature for SMC in both the studied epochs. The upstream to Ujani Dam region projects the increase varying between +↑8% to +↑12% in the short and long terms respectively.



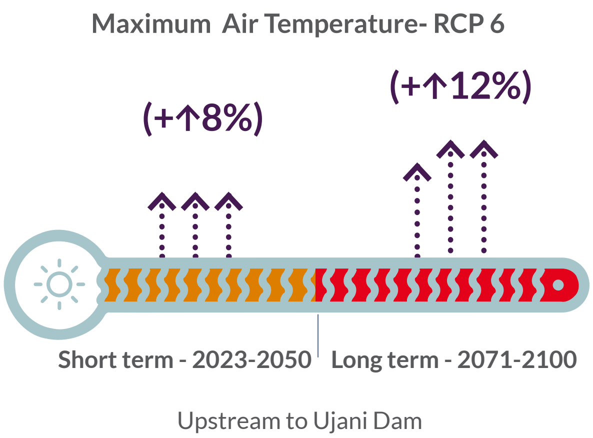


Table 12-3: Range of temporal variations observed in Maximum Air Temperature based on RCP 4.5 and 6 across the study area and domains during 2023-2100

Study domain	Short-term *(2023-2050)*		Long-term *(2071-2100)*		78-year long period *(2023-2100)*		Projected Average		
	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Short-term	Long-term	81-year long period *(2020-2100)*
RCP 4.5									
Bhima Upper	3%	7%	0%	9%	3%	9%	2%	4%	3%
Upstream to Ujani Dam	3%	7%	0%	9%	3%	9%	2%	4%	3%
SMC	4%	7%	1%	11%	4%	11%	2%	4%	3%
RCP 6									
Bhima Upper	6%	10%	2%	11%	6%	11%	1%	4%	2%
Upstream to Ujani Dam	5%	8%	2%	12%	6%	12%	1%	4%	2%
SMC	7%	13%	3%	11%	7%	13%	2%	4%	3%

12.5.3 Precipitation

Rainfall is an increasingly important subject and continues to be a major regional and micro-climatic factor for cities. Being vulnerable to rainfall extremes, cities witness floods and droughts, and are at the intersection of various socio-economic vulnerabilities induced by rainfall variations. As per the meteorological drought probability estimated between the years 1951 and 2021 (refer to Section 2, Chapter 7 for further details), the region reports having a drought probability of 23%. A decrease in rainfall can impact air quality, sanitation and hygiene, and food and nutrition sectors. It can also lead to public health concerns in the long term.

The range of projected temporal variations in precipitation has been consolidated for the 78-year analysis period. The spatial representation of four selected models[36] as per RCP 4.5 show the variations within the outputs of each model with respect to the baseline for short-term and long-term epochs.

Precipitation is a highly local phenomenon that is dependent on a range of atmospheric and anthropogenic activities. Both scenarios showcase no significant consensus among the range of models used for the precipitation changes. Scenario-wise projected changes in precipitation are detailed as follow:

1. RCP 4.5

Across the study areas Bhima Upper, upstream to Ujani dam and SMC limit for entire 78 years study period, the average change in precipitation is between +↑11-14% that indicates lack of consensus amongst the models. Most models continue to project an erratic increase and decrease for the precipitation with a decrease as high as -↓92% and an increase of nearly +↑203% for SMC over the 78-year-long period.

A similar pattern is observed for the upstream catchment area and the rest of the Bhima Basin with a decrease at most by -↓85% and -↓87% and an increase at most by +↑223% and +↑254%, respectively for both the study domains.

2. RCP 6

Across the study area, for entire study period, the average change in precipitation is between +↑5-9% that indicates lack of consensus amongst the models. SMC is projected to have the highest increase amongst the study areas by more than +↑438% in this scenario for the short-term period while the decrease for SMC is -↓78% for the long-term.

For the other study domains, Bhima Upper and Upstream catchment to Ujani, respectively, in the 78 year long period, a similar pattern for decrease and increase is observed: -↓81% and -↓86% decrease and +↑362% and +↑317% increase projecting both drought and flood years occurrences in the region.

78 year long period (2023 – 2100) SMC limits

Short term - 2023-2050 | Long term - 2071-2100

SMC limits

Table 12-4: Range of temporal variations observed in Annual Accumulative Precipitation based on RCP 4.5 and 6 across the study area and domains between 2023 - 2100

Study domain	Short-term *(2020-2050)*		Long-term *(2071-2100)*		78-year long period *(2023-2050)*		Projected Average		
	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Short-term	Long-term	**81-year long period *(2020-2100)***
RCP 4.5									
Bhima Upper	87%	174%	75%	223%	87%	223%	6%	19%	12%
Upstream to Ujani Dam	85%	196%	76%	254%	85%	254%	5%	18%	11%
SMC	90%	157%	92%	203%	92%	203%	7%	21%	14%
RCP 6									
Bhima Upper	66%	362%	76%	243%	81%	362%	0%	12%	7%
Upstream to Ujani Dam	69%	317%	76%	294%	86%	317%	2%	13%	9%
SMC	63%	438%	78%	276%	78%	438%	-2%	11%	5%

12.6 CONCLUSION

Most of the models are observed to have consensus in terms of air temperature and precipitation in the RCP 4.5 scenario, indicating proof of rising air temperature and alternate drought and flood pattern in precipitation changes. This would impact the energy and water demands of the city, which could give rise to higher emissions in this scenario. Additionally, it could also give rise to adverse impact on crops that are sensitive to high night temperatures in the reproductive phase, such as grain growth in rice or tuberization in potatoes (TERI, 2014). The differences in the short-term and long-term precipitation changes in RCP 4.5 across the studied regions indicate erratic patterns in rainfall changes, as also observed in the MSAAPC report.

RCP 6 also notes a rise in air temperature, which could lead to serious health hazards and extreme meteorological risks. RCP 6 doesn't provide high confidence results in case of precipitation, which could give rise to the potential precipitation related hazards, such as overwhelming the city's stormwater, medical and emergency infrastructure and resulting in persistent waterlogging and flooding issues in the case of a lack of commitment to preparedness. Moreover, the erratic nature observed in rainfall could impact the agricultural produce as excess rainfall gives rise to fungal diseases, weeds, and pests, worsening the food security in the region. To implement adaptation strategies, there is a need for more localised projections and monitoring stations information across the city as well as broader regions.

13. ASSESSMENT OF GHG EMISSIONS INVENTORY

13.1 WHAT ARE GREENHOUSE GASES ?

Greenhouse gases (GHG) are those that trap heat and contribute towards global warming. The main gases considered in this inventory include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Emissions from CH_4 and N_2O get converted to CO_2 equivalent (CO_2e) emissions by multiplying with their Global Warming Potential (GWP).

GWP is a measure that was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of the amount of energy that the emissions from 1 tonne of gas will absorb over a given period, relative to the emissions from 1 tonne of CO_2. The larger the GWP, the more the given gas warms the Earth as compared with CO_2 over that time and is called CO_2 equivalent or CO_2e in short. The duration usually used for GWPs is 100 years. As a common unit of measure, GWP allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

For example, CH_4 is estimated to have a GWP of 27-30 over 100 years[37]. An amount of CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. However, CH_4 also absorbs much more energy than CO_2. The net effect of a shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for a few indirect effects, such as the fact that CH_4 is a precursor to ozone, and ozone too is a GHG.

The GHG emissions inventory is developed on the basis of emission factors prescribed by the Global Protocol for Communities (GPC) and IPCC guidelines.

For the Municipal Solid Waste and Wastewater sector: Solid waste and wastewater do not have a direct emission factor, but IPCC chapters 5 and 6 have prescribed equations to calculate the emissions. After making the calculations, the direct emission is fed into the tool meant for the overall waste and wastewater sectoral emissions. Activity data can include electricity consumption, fuel sales, annual waste landfilled, etc. Emission factors help calculate the quantity of CO_2 released per unit of activity considered.

The simple formula for calculating GHG emissions is given in Figure 13-1.

Figure 13-1: **Illustrative formula for GHG emissions assessment**

GHG emissions =

Activity data x Emission Factor

13.2 NEED FOR A GHG EMISSIONS INVENTORY AT CITY LEVEL

A citywide GHG emissions inventory forms a critical piece of any Climate Action Plan (CAP) and provides an overview of sector-wise GHG emissions in the city. It allows cities to build evidence-based mitigation actions and policies to form a CAP and can be a powerful tool for monitoring progress toward a target, such as aligning actions with the goals of the Paris Agreement and Solapur's Race to Zero commitment.

A GHG emissions inventory helps the city to understand the GHG emissions contribution of different sectors and activities, prioritise mitigation actions, and monitor reductions. It also allows the city to direct funding towards high emitting sectors. Moreover, cities are able to meet reporting requirements, such as disclosing GHG emissions data through voluntary reporting platforms like Carbon Disclosure Protocols (CDP,) and meet funding criteria that require a baseline inventory. GHG emissions inventories also serve as a benchmarking tool for cross comparison between cities. It also allows for aggregation of city-level inventories with national/state inventories to measure the contribution of city mitigation actions to state or national emission reduction targets.

14. GHG EMISSIONS INVENTORY FOR SOLAPUR CITY

The GHG emissions inventory for Solapur includes an analysis of all the sectors/sources that emit GHGs into the atmosphere. The inventory was developed using the GPC framework and covers the three sectors of stationary energy, transportation, and solid waste management along with wastewater.

14.1 ASSUMPTIONS

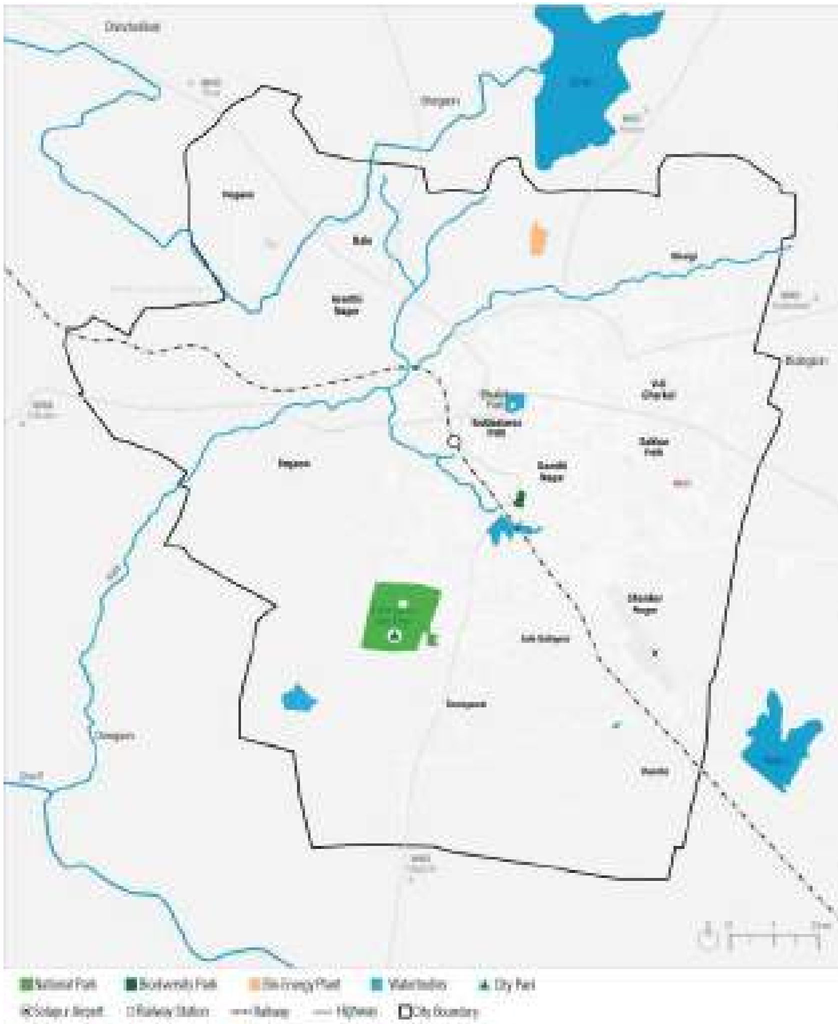
The GHG emissions inventory for Solapur is aligned with the GPC framework, a robust GHG accounting and reporting framework for cities prepared by the World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI – Local Governments for Sustainability (ICLEI)[38].

- The GHG emissions inventory was developed by using the City Inventory Reporting and Information System tool (CIRIS) of C40 cities, which was publicly available. It complies with GPC standards.
- The year 2021 was taken as the base year for the inventory, and the inventory boundary was limited to Solapur Municipal Corporation (SMC), which covers a land area of 178.57 km^2 and had a population of 12.27 lakh people as of 2021[39]. The inventory includes emissions from the industrial clusters of Maharashtra Industrial Development Corporation (MIDC) located within SMC limits, namely Akkalkot Road MIDC as seen in Fig 14-2.
- The GHGs covered include CO_2, CH_4, and N_2O. The inventory aligns with the BASIC inventory (Refer to Table 14-1) comprising emissions from stationary energy, in-boundary transportation, solid waste management, and wastewater treatment in the city.
- Scope 1 emissions include emissions occurring due to activities taking place within the city boundary, while Scope 2 covers emissions from grid supplied electricity. Scope 3 emissions include emissions occurring outside the city boundary due to activities taking place inside the boundary.

Table 14-1: BASIC inventory components under GPC

Emission sources and scopes included in BASIC inventory
• Scope 1 emissions from stationary energy sources (excluding energy production supplied to the grid, which shall be reported in Scope 1 total)
• Scope 1 emissions from transportation sources
• Scope 1 emissions from waste sources (excluding emissions from imported waste that shall be reported in Scope 1 total)
• All Scope 2 emissions from stationary energy sources and transportation
• Scope 3 emissions from treatment of exported waste

Figure 14-1: Map of Solapur city showing major landmarks and industries



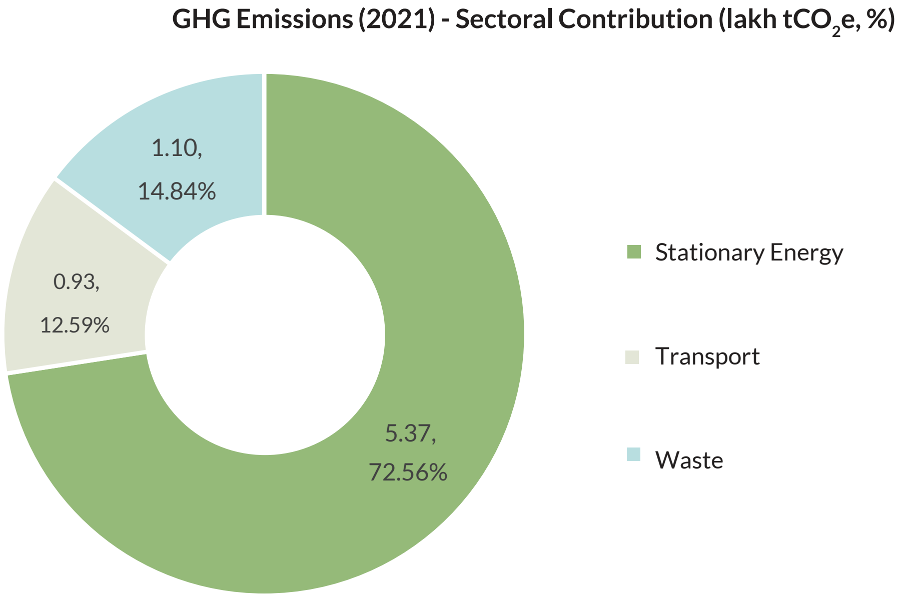
Source: WRI India analysis, SMC 2022

14.2 SUMMARY OF ESTIMATED GHG EMISSIONS IN SOLAPUR CITY

In 2021, the estimated GHG emissions in SMC area were 7.41 lakh tonnes of CO_2 equivalent (tCO_2e). This is approximately 0.60 tCO_2e per person, based on the estimated population of 12.27 lakh for the year 2021.

The stationary energy sector accounts for the highest contribution towards GHG emissions (72.6%), followed by waste (14.8%) and transportation (12.6%) sectors refer to Figure 14-2. The waste sector comprises two sub-sectors — wastewater and solid waste management.

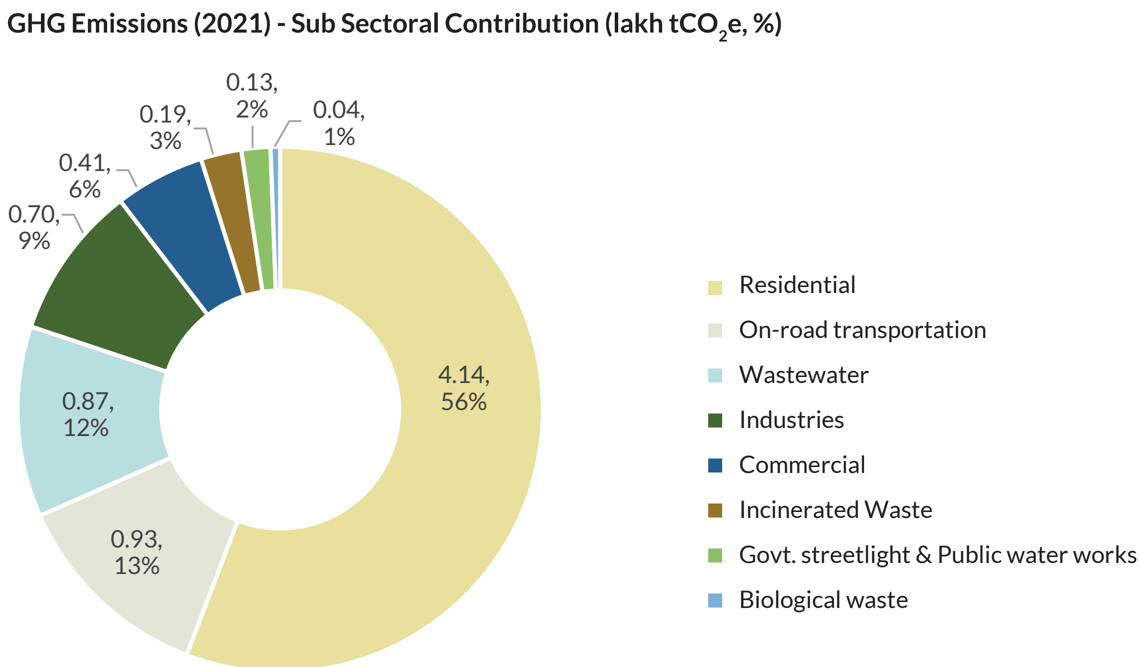
Figure 14-2: GHG Emissions Inventory – Summary



Source: WRI India analysis 2022

The sub- sector wise break-up is given in Figure 14-3. The four major sub-sectors that contribute substantially to the GHG emissions are residential sector (56%), on-road transportation (13%), wastewater (12%), and industrial (9.4%).

Figure 14-3: GHG emissions inventory – sub-sector wise break-up



Source: WRI India analysis (2022)

The sector wise break up of estimated GHG emissions are covered in the following sections.

14.2.1 Stationary Energy

1 Data availability

The stationary energy sector includes two segments — electricity and fuel (LPG) consumption.

- In Solapur city, electricity supply is managed by the state-run Maharashtra State Electricity Distribution Company Ltd. (MSEDCL) and energy generation by Maharashtra State Power Generation Co. Ltd (MAHAGENCO), another state-run company. Data on energy consumption by different user categories was collected and analysed. The data on electricity consumption for low tension (LT) and high tension (HT) category was collected for various user categories, such as residential, commercial, industrial, government utilities (public water works and treatment plants), and streetlights. There were a few other categories as well — agriculture, non-specified sources, and rooftop solar generation.
- In the case of Maharashtra state, energy is generated from different sources, such as coal- or gas-based thermal power plants, hydro power plants, etc. This energy mix has coal-based power plants as a major source of electricity generation (61%), followed by wind (11%), and gas (8.2%). Therefore, a common GHG emissions factor for electricity consumption is considered on the basis of the energy mix, and this GHG emissions factor is provided by the Central Electricity Authority of India (CEAI) for West zone. The GHG emissions factor provided by CEAI for the year 2021 is 0.79 t/MWh.
- Fuel consumption data is available only for the use of LPG by residential, commercial, and industrial sectors. There are no PNG services within the city.
- There is a National Thermal Power Corporation (NTPC) power plant, but it is situated outside SMC limits and, hence, not considered for the analysis.
- The field visits and consultations in the city indicate that firewood and coal are also used in the residential, commercial, and industrial sectors, but due to a lack of data availability, the contribution of these fuels to GHG emissions could not be estimated.

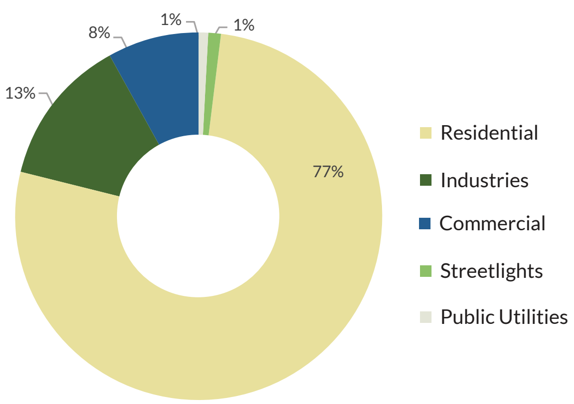
14.2.2 Sub-sectoral analysis- stationary energy sector

The stationary energy sector contributes around 72.6% (5.37 lakh tCO_2e) of the total GHG emissions of Solapur city.

- Within the stationary energy sector, the contribution to the total GHG emissions by the electricity consumption for different consumer categories is around 50.3% whereas the contribution of LPG fuel consumption for different consumer categories is around 49.7%.
- In terms of sub-sectors within the stationary energy sector - Residential buildings are responsible for ~77% of the total stationary energy related GHG emissions (~ 4.14 lakh tCO_2e), followed by the industrial sector contributing ~13%. The commercial, public utilities and streetlights are responsible for

the remaining ~10% (0.54 lakh tCO_2e) of the total GHG emissions attributed to the stationary energy sector.

Figure 14-4: GHG emissions from stationary energy – sub-sectoral contribution



Source: WRI India analysis (2022)

In the case of Solapur, Scope 2 emissions are higher because only 6574 MW of RE is grid-connected, which is around 1% dependency is on RE in the energy mix . Among these, about 63% of solar generated is from the wastewater sector. The residential, commercial, and industrial sectors contribute 41%, 26%, and 26%, respectively, while the institutional sector's share is 7%. Fuel wood is also used in confectionaries and other bakeries and for domestic use. There are around seven wood-operated crematoria under SMC jurisdiction.

14.2.3 Transportation Sector

1. Data availability

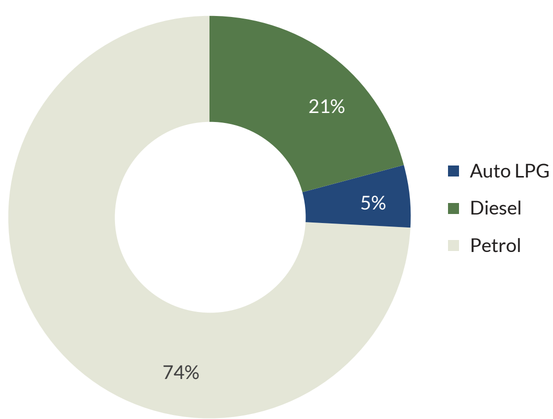
Solapur city has an on-road transportation system only. It has neither an intra city railway nor metro nor or water transport system.

- The transport sector emissions are estimated using the fuel sales method based on the fuel data received from the fuel companies on sales of auto LPG, petrol, and diesel from the petrol pumps located within Solapur city.
- The CNG service began in 10 locations within city limits in the year 2021. However, as the data was available for only 2-3 months, this was not considered in the analysis.
- Data on the number of vehicles registered with the Regional Transport Office (RTO) by fuel type from 2010-2021 was also considered to assess the current fuel mix in the vehicle fleet and understand the trends in vehicle usage in the city by fuel type.

14.2.4 Sub-sectoral analysis - transportation sector

In 2021, the contribution of the transport sector to GHG emissions was 0.93 lakh tCO_2e, which is around 13% of the total GHG emissions for the city. The petrol sales were very high in Solapur, resulting in 74% of the GHG emissions within the transport sector.

Figure 14-5: GHG emissions from Transport – sub-sectoral contribution



Source: WRI India analysis and Oil Companies' fuel data

14.2.5 Solid waste and Wastewater

1. Data availability

The city-level data was collected on solid waste management and wastewater treatment. The key data points referred are given below:

a. **Municipal Solid Waste**

- In 2021, around 240 tonnes per day of solid waste was generated, out of which around 50% was organic waste and 50 % dry waste. In terms of overall waste composition, the major components are wood (12%), stone (9%), textiles (9%), and plastic (6%). However, as per the SWM DPR 2019, organic waste which includes food waste is 58%, dry waste 30%, and inert waste 12%.
- The city undertakes organic waste treatment through the waste-to-energy process and compost treatment. There is improper regulation of waste segregation in the city, and the process of segregation takes place at the plant. Only legacy waste is treated at the landfill. All dry waste is converted to Refuse Derived Fuel (RDF) and is sent to a cement factory to be used as boiler feed.

b. Wastewater treatment

- In 2021, the estimated wastewater generation in Solapur city was 93.06 million litres per day (MLD) and the Sewage Treatment Plant (STP) capacity of 3 STPs combined was 150 MLD. However, the sewerage network coverage is only 60%. Therefore, only around 59 MLD of wastewater is treated while the remaining wastewater is discharged without treatment.
- Methane is captured during the wastewater treatment process, but due to low quality output, it is flared and only 40% is used for energy generation. In 2021, around 4,167 MWh of electricity was generated through STPs.

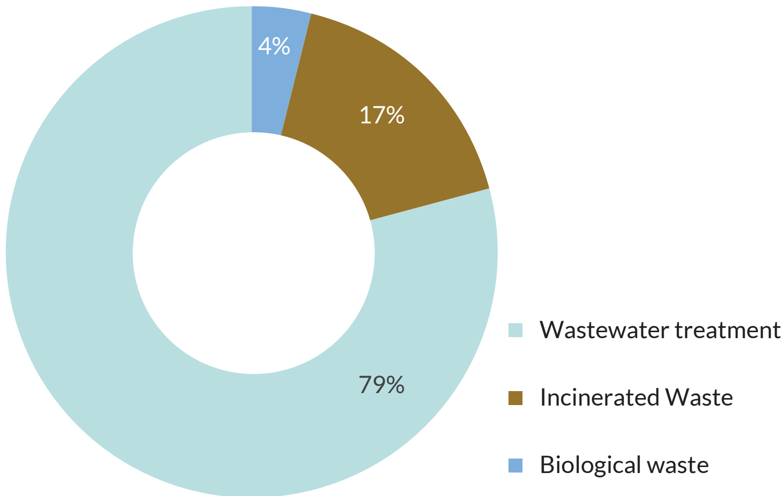
14.2.6 Sub-sectoral analysis - solid waste and wastewater sector

The contribution of waste sector to the total GHG emissions is around 1.10 lakh tCO_2e, which is nearly 15% of the total city level GHG emissions. The wastewater sector constitutes 79% (0.87 lakh tCO_2e) of the overall waste sector related GHG emissions.

The GHG emissions from municipal solid waste are primarily due to CH_4 emissions, N_2O emissions during the biological process, and CO_2 emissions from the incineration process of dry waste.

In the case of wastewater treatment processes, the primary emissions are from CH_4 and the CO_2 generated due to the flaring of CH_4.

Figure 14-7: GHG emissions from waste sector – sub-sectoral contribution



Source: WRI India analysis (2022)

14.3 WAY FORWARD ON MITIGATION

The GHG emissions inventory provides the baseline emissions for the city. Further, based on the Climate Action for Urban Sustainability (CURB) tool and other methods, three scenarios are developed, namely Business-as-usual, Existing and Planned, and Ambitious scenarios. The objective of the scenario exercise is to establish an evidence base that could be used to set emissions reduction targets for Solapur's energy, transport, and waste sectors in line with the Paris agreement to keep warming below 1.5-degree and identify the strategies to achieve those.

15. GHG EMISSIONS - SCENARIO ANALYSIS

15.1 APPROACH AND METHODOLOGY

15.1.1 Objective

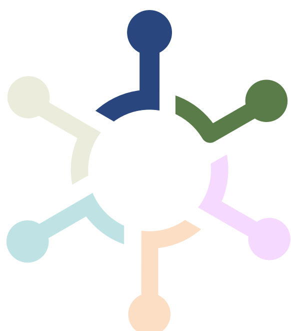
The objective of the scenario modelling exercise is to establish an evidence base on which the city can set emissions reduction targets for energy, transport, and waste sectors, in line with the Paris agreement to limit the temperature to 1.5-degree scenario and identify the strategies to achieve these. These scenarios would be used to structure the climate action planning analysis, document the city's current strategies, identify new strategies that Solapur can plan on implementing in the near and medium term, and assess barriers to the implementation of ambitious action. These strategies would help the city mitigate the growing climate risks and help understand the project financing needs for the city to set achievable targets. This exercise also aligns with the Maharashtra state's Race to Zero Campaign, of which Solapur city is a part.

15.1.2 Tools, Approach & Methodology

The scenario modelling for Solapur city has been developed using the CURB tool. The CURB is an interactive Excel-based tool designed by the World Bank in partnership with C40 Cities Climate Leadership Group, Global Covenant of Mayors, and AECOM Consulting. It helps cities develop emissions reduction targets for key sectors, assess investments required and prioritise low-carbon interventions based on cost, payback period, feasibility, and impact on energy consumption and emissions reduction[40].

CURB allows cities to plan across six sectors in an integrated way: private buildings, municipal buildings, public lighting, electricity generation, solid waste, transportation, and water and wastewater (Figure 15-1).

Figure 15-1: Scenario analysis through CURB tool - sectors and sub sectors covered



Source: Author's infographic based on the CURB user guide, World Bank

CURB is being used by cities globally to compare the cost, energy, and climate impact of different technological and policy solutions to direct investments, develop robust climate action plans, set informed targets, and acquire project financing. It is a free, open-access tool, driven by city-specific data, cost of water, fuels, and electricity and city baseline information for each sector. In cases where some data is not available, the tool allows the user to set proxy values. For the modelling study, the year 2021 has been accounted as the base year. The future interim target years are 2030, 2040, and 2050.

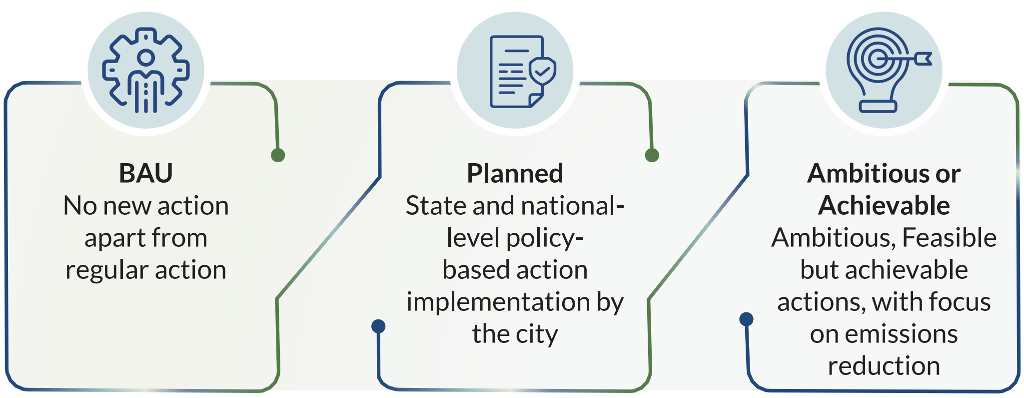
As per the tool, there are three main scenarios have been developed:

The targets and outputs that are modelled using the CURB tend to align with the RCP 2.6 scenario and the Paris goals of 1.5-degree reduction. In a few cases, it also considers RCP 4.5, which is an intermediate scenario. Emissions in RCP 4.5 peak around 2040, then decline. As per Intergovernmental Panel on Climate Change (IPCC) RCP 4.5 is a moderate scenario in which emissions peak around 2040 and then decline. RCP 8.5 is the highest baseline emissions scenario in which emissions continue to rise throughout the twenty-first century. This could be correlated to the current BAU scenario if no action is taken. In each scenario, there is a specific set of policy levers that provide relatively high GHG emission mitigation opportunities.

The goal is to reduce 80% of estimated emissions under BAU by 2050, rather than achieving net-zero emissions by 2050. This is because of the key challenges in achieving net zero by 2050 even under the Ambitious or Achievable scenario -

- Solapur is facing significant institutional and financial challenges. However, the city has shown a willingness to take measures to address the climate action plan targets.
- In 2021, the energy sector was the single largest contributor to the city's GHG emissions, at 72%. The share of emissions due to electricity consumption was around 37%. The electricity supplied in the city us

Figure 15-2: CURB tool scenarios



usually dictated by the state-run utility in this case MSEDCL. Hence, the city has very little control over its improvement and migration to cleaner forms of energy.

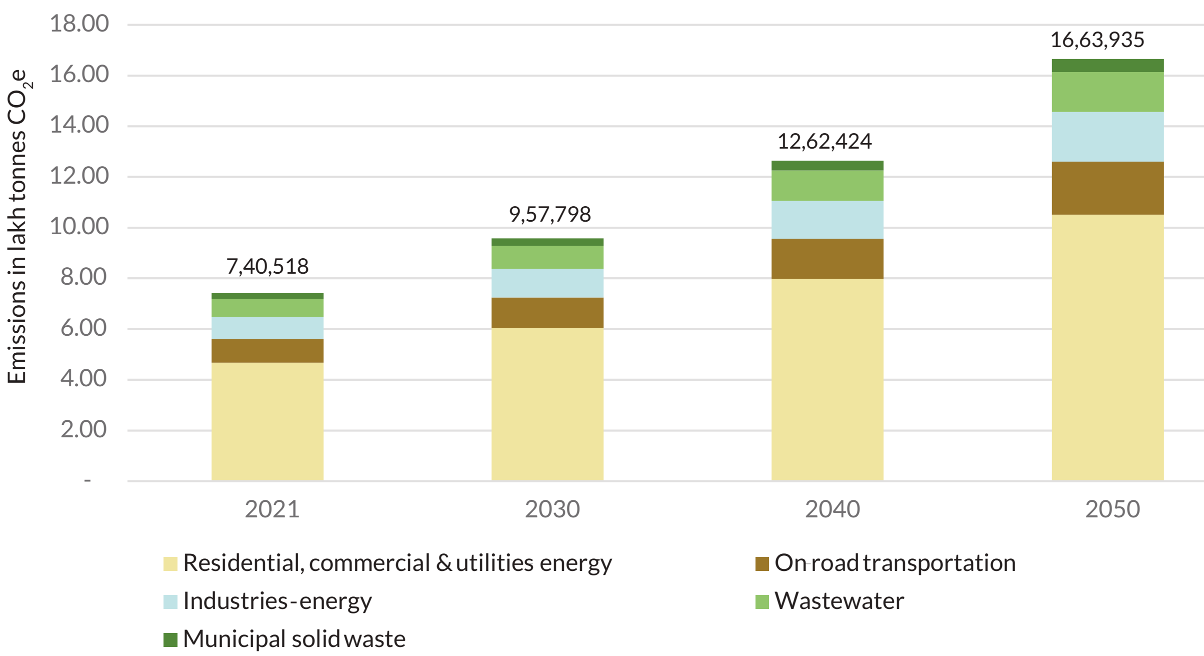
- In 2021, its per capita emissions were around 0.6 tCO2e per annum, which is much lower than other comparable cities like Nashik, where emissions were 1.30 tCO2e per annum per capita.
- This suggests that there are limitations to further improve Solapur's emissions reduction without focusing substantially on building institutional capacity and financing various initiatives.

15.2 SCENARIO ANALYSIS

15.2.1 Scenario-1: Business-as-usual scenario

The GHG emissions in 2021 accounted for 7.41 lakh tonnes of CO_2 equivalent (tCO_2e) estimated based on the GPC 4th Assessment Report. Under the BAU scenario, if no action is taken to mitigate climate change, the overall GHG emissions of the city are likely to increase nearly 2.25 times between 2021 and 2050, reaching 16.64 lakh tonnes of CO_2e/year in 2050.

Figure 15-3: BAU scenario: GHG Emissions projection based on annual average population growth from 2021 to 2050



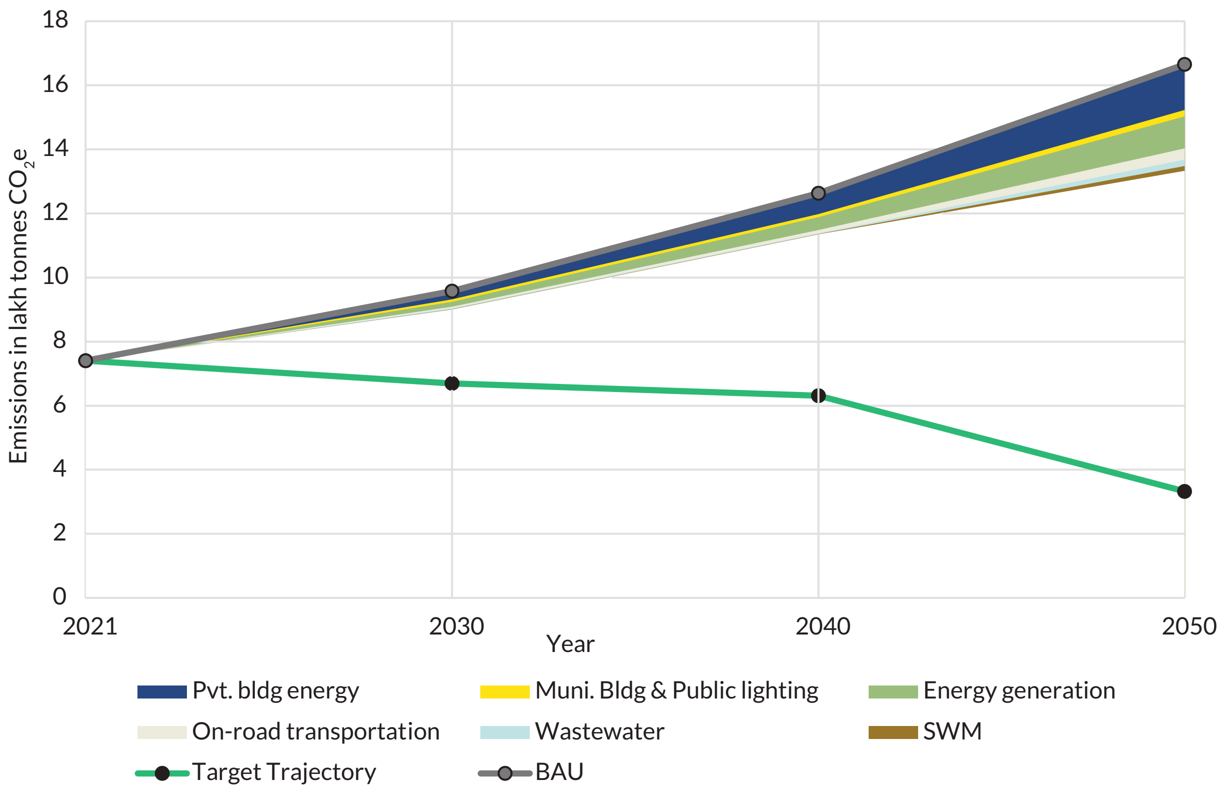
Source: WRI India analysis 2022

15.2.2 Scenario-2: Existing & Planned Scenario for Solapur city

The E&P scenario does not have a primary focus on emissions reduction due to the implementation of some projects, plans, policies, or strategies that are indirectly linked to emission reduction. However, certain national and state-level schemes have been implemented at the city which aimed to reduce a certain amount of emissions in the current and upcoming years. Using the city's current and upcoming plans and projects city, assumptions have been made for reducing emissions given these plans are to be implemented.

Based on the E&P scenario, 20% is the target for emission reduction based on the BAU scenario. Solapur will reduce emissions by 25% with planned scenario actions implementation by 2030. This will be followed by a 20% reduction in emissions by 2040, when the city has set up an overall target of 50%. By 2050, the overall target set up by the city is 80%. However, actions under the E&P scenario will help the city achieve only 22% of emissions reduction.

Figure 15-4: **Existing & Planned scenario: GHG emissions targets and gaps**



Source: WRI India analysis 2022

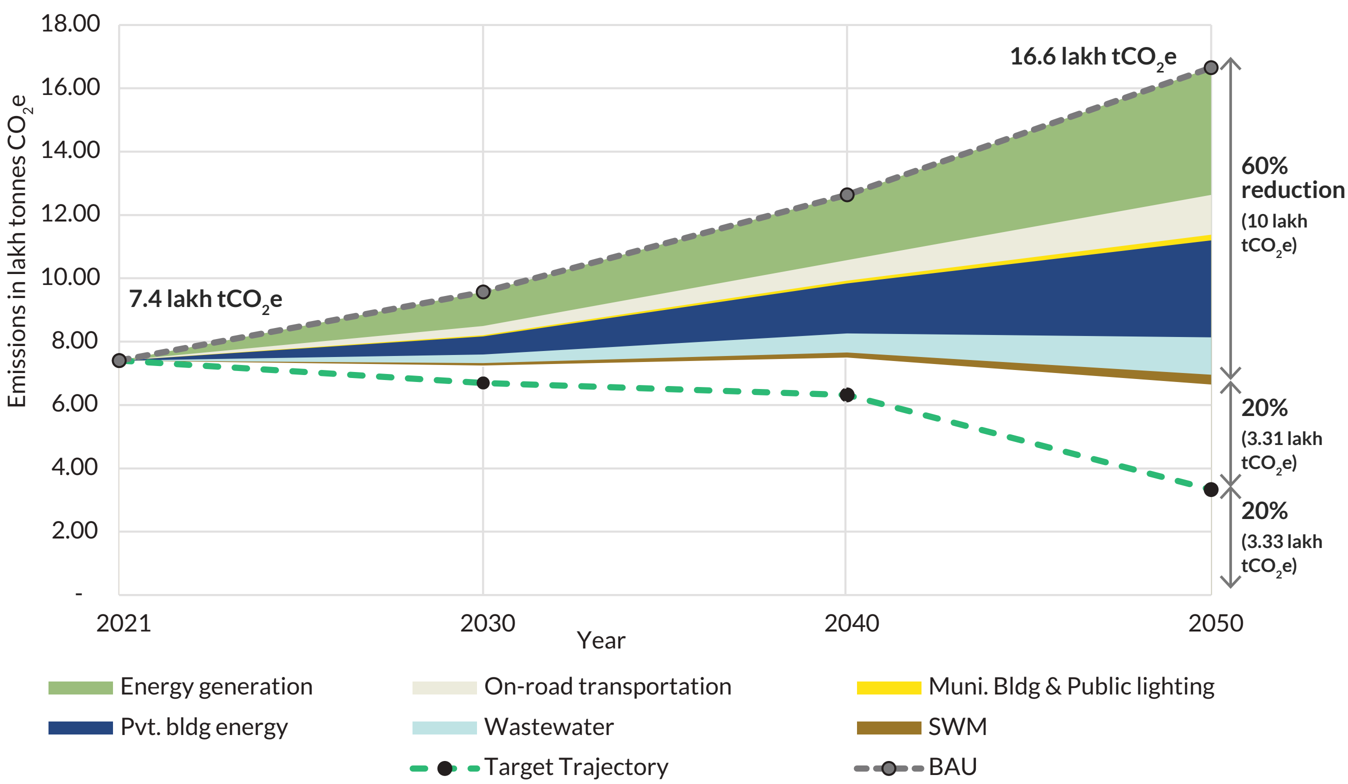
15.2.3 Scenario-3: Ambitious or Achievable Scenario for Solapur city

As per the Race to Zero commitment, Solapur city has decided to achieve emissions reduction with a certain target, which is more ambitious but feasible and yet achievable through specific strategies, plans, projects, and policies. Based on the emissions inventory, the city has been able to identify the sector that has the highest emissions contribution and the action that the city will implement to reduce emissions. Under the E&P scenario, the city will achieve only a 22% emissions reduction by 2050 and there will be a huge gap in the target achievement. Therefore, the city has decided to adopt an Ambitious scenario that will be implementable and reach the targets set up by the city.

The city has aligned some targets as part of the Paris agreement of 1.5 degrees and India's commitment to Net Zero by 2070. Hence, the city must develop concrete strategies and actions to achieve the emissions reduction targets in the interim years. With the support of the Maharashtra State Energy Calculator 2050 (MHSEC 2050) and a national-level policy for 50% RE mix energy generation by 2030 and 1 billion GHG emissions reduction target by 2030, city policy and action can be oriented in line with these targets.

Targets in the ambitious scenario have the potential to achieve approximately 60% emissions reduction by 2050 as compared with BAU emissions of 16.6 lakh tCO2e in 2050.

Figure 15-5: Ambitious scenario: Emission reduction targets



Source: WRI India analysis 2022

The GHG emissions reduction target for 2050 is 80% of the estimated emissions i.e. 80% of 16.6 lakh tCO2e, which is 13.28 lakh tCO2e . Assuming that the actions proposed as per the Ambitious scenario are implemented by 2050, the GHG emissions will be reduced by 10 lakh tCO2e, which implies approximately 75% reduction as compared with the target of 13.28 lakh tCO2e reduction by 2050. Thus, there will be residual emissions of 3.31 lakh tCO_2e, 9% of the emissions reduction target.

The residual emissions can be linked to a lack of technological advancement backed with research and development needed to mitigate further emissions from the sectors. There is also a need to create more carbon sinks.

As indicated, in the Ambitious scenario, the GHG emissions amount to 6.64 lakh tCO_2e as compared with the 16.6 lakh tonnes of CO_2e in the BAU scenario.

- In the Ambitious scenario, given the aggressive policy scenario at the state and national levels, a deeper decarbonization of the grid can be expected beyond 2040 because of India's high rate of renewable energy deployment and global pressure to retire coal power plants.
- The management of wastewater and solid waste systems will improve substantially. However due to a lack of financial resources and institutional capacity, there will be some gaps in achieving 100% coverage.
- Interventions such as fuel efficiency improvements in IC engine vehicles, vehicle electrification, increased use of alternative fuels, and restraining travel demand could limit or even reverse the growth trend of CO_2 emissions from the transport sector.
- A need for stronger action to decarbonize the road transport sector is clear. Even efforts under the High Ambition scenarios will fail to achieve carbon neutrality by mid-century.
- Residual emissions can further be reduced if the city sets a higher renewable energy target. Further research would be required to gauge the reduction of all long-term residual emissions.

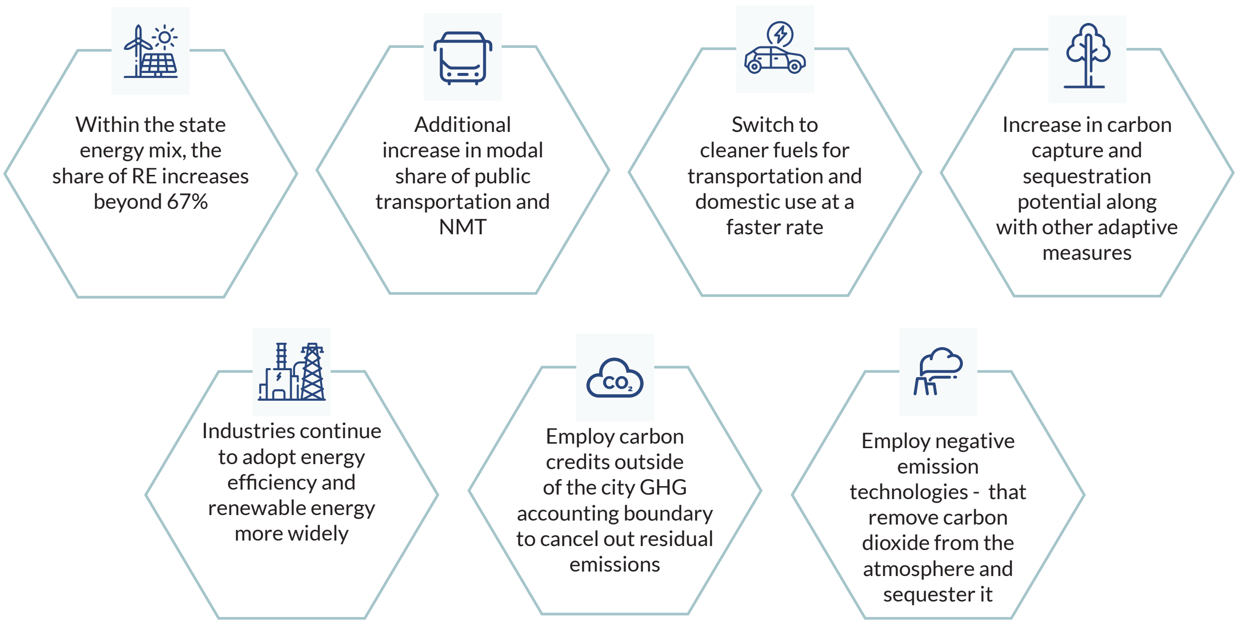
Limitations of the modelling analysis:

- No model is 100% accurate about scenario prediction as some degree of approximation is always required while making simulations for plausible pathways.
- Having the outputs in terms of impacts on GHG emissions, pollutants, jobs, GDP, etc., would depend on several considerations, such as structural modifications in the city, lifestyle changes, projection of energy demand and travel demand, over the time horizon. Long-term projections of these parameters generally induce uncertainties within the model.

15.3 NET ZERO BY 2050

Based on the city's institutional and financial capacity, constraints in political will, Solapur city will still have residual emissions in the year 2050. However, the projected emission reduction target aligns with Government of India's 2070 net zero emission reduction target. To reach a net zero by 2050, the Government of Maharashtra and SMC must take additional vital measures, as presented in Figure 15.6.

Figure 15-6: Measures to achieve the extended scenario



SECTION -V

Priority Sectors – Assumptions and Targets

SIDDHESHWAR TALAV
Photo credit: Abhishek Dulange

16. PRIORITY SECTOR IDENTIFICATION

16.1 PRIORITY SECTORS

Based on the baseline assessments, six priorities have been identified for developing mitigation and adaptation strategies for Solapur to transition to a net zero and climate-resilient city by 2050. The actions and strategies in the Solapur CAP are in alignment with the Inclusive Climate Action Planning approach and global, national, and sub-national climate and environmental priorities.

While these priorities are aligned with existing sectoral departments within SMC to ensure the efficient implementation of the Solapur CAP, there is immense scope to converge across sectors, catalyze collaborations across Departments, and reap the co-benefits of holistic solutions. The six priorities identified are presented in Figure 16-1:

Based on the VA and GHG assessments, six priority areas are identified to implement adaptation and mitigation actions. Based on the Ambitious scenario, the main sectors are analysed further and key strategy goals and targets are presented. The assumptions and targets are developed based on secondary research and consultations with various stakeholders.

Figure 16-1: Key priority sectors

16.2 SECTORAL STRATEGIES

The Ambitious scenario's assumptions and targets were developed through consultations with various stakeholders and secondary research. These stakeholders include SMC's departments, such as Water Supply, Public Works, Environment, Solid Waste, and Town Planning. It also included representatives from MSEDCL, fuel companies, and other local community organisations.

16.2.1 Energy

Solapur's greenhouse gas emissions inventory reveals that the energy sector is the biggest contributor to emissions in the city, followed by waste and transportation. To combat this, the city aims to have 39% of its total grid electricity generated from renewable sources by 2030, 50% by 2040 and 67% by 2050.

The MSEDCL supplies electricity to Solapur City and pledged to generate 50% of its electricity using renewable energy sources by 2030. Also, India has committed to sourcing 50% of its energy demand from renewable sources by 2030. The city has set targets of having 100% energy efficient lighting in residential, commercial and institutional subsectors including streetlights by 2050.

16.2.2 Sustainable Mobility

The Ambitious scenario is created while considering the city's current priorities and On-going projects and the realistic targets the city can aim for. The projections assume that the city will continue to reduce private mode shares and increase the share of both public transport and NMT to 35% by 2050.

The modal shift policy is designed to encourage the use of more efficient modes of transportation, including shifting from private means to public means of transport. It represents a percentage of the travel demand shifted from selected types of vehicles, such as passenger 2-wheeler and 4-wheeler vehicles.

The projections assume that the city will continue to prioritise the reduction of private mode shares and increasing mass transit usage. However, it is essential to note that despite these efforts, around 15% of the market is still expected to be driven by private vehicles. This is due to the status of public transport, citizens' perception of preferring private mode, and limited reduction of private vehicle dependency.

SMT plans to procure electric buses between 2025 and 2035. The transition to electric and cleaner fuel technologies were considered for setting up the targets for the Ambitious scenario.

16.2.3 Solid Waste Management

In the Achievable scenario, targeting 100% plastic and paper waste recycling is achievable by 2050 based on the CAGR growth rate. This would reduce the city's plastic waste by 25% by 2040 and help meet the EPR guidelines and state targets. To achieve this, the city needs to set up Material Recovery Facilities and ensure proper segregation and storage of plastic waste.

Currently, the tool does not provide the option to convert to e-fleet. As a result, the goal is to have 50% of all vehicles in the city running on CNG by 2050. This assumes that with sufficient financial resources, the city will be able to acquire EVs for all new vehicles by the year 2050.

16.2.4 Wastewater

Currently, four Sewage Treatment Plants (STPs) use the ASP (Activated Sludge Process), up flow anaerobic sludge blanket. However, the existing Sequential Batch Reactor (SBR) treatment system is not functional. It is assumed that if the city invests in the SBR for treating the wastewater, it will enhance the sludge treatment process.

By upgrading to enhanced biogas capture, there could be a 15% increase in efficiency. If further upgrades are made to two-stage AD by 2040, this will result in high removal efficiency for COD, TSS, and ammonia, leading to a 10-30% increase in methane yield.

Further, three sewage treatment plants (STPs) in the city run on an ASP. If the city upgrades two ASP-run STPs into an SBR, it can save more than 60% of the operating expenses required for a conventional ASP. Additionally, using SBR, high-quality effluent can be achieved in a very short aeration time, thus leading to an 80% efficiency in STP. This upgrade can also help enhance total biogas capture by 55% by 2040.

The key strategy goals for the Ambitious scenario for the sectors Energy & Buildings, Sustainable transport, and Sustainable Waste Management & Waste water for Solapur are listed in Table 16-1.

16.3 Target Table

Table 16-1: Sectoral targets for ambitious scenario

Indicator	2030	2040	2050
Private Residential buildings and energy			
Energy-efficient lighting in existing residential buildings	40%	50%	70%
Energy-efficient cooling in existing residential buildings	40%	55%	75%
Energy-efficient water heating in existing residential buildings	40%	60%	85%
Energy-efficient lighting in new residential buildings	45%	75%	100%
Residential PV on-grid connected electricity	25%	40%	60%
Private Commercial buildings and energy			
Energy-efficient lighting in existing commercial buildings	30%	80%	100%
Energy-efficient cooling in existing commercial buildings	30%	55%	80%
Energy-efficient water heating in existing commercial buildings	20%	40%	60%
Commercial PV on-grid connected electricity	10%	20%	40%
Municipal buildings, Public street -lighting and Traffic lights			
Energy-efficient lighting in existing municipal buildings	60%	80%	100%
Energy-efficient cooling in existing municipal buildings	60%	80%	100%
Public streetlight LED retrofit	50%	80%	100%

LED traffic signals	70%	90%	100%
Electricity decarbonization			
Solar PV	10%	15%	25%
Total by renewables	**39%**	**50%**	**67%**
Coal and others	61%	50%	33%
Sustainable Mobility			
Mode share for public transport	14%	25%	35%
Mode share of NMT and walking	40%	35%	35%
4 & 2 wheelers in modal split	35%	25%	15%
Share of auto in modal split	11%	15%	15%
Total modal split	**100%**	**100%**	**100%**
Electrification of passenger automobiles (Three-wheeler auto)	10%	25%	50%
Share of electrification of light-duty freight	5%	15%	35%
Share of electrification of buses	5%	15%	35%
Fuel switch of all on-road transport (CNG , electric etc.)			
2W	25%	45%	75%
3W	25%	50%	100%
4W	10%	25%	50%
LDV	10%	40%	65%
HDV	5%	20%	40%
Bus standard	20%	40%	70%
Municipal Solid Waste Management			
Share of organic waste composted	60%	80%	90%
Share of CNG SWM transport vehicles	10%	30%	50%
Share of recycling – Paper waste	40%	65%	90%
Share of recycling – Plastic waste	40%	65%	90%
Waste–energy optimization	30%	50%	80%
Wastewater Management			
Improved centralized treatment	30%	55%	80%
Improved decentralized treatment	30%	55%	80%
Waste-water to biogas optimization	30%	55%	80%
Water Management			
Share of pumps with improved efficiency	15%	30%	50%
Share of NRW	40%	25%	15%

The strategies in the Ambitious scenario inform sector-wise targets and actions for the waste, energy, and transport sectors. An example of pathways strategies and associated actions under each strategy for the sectors are illustrated in figure 16-2.

16.4 Summary of Strategies

Figure 16-2: Strategies under the 6 priority sectors

a. Recommendations - Energy & Buildings

- **Strategy E&B-1:** Decarbonise grid through an increase in RE mix in the electricity generation, with a target share of 42% by 2030, 56 % by 2040, and 67% by 2050.
- **Strategy E&B-2:** Unlock the city's energy efficiency and conservation potential with a target for energy-efficient demand management at 50% by 2030, 70 % by 2040, and 90% by 2050.
- **Strategy E&B-3:** Switch towards cleaner fuels for cooking and water heating in residential, commercial, and institutional sectors, with targeted emissions reduction of 22% by 2030, 31% by 2040, and 32% by 2050.
- **Strategy E&B -4:** Facilitate low carbon transition of industrial process.

b. Recommendations - Sustainable Mobility

- **Strategy SM-1:** Strengthen the public bus transport system to ensure that it is affordable, reliable, and sustainable and provides access to all by 2030.
- **Strategy SM-2:** Introduce policies and interventions that promote NMT infrastructure and improve last-mile connectivity.
- **Strategy SM-3:** Facilitate the transition of IPT and private vehicles to cleaner fuels through incentivisation and awareness programmes.
- **Strategy SM-4:** Prepare a comprehensive freight management plan for the city along with the transition to cleaner fuels.

c. Recommendations - Solid Waste Management

- **Strategy SW-1:** Achieve 100% waste segregation at source and promote community-based organic waste management by 2030.
- **Strategy SW-2:** Adopt a Zero landfill approach towards waste management, focusing on reducing, reusing, recycling and recovering by 2040.
- **Strategy SW-3:** Adopt sustainable and inclusive practices for waste management and fuel usage by 2030.

d. Recommendations - Urban Greening and Heat Mitigation

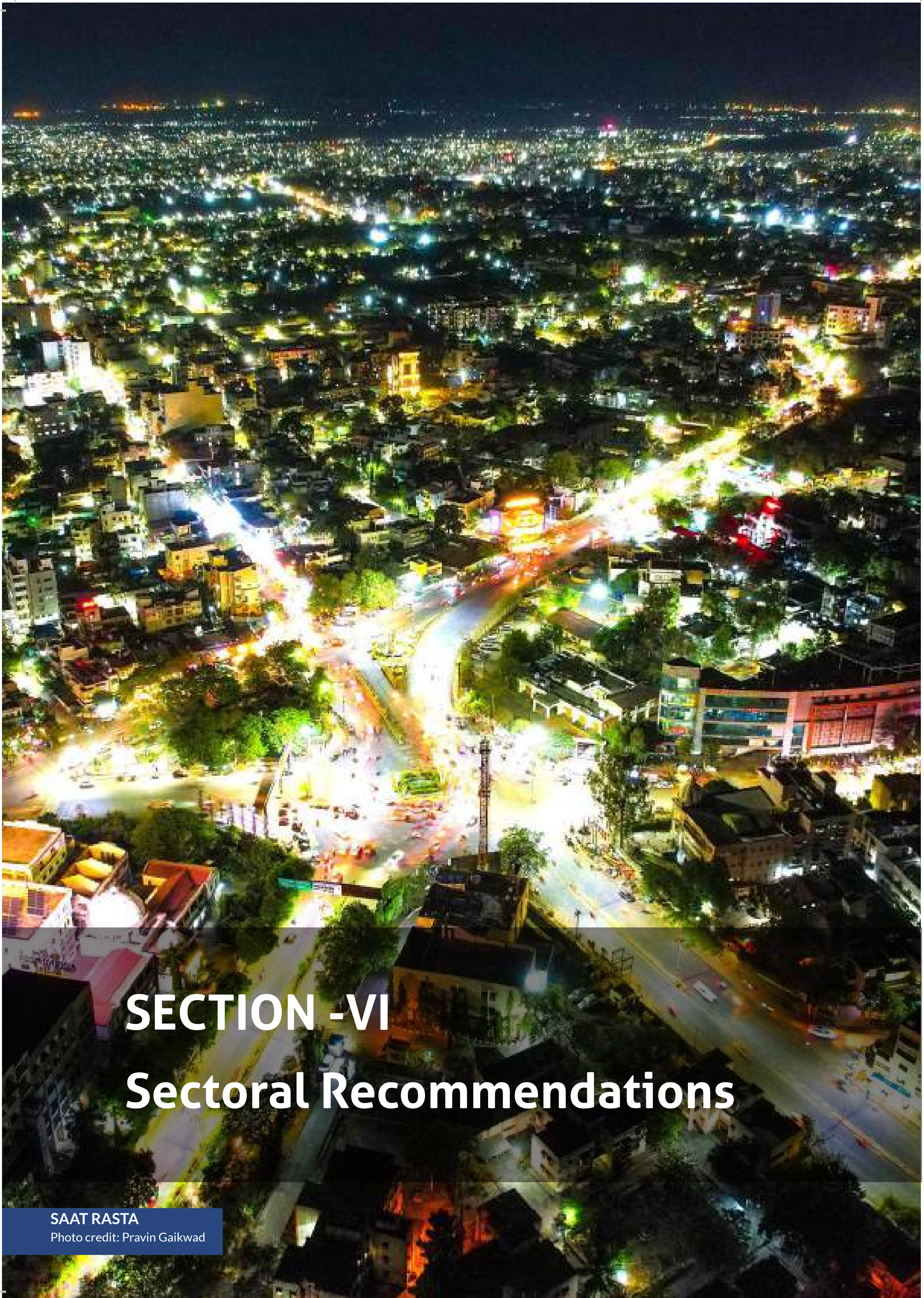
- **Strategy UG-1:** Increase vegetation cover and access to recreational spaces and surface permeability for groundwater recharge to 30-40% by 2030.
- **Strategy UG-2:** Enhance, maintain, and preserve tree cover in the city and increase the healthy green cover to 10-15% by 2030.
- **Strategy UG-3:** Reduce heating effect through greening measures by 2040.
- **Strategy UG-4:** Increasing awareness and sensitisation to help restore, maintain and enhance the city biodiversity ecosystem.

e. Recommendations - Water Resource Management

- **Strategy WS-1:** Extend the formal piped water network to improve water access and address intermittent water service.
- **Strategy WS-2:** Adopt measures to reduce UFW from 55% to 15% and NRW management through governance, technological, and Smart interventions.
- **Strategy WS-3:** Adopt and implement supply-side management measures, such as optimisation of consumer demand, behaviour change, and awareness.
- **Strategy GW-1:** Map the aquifers within SMC areas, and implement aquifer rejuvenation and management measures.
- **Strategy GW-2:** Promote rainwater harvesting.
- **Strategy WW-1:** Collect and treat 100% of the wastewater generated within SMC through a combination of centralised and decentralised wastewater management systems.
- **Strategy WW-2:** Capture methane from STPs by improving the system at Degaon STP and installing a new system at the remaining STPs.
- **Strategy WR-1:** Explore opportunities for wastewater recycling, and supply the same to the NTPC plant for their processes.
- **Strategy WR-2:** Explore opportunities for wastewater recycling and reuse for non-potable purposes.

f. Recommendations - Air Quality

- **Strategy AQ-1 :** Strengthening Air Quality Monitoring: Improve air quality monitoring and create avenues for decentralised data collection to strengthen data gathering, monitoring, and information dissemination by 30% by 2030.
- **Strategy AQ-2:** Reduction of air pollution levels by 20-30%: Target the reduction of air pollution levels by 50% through mainstreaming targeted actions in the transport,
  non-exhaust emission (NEE) and waste management sectors by 2030.
- **Strategy AQ-3:** Air pollution-related activity Mapping: Identify and monitor current and
  future activities (apart from transport and waste) that contribute towards the city's high emission levels and take measures to regulate them.
- **Strategy AQ-4:** Disseminate information on the risk and impact of air pollution on human health; address air pollution through a multi-sector approach.



SECTION -VI

Sectoral Recommendations

SAAT RASTA
Photo credit: Pravin Gaikwad

17. RECOMMENDATIONS - ENERGY & BUILDINGS

17.1 SECTORAL OVERVIEW

The assessment of the stationary energy sector in Solapur city covers two segments: electricity and fuel (LPG) consumption.

17.1.1 Buildings

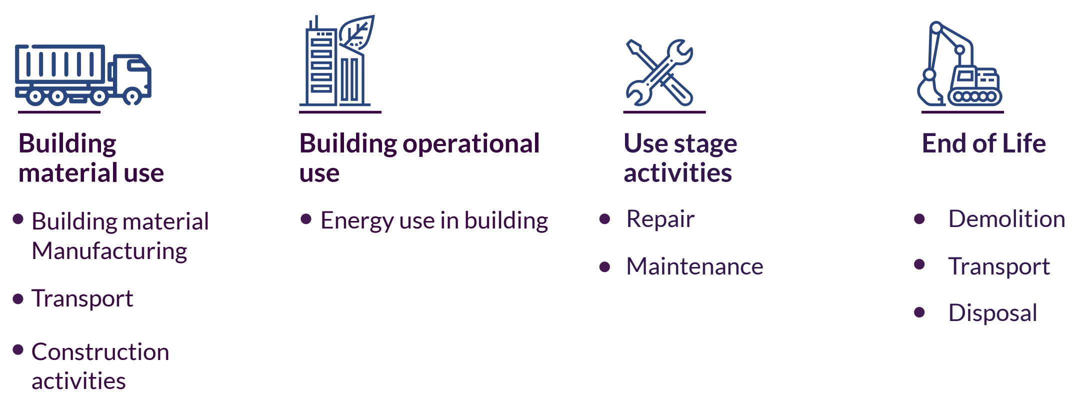
The buildings and construction sector plays a key role in accelerating the transition towards a low-carbon, resilient, and sustainable future in India. As one of the highly energy-intensive sectors in the country, it contributes significantly to the overall GHG emissions as compared with other end-use sectors.

Energy consumption and carbon emissions in the built environment are largely born out of the use of electricity and building materials. The emissions associated with the energy use in a building are termed as operational emissions. The ones associated with building material production, construction of a building, renovation and repair, and demolition at the end of life are termed as embodied emissions[41].

In the CAP document, the operational emissions are considered for the analysis i.e. the electricity consumption by different user categories.

The electricity supply within Solapur city is managed by the state-run Maharashtra State Electricity Distribution Company Ltd. (MSEDCL). The electricity for streetlighting and lighting services in municipal utilities is maintained by the Electrical Department at SMC. Energy generation is handled by Maharashtra State Power Generation Co. Ltd (MAHAGENCO), another state-run company, and other private generating companies such as Tata Power with whom the MSEDCL has power purchase agreements. As per the Revised City Development Plan for Solapur 2041, of the total roads in the city, only 45% are covered with the streetlighting provided by SMC.

Figure 17-1: Stage of energy consumption and carbon emissions in buildings



Source : https://aeee.in/tackling-embodied-carbon-from-indias-building-sector/

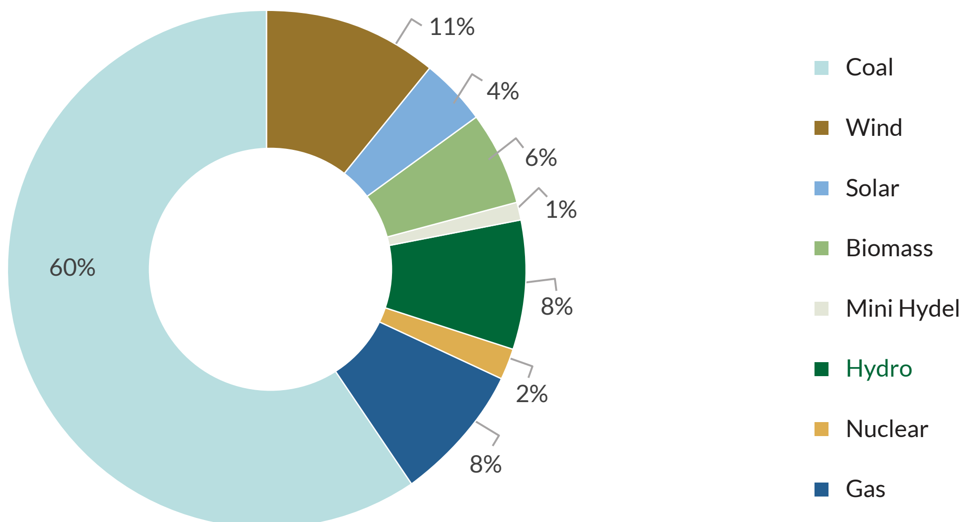
In the case of Maharashtra State, energy is generated from different sources, such as coal or gas-based thermal power plants and hydropower plants. The major source of electricity is coal (60%), followed by renewable energy (23%), gas (8%), hydro (7.5%), and nuclear (1.5%)[42]. Therefore, one of the decarbonisation strategies under the building and energy sector is to improve the energy mix such that it is based on cleaner fuel which is usually dictated by the state. Solapur Super Critical Thermal Power Station with a capacity of 1320 MW is situated on Hotgi Road in Solapur District.

SMC can contribute by sensitising citizens and other users so that they demand for the management and promotion of renewable energy, such as rooftop solar in institutions and residential buildings, and adoption of energy efficiency improvement measures.

Solapur city has a hot and dry climate as a result of which energy consumption is very high, especially in summers, for maintaining thermal comfort. The energy sector comprises electricity generation, demand & supply, and other cooking fuels, etc. In the Indian context, cities generally do not have much control over the generation, distribution, or supply of electricity to fulfil their needs. However, they can promote and support decentralised energy systems, solar rooftops and waste to energy generation in solid and liquid waste although in less quantum.

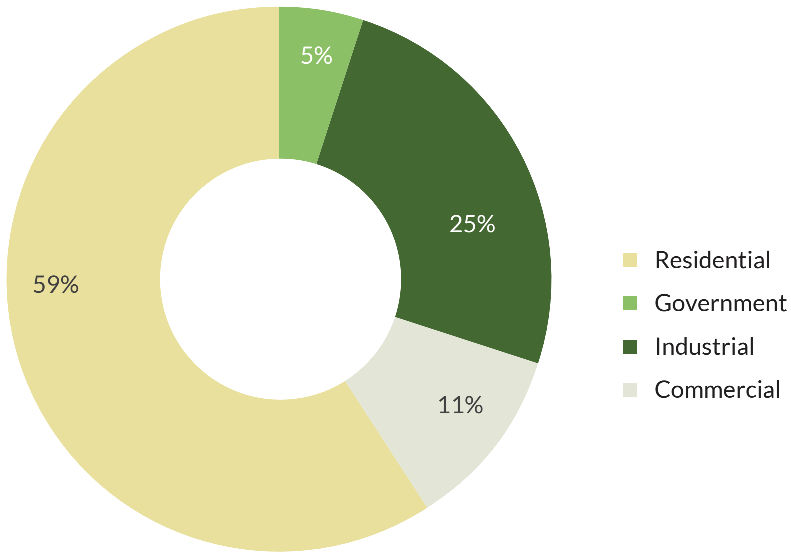
According to DISCOM, Solapur city has 100% access to electricity. In 2021, 59% of electricity was consumed by the residential building sector, followed by industrial 25%, commercial 11%, and the government sector 5%. In 2021, as part of the rooftop solar initiative, the residential sector generated 2,695 MW of solar energy, followed by commercial 1,713 MW, industry 1,709 MW and government sector 457 MW.

Figure 17-2: Energy mix



Source: Central Electricity Authority of India

Figure 17-3: Energy consumption by sectors (in MW)



Source : DISCOM

17.1.2 Energy - Fuel (LPG) usage

On fuel consumption, data is available only on the use of LPG by the residential, commercial, and industrial sectors. In the year 2021, the residential building used nearly 94,000 MT of domestic LPG in cooking and water heating, while commercial buildings used 4,000 MT of LPG used, followed by industry with approximately 45 MT. During field visits and consultations in the city, it was observed that firewood and coal are also used in the residential, commercial, and industrial sectors, but due to the unavailability of data, the contribution of these fuels to GHG emissions could not be estimated.

17.1.3 Buildings and Energy GHG emissions

In 2021, around 79% of emissions were generated by the stationary energy sector alone, owing to the consumption of electricity and other fuels. Of this, residential and commercial sectors together contributed 69% of the total energy emissions, followed by industries with 10%.

In terms of energy efficiency and conservation, the city is aware of the norms of the Green Buildings and Energy Conservation Building Code (ECBC). However, the norms have not been mandated. In Solapur, the five-star hotel Balaji Sarovar Premier is the first in the city to have obtained an Indian Green Building Council's (IGBC) Leed India Gold rating.

In terms of other measures, the city corporation has installed more than 50,000 LED streetlights and plans to replace the remaining streetlights with LED. Apart from these actions, no other energy conservation or efficiency has been planned by the city authorities.

In MIDC, many industries rely on using conventional and traditional production technology for various production processes where a huge amount of energy is consumed. Solapur city has 170 registered bakeries, of which about 100 operate from the city core. These bakeries use coal, firewood or DG sets as fuel for operating their production. In the areas where a large number of bakeries are concentrated, the emissions are high.

Moreover, kerosene, wood, and coal are used as secondary fuel types in low-income settlements for domestic purposes. However, there are no official records, owing to which these have not been factored into the emission calculation. Additionally, wood and coal are used in crematoria, hotels and restaurants, bakeries, and open eateries. As per the primary discussion on the ground, wood usage is approximated to 1,095 tonnes per year and 68,125 tonnes per year for residential (low-income households).

17.2 ON-GOING INITIATIVES

As the city does not have much control over energy generation or supply, not much is happening with respect to emission reduction initiatives except promoting and supporting the installation of the rooftop solar system. Due to climatic conditions, there are more than 280 hot days in a year, making rooftop solar a more convenient option for renewable generation (RE) generation in the city. So far, 765 residential rooftop solar have been installed in the city, followed by 206 commercial and 22 industrial buildings (DISCOM, MSEDCL).

The city corporation has also installed 580 KW rooftop solar on various public premises with the help of the O&M agencies. In energy efficiency, in 2021, the city claimed to reduce energy bills by 40% by replacing LEDs with more than 50,000 streetlights.

Table 17-1: Renewable energy mix

Sub Sectoral	On-going Initiatives
RE mix electricity	Rooftop solar on private and public buildings; Maharashtra Govt has planned to 12320 MW electricity generation through distributed RE by 2030; Govt of India has targeted 50% electricity generation from RE
Energy Efficiency & Conservation	SMC has a policy aligned with the state govt for a 5% relaxation in FSI for green building projects; Public lighting transition to LEDs by 2030; Promoting ECBC norms for the energy efficiency initiatives in buildings for a reduction in energy demand; Energy audit for water and wastewater treatment plants; Minimise energy consumption during water supply; SMC in collaboration with Maharashtra Energy Development Agency (MEDA) may take up energy conservation measures, such as solar signalling and street lighting system

17.3 KEY GAPS AND CHALLENGES

Neither the DISCOM nor the city have provided well-defined guidance or instructions for grid decarbonisation. DISCOM too does not have an explicit target for RE base electricity supply to the city with focus on emissions reduction.

- Low mandate for energy efficiency and conservation: The city has no mandate for energy efficiency in existing and new buildings, except in state-level policy. As a result, building groups and associations take no energy efficiency initiatives.
- Lack of specific grid decarbonisation targets: There is a huge vision gap found in the long-term grid decarbonisation target by DISCOM.
- Less awareness of the use of rating appliances: Citizens and electrical appliance dealers have less market awareness of the BEE star -rated appliances. Additionally, as per Solapur Electronics Dealers Association (SEDA), people are not much interested to purchase 3-star appliances due to the high price, thus ignoring energy efficiency.
- Less uptake in passive building design: The city is a part of a hot and dry region. The planners and architects focus least on the passive design of the buildings for natural lighting and thermal comfort. Minimal attention is paid to using building materials as per indigenous requirements and less embodied carbon for roofing, cladding, insulation, etc.
- Ignorance monitoring in the building sector: One of the huge gaps seen is that after the building permission is granted, there is no monitoring mechanism in place to check the measures carried out from an energy perspective. Also, neither DISCOM nor the city officials are conducting any awareness programmes on energy efficiency or rating base appliances used.
- No support for RE mix electricity generation: There is less intent to move towards decentralised energy generation in the city and to demand control on green electricity use. DISCOM does not receive support from the city and generation agencies for setting up distributed RE mix electricity generation targets. There is a gap due to a lack of support to DISCOM for setting up RE mix generation and distributions at the end-user level.
- Data gaps for another fuel type: Informal and low-income communities are using kerosene, firewood, and coal as cooking fuels. However, there tends to be no data on the use of secondary fuel types for domestic purposes. Small businesses such as bakeries and MSMEs use coal, firewood, and DG sets for production purposes, but there is no data to support this claim. Hence, secondary fuel-based emissions have neither been calculated nor included in the city emissions summary.

17.4 RECOMMENDATIONS

17.4.1 Sectoral Aspiration

“Sustainable energy planning through ensuring access to affordable, reliable, and more sources of renewable energy”.

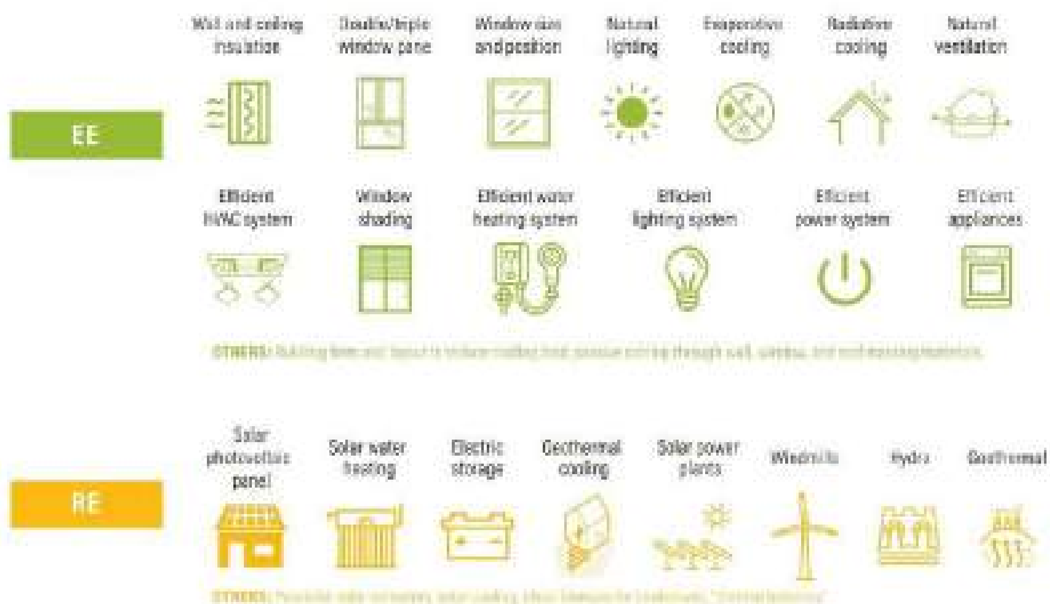
There are four key approaches:

- Grid decarbonisation, with a focus on solar power
- Energy efficiency and conservation in buildings (residential, municipal, and commercial)
- Fuel switch in residential, commercial, and industrial sectors
- Low carbon transition in industries

17.4.2 Sectoral Strategies & Actions

- **Strategy E&B-1:** Decarbonise grid through an increase in RE mix in the electricity generation with a target share of 42% by 2030, 56 % by 2040, and 67% 2050.
- **Strategy E&B-2:** Unlock the city's energy efficiency and conservation potential with a target for energy-efficient demand management at 50% by 2030, 70 % by 2040, and 90% by 2050.
- **Strategy E&B-3:** Switch towards cleaner fuels for cooking and water heating in residential, commercial, and institutional sectors, with targeted emission reductions of 22% by 2030, 31% by 2040, and 32% by 2050.
- **Strategy E&B -4:** Facilitate low carbon transition of industrial process.

Figure 17-4: Illustrative measures to achieve energy efficiency and shift towards renewable energy at building level



Source: WRI India Analysis

17.4.3 Strategy-wise Actions

Table 17-2: Strategy E&B-1: Decarbonise grid through an increase in RE mix in the electricity generation with a target share of 42% by 2030, 56 % by 2040, and 67% 2050

Action Description	Stakeholders & Finance	Indicators
Prepare a Solar Master Plan for Solapur City focusing on • Assessment of the potential for solar systems on government buildings and utilities such as WTPS and STPs • Identification of measures to encourage residential, commercial, institutional, and industrial users to adopt rooftop solar installation • Business plans for adoption of measures, such as the use of 100% green energy for lighting and other office purposes, by 2030 within all SMC and allied agency premises • Setting up a RE cell within the city with all concerned stakeholders to comprehensively manage the energy demand and supply within the SMC area For example, Thane and Pune cities have prepared Solar Master Plans. Surat Municipal Corporation has installed solar power plants located at various locations in the city, including three WTPs and 18 municipal schools, which together generate 1 MW energy. **Timeframe: 2026**	Lead: SMC. SEDA Support by: Consultant, Experts, MAHADISCOM, RWAs, SEDA, Commercial Associations, MEDA, **Finance**: CSR fund, funding from PV manufacturers, Private Investors, SMC budget, Co-operative banks, NCAP fund	**Output:** Solar Master Plan published, RE cell installed Rooftop solar installed (%) on private and public buildings; RE mix energy generated (%) No. of streetlights replaced to LED solar **Outcome:** Emissions reduction in the energy sector (%)
Strengthen waste to energy (W2E) system at STP and SWM processing sites, with net metering installed at all units. **Timeframe: 2030**	Lead: SMC Support by: Consultant, Experts, DISCOM Finance: Cooperative Banks, Central Financial Assistance (CFA), Nationalised banks, CSR fund, SMC budget, Smart City budget, NCAP fund, AMRUT, state RE subsidy, development banks	**Output:** No. of initiatives taken for W2E, RE electricity mix generated (%) **Outcome**: Emission reduction (%); Energy cost reduced (%)
Carry out a feasibility study to set up a local hybrid RE generation plant on the lines of the floating solar plan ts at Siddheshwar lake and Kambar Lake For example, the commercial operation of the 20-MV Ramagundam floating solar PV project in Telangana will begin from July 1, 2022. **Timeframe: 2035**	Lead: SMC Support by: SCADA, NTPC, BHEL, DISCOM, Solar Panel manufacturers etc. **Finance:** Central Financial Assistance (CFA), PV manufacturers, Private investors	**Output:** No. of hybrid plants implemented; RE mix electricity generated (%) **Outcome:** Emissions reduced (%)

Action Description	Stakeholders & Finance	Indicators
Carry out a feasibility study to set a mega solar PV parks with support from private investors in barren/open lands in and around the city on the lines of the Welspun 22 MW solar PV plant in Maharashtra. For example, NTPC Solapur Solar PV Park 1 in India is a 33.6 MV Solar PV project planned for Maharashtra construction to commence in 2024 in a single phase and operationalisation in 2025 [43] **Timeframe: 2040**	Lead: SMC Support by: Consultant, Experts, DISCOM, Investors, Institutions, Solar Partners etc. Finance: Central Financial Assistance (CFA), PM KUSUM, Private investors, SMC fund	**Output:** PV park set up; Electricity generation through PV parks (%) **Outcome**: Emissions reduced (%)

Table 17-3: Strategy E&B-2: Unlock the city's energy efficient and conservation potential with a target for energy-efficient demand management at 50% by 2030, 70 % by 2040, and 90% by 2050

Action Description	Stakeholders	Indicators
Promote increasing energy efficiency across user categories through a series of interventions such as the following: • Carry out sensitisation and awareness among users on BEE-rating appliances in all old and new buildings premises. Work with SEDA and other electrical dealers and retailers to promote the sale of LED bulbs, energy-efficient fans and coolers and other electronic products. • Focus on using 100% LED lighting for offices and streetlights, sensor-based lighting within SMC's premises, gardens etc. • SMC to procure 4- or 5-star rating-based appliances and make it mandatory for the contractors and agencies to adopt the same. • Carry out an energy audit of utilities and SMC buildings once in 3- 4 years. • Prepare DPR under Municipal Energy Efficiency Program (MEEP) 2016 aimed at transitioning to 100% LED lighting with Energy Efficiency Service Ltd (EESL). • MSEDCL should prepare a roadmap for SMART meter applications for energy demand management. **Timeframe: 2028**	Lead: SMC Support by: Consultant, Experts, DISCOM, Investors, Institutions, Solar Partners etc. **Finance**: CSR funds, Government colleges, SMC budget, Private investors Central Financial Assistance (CFA), CSR fund, Institutions	**Output**: No. of initiatives implemented; Energy demand reduced (%) No. of streetlights replaced No. of programmes conducted No. of energy audits conducted **Outcome**: Energy cost reduced (%)

Action Description	Stakeholders	Indicators
Promote passive designs and use indigenous building materials. • Prepare cross ventilation and passive design for more thermal comfort in low-cost housing project schemes for low-income groups. • Promote energy-efficient designs in new residential and commercial buildings. • Give special permission to the green building developers with tax rebates and other associated processes. • Form Net Zero Energy Building Council with city planners and architects for green building promotion and implementation support. • Mandate newer building plans and those under redevelopment to consider climate-friendly design considering HVAC technologies in buildings. • Promote more indigenous building materials to reduce transportation cost and less embodied carbon. **Timeframe: 2030**	**Lead:** SMC- Town Planning, Building Permission Dept. **Support by:** CREDAI, Planners, Architects, Designers, Material Manufactures, developers, Authorities, Experts, Think Tanks, R&B, Consultants **Finance**: SMC budget, state support, green building incentives	**Output:** No. of buildings having passive design; Lowered building temperatures, reduced need for cooling No. of buildings signed up for NET Zero Energy Building initiatives **Outcome:** Energy demand reduction (%), Emissions reduced (%); Energy cost reduced (%)

Table 17-4: Strategy E&B-3: Switch towards cleaner fuel for cooking and water heating in residential, commercial, and institutional sectors with a targeted emission reductions of 22% by 2030, 31 % by 2040, and 32% by 2050

Action Description	Stakeholders	Indicators
Promote a switch towards cleaner fuels in residential, commercial, and institutional sectors through the following series of interventions: • Collect data on the usage of fossil fuels, such as coal, kerosene, and firewood, used for cooking and water heating purposes and analyse it so as to plan for a phase-wise transition to the cleaner fuels. • Promote and incentivise the use of LPG, PNG, solar and induction-based systems for cooking, processing, and heating water. • Mandate the use of solar-based water heating in all new residential, commercial, and institutional buildings. **Timeframe: 2030**	Lead: SMC, DM office Support: Fuel companies, SEDA, Local retailers, Institutions, Experts, Consultants etc. **Finance**: SMC budget, CFA, state, and central scheme, NCAP	**Output:** Consolidated data on the use of fossil fuels No. of residential, and commercial units switched to cleaner fuels No. of HH adopted solar cookers and solar heater **Outcome:** Emission reduction (%)

Table 17-5: Strategy E&B-4: Facilitate low carbon transition of Industrial Process

Action Description	Stakeholders	Indicators
Identify a series of interventions along the following areas for low carbon transition of industries: • Implementing a Combined Heat and Power (CHP) system in the textile clusters to provide clean, efficient and affordable power and heat to the industries CHP is widely used across the globe to make energy systems more efficient by generating electricity from gas engines and steam through waste heat recovery from those engines. • Develop W2E solutions by increasing the use of biogas in power production. • Integrate renewable energy in industrial processes through solar thermal application[44], solar PV, and rooftop solar systems. • Expand efficient transport systems used for industrial purposes using cleaner fuels that could leverage micro-grid infrastructure. • Reduce water consumption through the implementation of effective water recycling measures so as to indirectly reduce energy consumption for water pumping. • Use energy saving potential technologies, such as installation VFD on motors, energy-efficient pumping, boilers, cooling towers, waste heat recovery in furnaces, and ovens. Improve insulation in thermal systems. For example, In a cluster in Surat's Pandesara textile industrial area, a detailed study was conducted on resilience building. **Time frame: 2035**	**Lead:** SMC, MIDC, Industrial associations **Support:** Industrial Association, Technology providers, Experts, Consultants, DISCOM, Ministry of Industries, MSME associations **Finance:** Industry contribution, Subsidy/ incentives from state/ central schemes, NCAP	**Output:** No. of industries that have generated RE mix energy; Energy demand reduction (%) **Outcome:** Emissions reduced (%); Energy cost reduced (%)

NEAR HARIBHAI DEVKARAN SCHOOL
Photo credit: Chetan Ligade

18. RECOMMENDATIONS-SUSTAINABLE MOBILITY

18.1 SECTORAL OVERVIEW

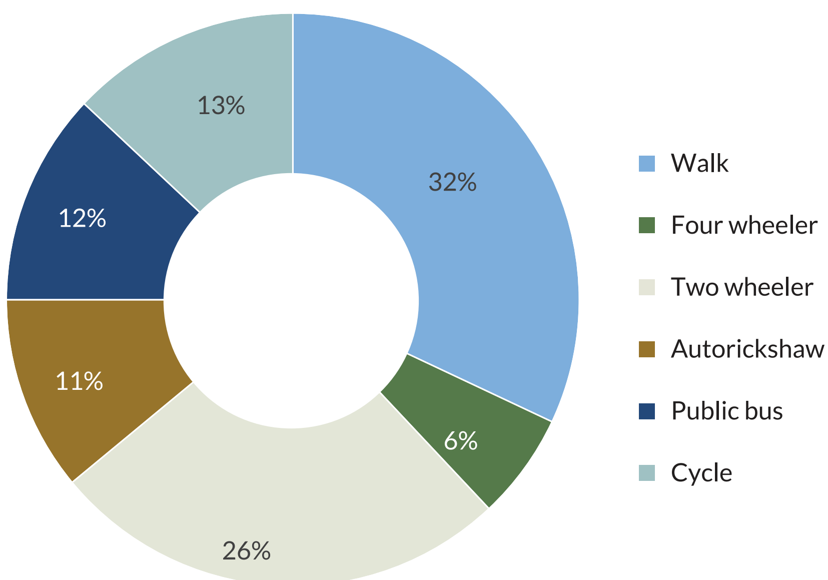
Sustainable transport refers to low and zero-emission, energy-efficient, affordable, accessible, and equitable modes of transport, including EV and alternative fuel vehicles in the motorised sector. Given this, transit-oriented development, walking, and cycling are considered the best non-motorised transport options in the city.

Basis the CMP 2015, data on the modal share of vehicles in Solapur city reveals that about 32% of the trips are made using private modes (4W, 2W), 12% using public buses, 11% using paratransit modes, and 45% are trips made on foot and on bicycle. Further, 90% of the trips on foot are within 0.5–4km. The city's growth appears to be unidirectional and has failed to expand much in all directions. Therefore, shorter commutes are still possible in the city, which points to the fact that walking and cycling infrastructure should be upgraded. 61% of trips via auto-rickshaw are within 2-6 km, whereas in the case of buses, 34% of the trips are within 2-6 km and 28% of the trips are beyond 10km. There is a high reliance on paratransit mode in the absence of public transport modes, especially trips lesser than 6km. About 40% of the trips by private modes (2W and 4W) are within 2-6 km and around 23% are beyond 10km. There aren't many trips in the city that require travel of 6-8 km.

18.1.1 Road network and non-motorised transport (NMT)

As of 2019, Solapur city had a 1,903-km road network, with the highest right of way being 9 m. Out of the total road network, only 80.73 km i.e. 4.24% are covered by footpaths, despite pedestrians and cyclists having a higher modal share. The only cycling track in Solapur city lies in front of the SMC office. The lack of

Figure 18-1: Modal share: Distribution of trips by mode



Source: Comprehensive Mobility Plan 2015 quality footpaths and safety for cyclists and encroachment by vendors are some of the issues that deter people to take up NMT modes for commuting.

On-street parking reduces the road capacity, further adding to the congestion. Vijapur Road, Karkhana Road, Akkalkot Road, Park Chowk, Zhila Parisad Road, Saraf Katta, Kontam Chowk Area, Station Road, and Navi Peth are the main areas crowded with unauthorised on-street parking (CMP 2015). The SMC does not have a comprehensive draft of a parking policy. However, they have paid parking facilities for 2W, 3W, and 4W. Off-street parking facilities provisions are available at the District Court, Employment Chowk, the railway station, and the temple premises.

18.1.2 Public Transport

Public transport in Solapur city is inadequate, with non-operational bus services in multiple routes. SMC has a dedicated Transport Department and has formulated a Comprehensive Mobility Plan (CMP) in 2015, which is almost a decade old.

As per the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) report 2013, public bus transport in Solapur was run by Solapur Municipal Transport (SMT) that was established in April 1965 under the Bombay Provincial Municipal Corporation (B.P.M.C.) Act 1949. In 2010-12, SMT was operating 106 buses owned by it and an additional 40 on hired basis. In 2013, the fleet size was 146 because no new buses had been purchased to increase the fleet. Due to the poor condition of buses, high operational costs, and the costs associated with running and maintenance, the buses are not operational. According to the Service Level Benchmarks (SLB) prescribed by the Ministry of Housing and Urban Affairs MoHUA[45], Solapur currently has 202 buses or 0.19 buses per 1000 population (CMP 2015) based on Solapur's estimated population of 10,61,866 in 2015. The requirement of buses for Solapur's 2021 estimated population of 10,89,857 was approximately 440 buses, which will increase to 490 for the 2031 estimated population of 12,28,157, based on the MoHUA definition of 0.4 no. of buses per 1000 population to maintain LOS level 2.

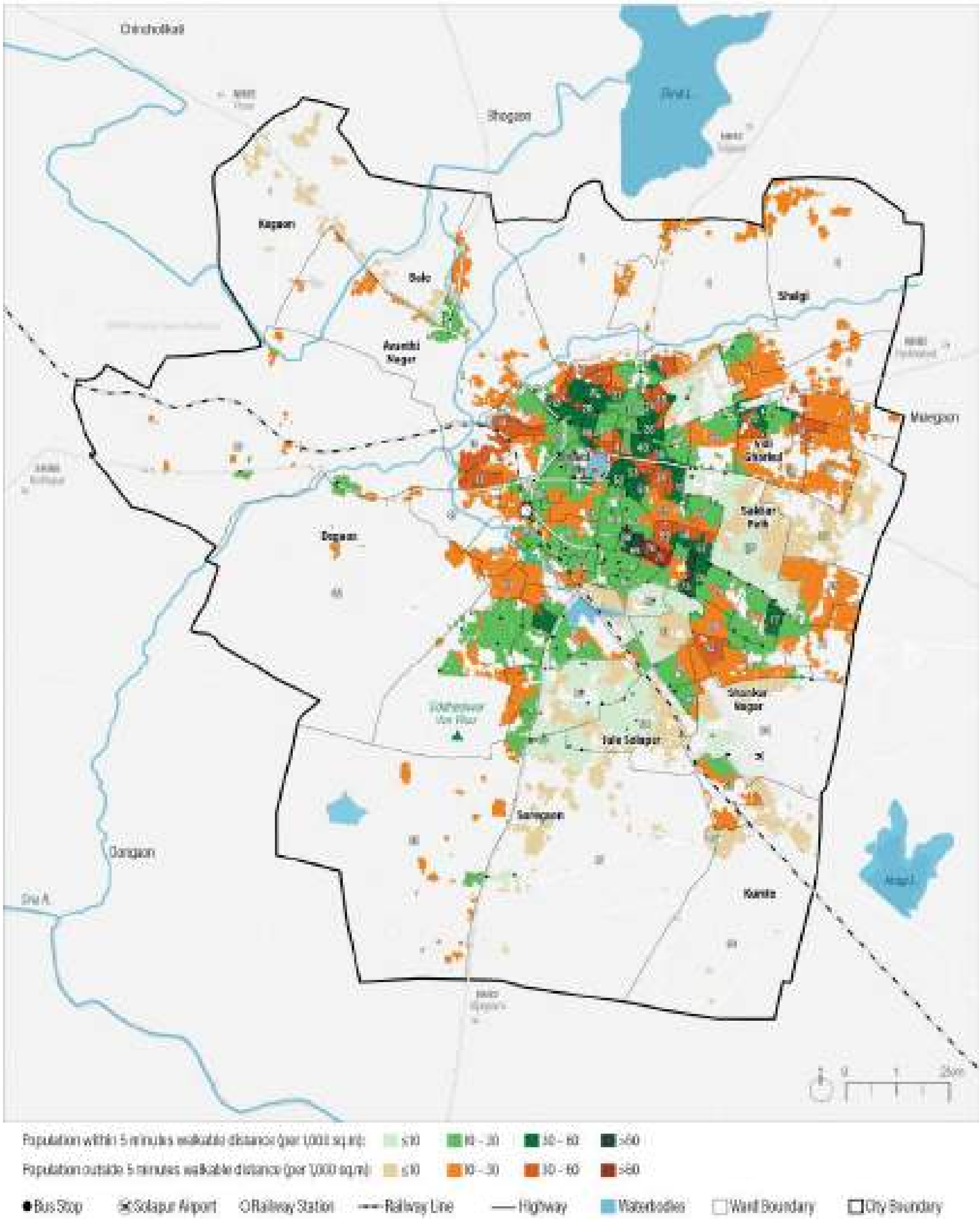
In 2007-08, the ridership was 46,148 against a fleet of 127, which rose to 50,724 in 2012-13 against a fleet size of 146 (JNNURM 2013). However, currently, of the 146 buses in the city, only 22 diesel buses are operating. As of 2021, the average daily ridership is 1,796. The public bus system of the city has seen a massive decline in ridership. Basis the RTO's vehicle registration data during the period 2010–2021, 1,541 buses have been registered, of which about 99% are diesel-based.

Also, there was no such provision for last mile connectivity in the city in the absence of an operational public bus system or plans for other transit facilities in the city. However, the city is planning to procure 10-50 electric buses under various government schemes such as NCAP and FAME [46].

18.1.3 Access to Bus-stops

A mapping of 131 bus stops was carried out based on the information provided by SMT. It was observed that around 48.46% of Solapur's population lives within 5 minutes' access of each bus stop in the city. However, there are only a few routes that are operational, given only 22 buses are running. Information on the current state of bus stops and routes was unavailable.

Figure 18-2: Access to bus stops (within 5 minutes of walkable distance)



Source: Census 2011, World Settlement Footprint Evolution, SMC, WRI India 2022

Basis the bus stops that were mapped, areas such as Vidi Gharkul, MIDC, Murarji Peth to the east of the core city, and Shankar Nagar are the higher density areas, which fall outside the ease of access (within 5 minutes walkable distance). Damini Nagar (ward no. 15) and Laxmi Peth (ward no. 17) having a population density of more than 20 persons per 1000 sqm have the least ease of access to bus stops with no population having access to one within 5 minutes walkable distance.

Therefore, given the current state of affairs, it can be assumed that there is an increase in private (2W, and 4W) and paratransit mode share in the city.

18.1.4 Private modes (2W, 4W) and IPT

1. IPT

Residents of Solarpur city face issues of public transport accessibility due to fewer bus fleets. As a result, they use IPT as the main mode for travel.

Basis RTO's 2010-2021 vehicle registration data , the total number of autorickshaws ub the city is 10,980. In the case of passenger W in the city, 91% run on petrol/LPG, 6% petrol, 1% diesel, and 0.01% of these are petrol/CNG-based and electric vehicles (EV).

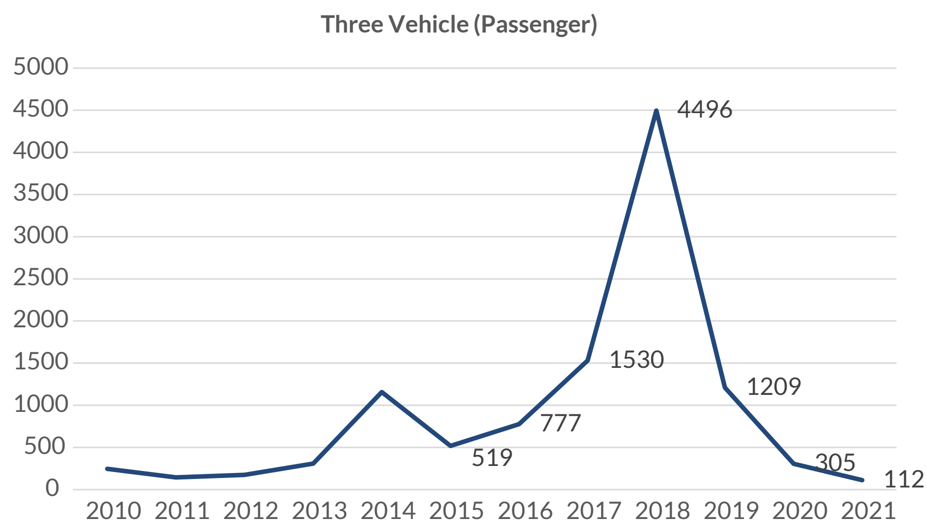
The number of registrations for passenger 3W has seen an increase in the years from 2015 to 2018, after which the registrations have seen a decline as in Figure 18-3. Passenger 3W (petrol/LPG) have seen a negative CAGR, of -6.94%.

There are no apps-based taxi services, such as Ola and Uber, in the city yet. However, the number of cabs is 1,049. About 95% of these run on diesel.

2. 2W and 4W

As per CMP 2015, 32% of trips were made using private modes 2W and 4W. However, basis the CAGR computed, the share is likely

Figure 18-3: 3W passenger registration



Source: Vehicle registrations data as provided by the RTO to increase. Another reason for the increase is the discontinuity of public buses. From vehicle registration data from the RTO (2010–2021), 2W grew with a CAGR of 0.73% and 4W with a CAGR of 1.71%. A majority of the 2W run on petrol. In the case of 4W, 57% run on diesel, 36% on petrol, and 4% on petrol/CNG/LPG.

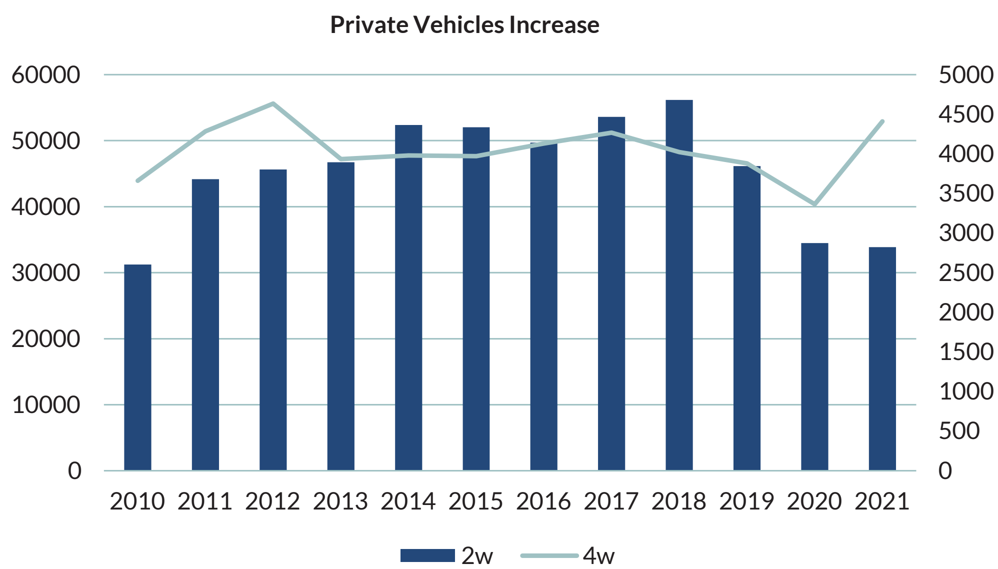
In the case of 4W, most operate using diesel as a fuel, which leads to tailpipe emissions being a major cause of air pollution in the city. Electric vehicles have also seen registrations since 2018 in 2W and 4W components, although the share is considerably low as compared with ICE.

18.1.5 Urban Freight

Being an economic and trade hub of Maharashtra, urban freight in Solapur is a major activity. As the city is connected with various other major cities and states through NHAI and State highways, freight activities take place within and outside the city boundary.

From RTO's 2010-21 vehicle registration data, a total of 1,951 goods 3W have been registered. This number grew, with a CAGR of 3.83%. The number of goods carrier vehicles in the city is 21,208. About 99% of both goods 3W and goods carrier vehicles run on diesel. They grew with a CAGR of 4.16%.

Figure 18-4: 2W, 4W registrations



Source: Vehicle registrations data as provided by the RTO

18.2 ON-GOING INITIATIVES

SMC departments and other relevant sectoral agencies are currently undertaking programmes and activities.

Table 18-1: On-going initiatives

Sub Sectors	On-going activities
Public Transport	22 bus fleets are functioning CMP drafted in 2016 Planning procurement of 10 e-bus by 2030
NMT	60.89 km of roads have footpaths, more coverage of footpath Only 90-meter cycle track built out of the proposed 24 km as per CMP
Private vehicles and IPT	92% EV registered in 2 wheeler 31% CNG registered in 4 wheeler in 2021 10,980 auto-rickshaws on the road, which has the highest mode share in 2021 Very few e-Rickshaws registered in 2021
Urban Freight	CMP 2016 has some suggestion for primary, secondary, and tertiary-level terminal development. The city is facing issues in preparing a transportation road map to align with CMP

Source: WRI India analysis

18.3 KEY GAPS AND CHALLENGES

The emissions contribution of fossil fuels (14%) was the second-highest among all sources of city emissions owing to the high dependency in vehicular activities. The measures related to transportation are not aligned with the CMP. This is a major gap and calls for the need to understand the barriers in implementation related to policy, finance, institutional governance, and knowledge.

1. Limited public transport infrastructure and decline in ridership

As mentioned in the sub-section on public transport, only 22 buses are operating on selected routes. The city needs a comprehensive public transport strategy. Moreover, the diesel-run buses are extremely fossil fuel intensive. Their operational and running costs are high too, given that no new buses have been procured since 2013. Although the infrastructure in the form of bus stops exists, these aren't being utilised. Moreover, the lack of data in digitised format restricts access to data for decision-making. This has also led to an increase in the usage of 2W and 4W. There is absence of an institutional structure that would be responsible for ensuring coordination and supplying information to passengers about the services available.

2. Vehicle fleet highly dependent on fossil fuel, low penetration of EVs

As discussed earlier , buses, private 4W, cabs, 3W goods and goods carrier vehicles majority of them run on diesel. There is very low penetration of EV in the 2W and 3W space owing to limited infrastructure. Solapur aims to procure e-buses. However, without a comprehensive strategy for bus-based public transport and route rationalisation, the procurement of buses does not seem likely.

3. Insufficient NMT infrastructure

In Solapur, where a sizeable portion of the population prefers walking as a commute mode, only 4.24% of the road network is covered by footpath. Junctions are poorly designed, with no zebra crossings and other provisions. The only cycle track measures 90 metres. The city lacks the vision to strengthen its NMT infrastructure provisions.

4. Unorganised IPT

Since 2019, Solarpur city has witnessed a decline in 3W passenger registrations. However, as public transport is sparse, a sizeable number of people can be expected to rely on 3W for their commute. There is a lack of clarity regarding the routes that the 3W ply on and the fares.

5. Lack of a vision for mobility in the city

Although the CMP was prepared in 2015, a decade has passed. The transport sector is highly dynamic and significantly dependent upon the ever-changing infrastructure of vehicles. The city lacks vision in terms of the overall mobility needs of the people.

6. Penetration of digitised payment

There is less awareness of the use of digitised payments, especially in the transport sector Owing to the limited number of operational buses and a lack of support infrastructure for the city's public transport system. This holds true for IPT drivers as well, who refuse to accept digital payments via UPI.

18.4 RECOMMENDATIONS

18.4.1 Sectoral Aspiration

Decarbonisation of the transport sector can be achieved by developing viable public transport systems and non-motorised infrastructure along with making an equitable transition to cleaner fuels in both passenger and freight segments. The overall target is to attain reduction of GHG emissions by 20% by 2030, 50% by 2040, and 70% by 2050.

18.4.2 Sectoral Strategies & Actions

Key strategies are presented below.

Figure 18-5: Urban Transport – Key strategies

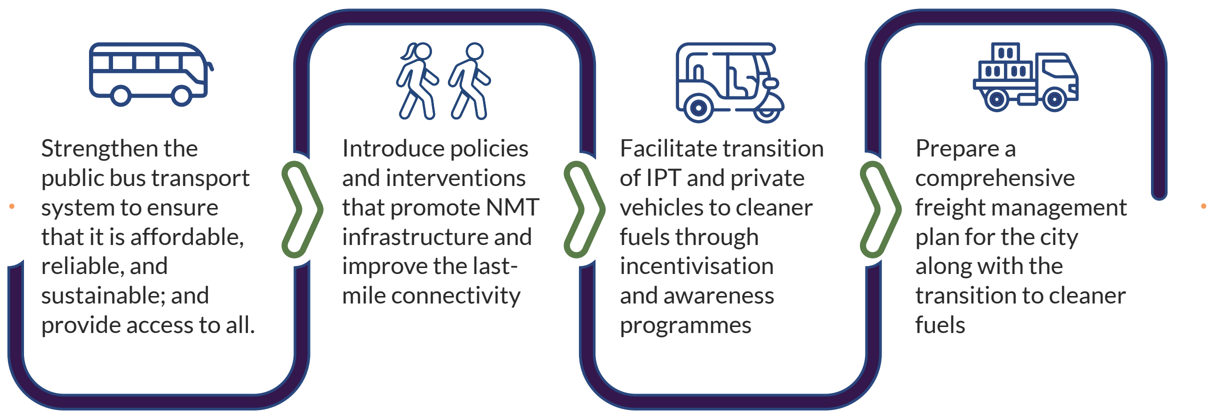


Table 18-2: Sustainable mobility - Key strategies

No.	Particulars
Strategy SM-1	Strengthen the public bus transport system to ensure that it is affordable, reliable, and sustainable; and provide access to all by 2030.
Strategy SM-2	Introduce policies and interventions that promote NMT infrastructure and improve the last-mile connectivity
Strategy SM-3	Facilitate transition of IPT and private vehicles to cleaner fuels through incentivisation and awareness programmes
Strategy SM-4	Prepare a comprehensive freight management plan for the city along with the transition to cleaner fuels

18.4.3 Strategy- wise Actions

Table 18-3: **Strategy SM-1 : Strengthen the public bus transport system to ensure that it is affordable, reliable, and sustainable; and provide access to all by 2030.**

Action description	Stakeholders and Finance	Indicators
Focus on strengthening the public bus transport system through a series of interrelated interventions and actions listed below: • Increase the bus fleet size, from 202 to 490, by 2031 by repairing and retrofitting the current fleet and procure new CNG and electric buses to use cleaner fuels. • Increase the frequency of buses, with one bus every 4-6 minutes, to match SLB LOS 2. • Extend the public bus transportation system to various industrial locations and areas with less accessibility in the city. • Prepare a roadmap for city buses, which will include a provision for special corridors. • Set up an Intelligent Traffic Management System (ITMS) system that can help in route rationalisation, bus tracking, and monitoring other operational parameters in real-time. • Install GPS tracking system in buses to track their real-time location, and link the information with the public information system. • Adopt gross cost model for procurement and operations of the public bus transport system to integrate the efficiency of the private player and reduce the financial burden on SMT. For example, Pune Mahanagar Parivahan Mahamandal Ltd (PMPML) has converted its entire fleet of around 1,000 buses into CNG. Recently, it deployed around 150 electric buses on the gross cost model. It has also set up the ITMS system to efficiently manage a system comprising 750 buses. **Timeframe: 2025 to 2035**	Lead: SMT-SMC Supporting: RTO, Road Dept, State Govt, Central Govt, Bus operator, Transport Planner, Consultants, Experts for planning **Finance:** SMC budget; PPP Project; FAME 2.0 subsidy; CSR, State Schemes, NCAP fund	**Output:** No. of buses increased; Frequency increased (%) No. of new buses procured (Electric, CNG) Bus fleet deploy for various services (%); PBS cover for last mile connectivity (%); City Area covered with BRT or City buses (%) Ridership increase (%); Riders benefitting from the service (%) Workers using the bus for their commute (%) **Outcome:** Private vehicle use decrease (%); Emission reduction (%), Ridership increase (%), Congestion reduction in peak time (%) Increase in Km of bus routes covered; Industry benefited with labour force arrival through public transport (%); Labours benefitting from cost reduction (%)
Tap into State and Central EV schemes for the identification of new financial mechanisms for projects related to adoption of EV and procurement of EV buses. **Timeframe: 2025 to 2030**	Lead: SMT-SMC Supporting: Central and State govt concerned dept; Consultants; Service providers; **Finance**: SMC budget; FAME 2.0 subsidy; State EV subsidy; PPP Model; NCAP Fund	**Output:** No. of bus fleets of EV; No. of charging infrastructure installed; No. of routes covered **Outcome:** Improved air quality at monitored junctions (%, Emission reduction (%); Improved health due to lower emissions (%)

Table 18-4: Strategy SM-2: Introduce policies and interventions that promote NMT infrastructure and improve last mile connectivity

Action description	Stakeholders & Financing	Indicators
Prepare a city-wide comprehensive NMT plan, with a focus on the following initiatives and actions: Identify major routes for providing NMT infrastructure based on activity mapping and identification of major activity generating areas Increase the number of footpaths and cycle tracks for shorter commute. Formulate an area plan for selected neighbourhoods for increased access and connectivity to schools, parks, and playgrounds. Promote cycling with a dedicated cycle track, with parking facilities at educational institutes and commercial buildings. Identify and connect the routes with rickshaw stands and bus stops in the neighbourhood. **Timeframe: 2028**	Lead: Roads Dept., Town Planning & Building Dept. Supporting: concerned industries; Labour suppliers; Service providers; SMT-SMC ITMS team; Worker communities **Finance**: SMC budget; CSR Fund; ITDP project; Cycle Mayor project; Cycle for change, PPP, NCAP, CITIIS;	**Output:** Total road cover with quality footpaths (%); Road covered with dedicated cycle lane (%) Increase in the number of Pedestrians using footpaths Improved pedestrian safety (Qualitative survey) No. of area-based mobility plans with increased access to pedestrian and cycle lanes in selected neighbourhoods Streets planned for dedicated cycle track (%); Vehicle reduction; Parking spaces reserved for cycles (%) No. of benches, streetlights, or trees planted **Outcome:** Increase in people using footpaths(%), Private vehicles reduce on the road (%); Emission reduction (%) ; Improved health (%), Increase in public transport ridership (%) Improved access to schools, parks, and playgrounds (%)
Provide footpaths that support pedestrian-friendly infrastructure, such as street furniture, benches, appropriate lighting, food kiosks, and access to wheelchairs; maintain tree cover on lengthy streets and provide permeable pavements in areas prone to waterlogging. **Timeframe: 2030**	Lead: SMC Stormwater Dept, Gardens Dept, Electricity Dept, Town Planning Dept Finance: SMC budget	**Output:** No. of benches, streetlights, and trees **Outcome:** % of the footpath with coverage of pedestrian infrastructure
Facilitate collaborations with private players in the market, OEMs aimed at providing last mile connectivity. **Timeframe: 2030**	Lead: SMC, SMT, RTO, OEMs Finance: SMC budget	**Output**: No. of capacity building workshops, with mobility related private players in the market **Outcome**: % of people capacitated
Increase road tax, carbon or PUC tax, and install parking metres for on-street parking of private vehicles. **Timeframe: 2023-27**	Lead: Transport Dept-SMT Supporting: Consultant; RTO; Town Planning Dept; SMC Tax Dept; Parking Agencies Finance: SMC budget; PPP model; NCAP fund	**Output:** Private vehicle registration reduced (%); EVs increased in on-road (%); Tax revenue increased (%) **Outcome:** Emissions reduction (%)

Table 18-5: Strategy SM-3: Facilitate the transition of IPT and private vehicles to cleaner fuels through incentivisation and awareness programs

Action description	Stakeholders & Financing	Indicators
Promote the setting up of EV charging infrastructure for uptake of EVs (all categories i.e. 2W, 3W and 4W) through PPP mode, provision of incentives, facilitation of processes, etc. **Timeframe: 2030**	Lead: SMC Supporting: Electricity Dept, Auto rickshaw unions, cab driver unions, citizens, OEMs, Builders lobby, Town Planning office, etc. Finance: FAME Phase II for 3W, AMC budget, NCAP funds, PPP	**Output:** No. of charging stations infrastructure installed **Outcome:** Increase in uptake of EV taxis and 3W and growth in registration by RTO, reduced fuel consumption for the transport sector, improved AQI
Identify gaps in public transport delivery and demand by mapping IPT routes in the city **Timeframe: 2025**	Lead: SMC-SMT GIS Dept, Auto-rickshaw unions, academic institutes Finance: SMC budget; CSR Fund;	Output: No of IPT routes mapped Outcome: IPT routes to supplement public transport

Table 18-6 Strategy SM-4: Prepare a comprehensive freight management plan for the city along with the transition to cleaner fuels

Action description	Stakeholders & Financing	Indicators[47]
Prepare a detailed freight management plan for the city of Solapur and its urban agglomeration area with a focus on the following areas: • Identify and map major trading hubs and industrial areas, transport routes, types of vehicles, fuel used, etc. • Carry out sensitisation workshops and awareness programmes for goods vehicles owners and drivers on the need to shift to cleaner fuels and EVs; introduce them to financing schemes, understand their key requirements for a shift, etc. • Propose logistic parks for the creation of a terminal for goods supply management at key locations, such as along Solapur-Hyderabad on NH-9, Mangalore Road NH-13, Pune Road NH-9, Tuljapur Road NH 204, and Old Vijapur Naka. • Make provision for on and offstreet parking for delivery services to avoid congestion on the roads near loading and unloading areas. • Restrict movement of freight (specifically diesel vehicles) during the day, peak hours of traffic and high pollution days. • Plan for rolling out EVs and pilot testing, especially in the 3W and 4W goods space **Timeframe: 2022-25**	Lead: Transport Dept; Planning Dept Supporting: Consultant; RTO; service providers; traffic police; Transport Association; Industries Association; Loading-Unloading Association Finance: SMC budget; PPP model; SMART city project; State budget	**Output:** Freight plan to be prepared and accepted by the authority No. of terminals built; No. of vehicles reduced in the city for urban freight Traffic jams reduced during the day and peak hours (%); Reduction of freight movement during the day (%) No. of new green jobs created **Outcome:** Emission reduction (%), Travel time reduction (%) Reduction in fossil fuel consumption in freight, Improved AQI Reduction in heavy and light duty vehicles (%)

LAXMI MARKET
Photo credit: Laxmi Market

19. RECOMMENDATIONS-SUSTAINABLE WASTE MANAGEMENT

19.1 SECTORAL OVERVIEW

Municipal Solid Waste (MSW) management in Solapur is a systematic process comprising 30% waste segregation at source, 100% primary collection, transportation for secondary segregation at the landfill site for processing and final treatment. It is an integrated process comprising several collection methods, a mix of transportation equipment, and segregation of waste volume and quantity with methods such as composting, waste-to-energy (W2E) and dry waste sent to cement factories for incineration.

MSW contributes 1.19 lakh tonnes of CO_2 equivalent (tCO_2e), which is 15% of the total GHG emissions in the city.

19.2 GENERATION, COLLECTION, AND TRANSPORTATION

19.2.1. Waste Generation

In 2021, the city of Solapur generated 240 TPD of MSW. The projected waste generation is 344 TPD by 2030, 464 by 2040, and 584 by 2050.

The major contributor to MSW generation is the residential sector with 91%, followed by 8% from commercial, hotels, restaurants, and roadside eateries; and 1% from the rest of the sectors including vegetable markets, fish markets, and institutions. The average waste generation is around 237 grams per person per day.

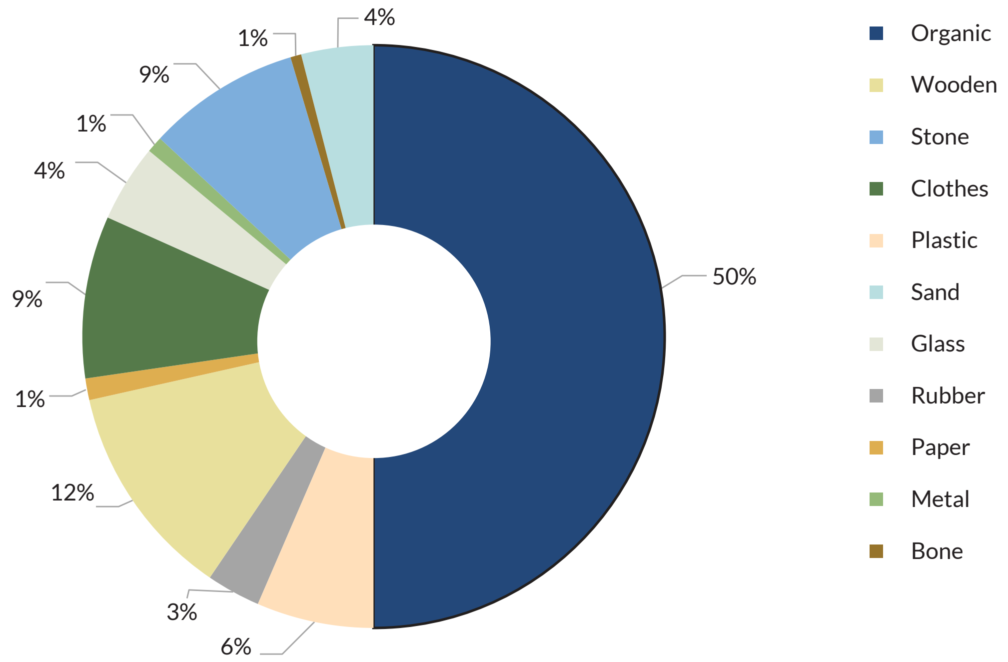
As per primary data from the Solid Waste Department, 50% of waste is organic waste and the remaining is inorganic, of which the major components are wood (12%), stone (9%), textiles (9%), and plastic (6%). However, as per the SWM DPR (2019), organic waste consisting of food waste comprises of 58% while dry waste is 30% and inert waste is 12%.

Table 19-1: MSW in Solapur – estimated projections

Year	Population (AI and II method)	Floating population	Per capita Waste Generation (kg/day)	Floating population per capita waste generated (kg/day)	Waste generated by normal population (TPD)	Waste generated by floating population (TPD)	Total Solid waste generate (TPD)
2019	1063168	53158	0.23	0.023	249.42	1.25	250.67
2024	1130738	56537	0.26	0.026	292.88	1.46	294.35
2029	1196626	59831	0.29	0.029	342.21	1.71	343.92
2034	1260833	63042	0.32	0.032	398.10	1.99	400.09
2039	1323358	66168	0.35	0.035	461.33	2.31	463.63

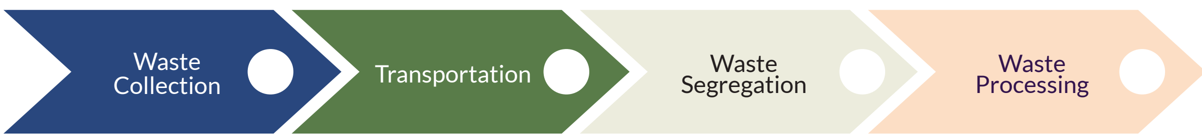
Source: SWM DPR (2019)

Figure 19-1: Composition of solid waste



Source: MSW records (2021)

Figure 19-2: Process of waste management in Solapur



Source: SWM Dept, SMC

19.2.2 Waste Collection, Segregation, and Transport

The city of Solapur has 26 administrative wards and all of these are covered by the door-to-door method, including the slum areas, which are administered by SMC staff. SMC has made efforts to distribute around 84,420 units of dustbins for wet and dry waste segregation by 2020. However, basis data collected at the waste processing site, segregation takes place at the site. There are rare instances of waste segregation practised at the household level.

Commercial establishments, offices, and institutions dispose of the waste in the SMC vehicles. There are 1,043 number small roadside hotels (*dhabas*) and 750 restaurants in the city. Most hotels and restaurants in Solapur city practise segregation of dry and wet waste, which is collected by the SMC. Waste from the APMC market (mainly comprising fruit waste) is dumped within the premises of the market. A part of the waste from the meat and fish market in the city is collected by the fish breeders once or twice a week.

The community bins for secondary collection of waste are installed at several locations in the city. SMC installed 429 capacity bins of 4.5 m^3 each and 290 of 1.1 m^3 each for secondary collection. Mixed waste from these bins is carried in dumper placer/ compactor trucks to the New Tuljapur road site for further segregation and treatment.

The city has very poor practices in waste segregation in all sectors. Most of the segregation takes place at the landfill site, and only 30% of total waste generation is segregated at source, which includes mostly bulk waste generators (BWGs)-like hotels, restaurants.

1. MSW Transportation

Three and four-wheeler auto tippers are used for primary waste collection. The process of transporting primary waste collection from the transfer station to the landfill site is undertaken by different categories of vehicle class. There is no information on the utilisation of the vehicle fleet and whether the vehicles are used up to their capacity and have been planned for trip optimisation . However, the solid waste is transported by a vehicle that runs on diesel fuel. The vehicular information is presented in Table 19-2.

Table 19-2 : Vehicle registrations (SWM DPR 2019)

Vehicle & Equipment Details	Type	Capacity (Ton)	Nos.
Auto Tippers	3Wh	0.35	70
	4Wh	0.4 (TATA ACE)	35
	4Wh	0.5 (TATA ACE)	90
	4Wh	0.7 (TATA SUPER ACE MINT)	30
Lorry	Heavy Duty	3 (TATA)	1
Dumper	Heavy Duty	2 TATA 709)	8
Compactor	Heavy Duty	9	16
Mechanical Sweeper	Heavy Duty	NA (Eicher)	2
Containers for Dumper	Heavy Duty	4.5 CUM	3

Source: SWM DPR (2019)

Auto tippers are assigned two trips each per day for waste collection in eight zones of SMC. The refuse compactors at the proposed transfer stations also take two trips a day.

Currently, four transfer stations are operational. These are Water Tank - Jule Solapur, Leprosy Colony Kumtha Naka, Vishnu Mill Indrabhuvan and PHE Bungalow Rupa Bhavani. Four transfer stations are proposed in the DPR and are in the tendering process. Their locations are Yashwant Mill near Manikanchan (survey no. 146), near Market Yard plot no. 8, Zunjech layout copy, Nehrunagar CTS no. 27 Aditya Nagar layout and ADTP office[48] to meet the current and projected future demands.

19.3 PROCESSING OF WASTE

1. Waste Management at the Landfill	In 2004, SMC entered into an agreement with CICON Environment Technologies Pvt. Ltd (CETL) for the processing of the waste generated in the city on the Build-Own-Operate- Transfer (BOOT) model. As part of this agreement, CETL designated a special purpose vehicle (SPV) named Solapur Bio-Energy Systems Private Limited (SBESPL) to set up a waste processing plant. The by-products of the process are biogas and compost. At present, the SPV has constructed and operated a bio-methanation plant of 300 TPD capacity at the Tuljapur disposal facility, which is processing approximately 120 TPD (as conveyed by SBESPL) of biodegradable waste into the bio-methanation plant. Dry waste is mostly used as RDF and sent to the nearest cement company for incineration purposes, and the rest of the waste is sent into the landfill. A Scientific Landfill Facility (SLF) is proposed at the New Tuljapur Road site for the inert waste. Apart from the biodegradable waste, the remaining waste is currently being dumped into the landfill site. The residual and inert waste from the existing dumping site at S. N. 74/1, New Tuljapur Road is to be cleared. Basis the Total Station Survey conducted in November 2018, the volume of legacy waste is 6,91,593 m^3. As per the drone survey report, the total volume of waste at the APMC area is 15,210.05 m^3 and at the Bhogaon site is 1,88,697 m^3 . The existing waste dumps have more than 70% of inert waste, which is to be transferred to the quarry adjacent to Solapur-Beed Road proposed for the scientific disposal of bio-mining rejects.
2. Wet waste management	Solapur Bioenergy has set up a processing facility for screening mixed wet waste. The screening is based on the weight and type of the waste for further process for bio methanation plan and composting. Less than 40 mm screening is sent for bio methanation, and between 40 and 110 mm of organic waste is sent for composting. Bioenergy has generated an average of 4 MW of electricity per day from bio methanation plants and out of generated energy some the used for captive energy for plants, and the rest of the energy is transferred to the grid. With the compositing, Bioenergy has generated more than 20 tonnes of manure from the process and is selling this to the farmers in the district.
3. Biomedical Waste Management	A biomedical waste treatment facility of 3 TPD capacity has been set up at Bhogaon. The facility is operated by Bioclean Systems (India) Pvt. Ltd.
4. Dry waste management	Due to the poor segregation process, the dry waste is converted to RDF and sent to cement factories for incineration purposes on a daily basis. Presently, the entire collected waste is handed over to SBESPL. As per the agreement between SMC and SBESPL, the responsibility to manage recyclable waste lies entirely with SBESPL.

	5. Construction and Demolition Waste Management	The construction and demolition (C&D) waste comprising mostly of inert and non-biodegradable materials, such as concrete, plaster, metal, wood, and plastics, are being dumped haphazardly, and a part of this waste is getting mixed up with the municipal waste. Local residents are also utilising it for plinth-filling works. Presently, SMC does not have a record of the quantity of waste generated/ dumped daily in the city (SWM, DPR 2019). C&D waste has to be stored within the premises of the construction site either in skip bins or suitable containers and must be either directly emptied at the notified disposal site or transported by availing the municipal facility. However, the C&D waste is used for filling up the low-lying flood-prone area. Not much of C&D waste finds its way to the municipal MSW system.
	6. E-Waste Management	Presently, SMC does not have an E-waste collection, transportation, or processing facility.

19.3.1 MSW Employees

Employees include the cumulative staff who are permanently employed as well as the staff under contract or daily wages including 715 sweepers, 779 sanitary workers, and 54 health/ sanitary workers. A Sanitary Inspector manages the day-to-day operations of the SWM Department comprising collection, transportation, processing, and disposal.

Moreover, the workers are also involved in waste segregation and composting at the SBESPL plant.

Table 19-3: MSW Staff

Manpower	Number of Permanent	On Contract
Drivers	1	127
Loaders and helpers	-	161
Sweepers	715	-
Sanitary Workers	779	200 (daily wages)
Supervisors	-	6 (on contract basis)
Health/ Sanitary Inspectors	54	-
Rag-pickers/ junk dealers	298	-

Source: SWM DPR (2019)

19.4 ON-GOING INITIATIVES

Table 19-4: On-going initiatives

Waste Segregation, Collection and Transport	Organic Waste Management	Dry waste Management	Landfill
• 30% segregation at source and a push for increased practice • 100% door-to-door collection in residential and commercial premises • Segregated waste collection from hotels and restaurants • 4 transfer station created and 4 more in the process • Machinery and manpower are trying to manage waste transfer	• 300 TPD capacity bio-methanation has been installed • Installed screening through a segregation facility for organic waste • An average of 4-MW electricity is generated, which is used for running the plant and excessive energy transferred in grid • Average 20-25 tonnes of compost generated and sold to the district farmers as fertiliser	• Dry waste converted to RDF and sent to the nearest cement factory for incineration • Informal practice of plastic and paper waste collected by rag pickers and waste collectors and sold to vendors in an unauthorised way • One MRF centre has constructed at landfill site and four more are proposed for higher level of waste segregation	• Only legacy waste at the landfill • Planning On-going for C&D waste process • Landfill bioremediation tender is already allotted and process will be completed by 2025

19.5 KEY GAPS AND CHALLENGES

- **Lack of waste segregation at source**: The city claims that 30% of segregation happens at source. SMC manages the collection and transportation of waste. the remaining process under waste management, including waste segregation, composting, and recycling, is the responsibility of SBESPL. Unsegregated waste reduces the quality of waste meant for waste-to-energy plants. The bioenergy plant sources wet waste from nearby farms for further composting and bio methanation processes. The entire system must be designed to fill the necessary gaps.
- **Lack of Awareness/ Communication:** The city does not have adequate information and, therefore, lacks formal training in sustainable waste management practices. The staff are mostly contractual. They lack education and, therefore, might lack an understanding of the processes of waste segregation. There is a need for formalisation, provision, and use of adequate safety equipment, social security in the form of insurance and regular medical check-ups and training for the staff.
- **Lack of Waste Segregation practices:** Due to lack of awareness, people refrain from segregating their waste, and so do the commercial establishments. It is unfair to expect waste workers to segregate waste. The workers-to-population ratio is 0.15. There is a need to bring in additional players through the provision of financial and administrative

support through implementation mechanisms.

- **Absence of Measuring, Reporting and Verification and Material Recovery Facility station**: Due to the absence of Measuring, Reporting and Verification **(**MRV) or Material Recovery Facility **(**MRF) at the community level, dry waste collection is not being facilitated. As a result, plastic paper and other waste, which is easy to recycle and reuse, is sent for incineration. There is an informal practice to separate dry waste during waste collection, but very few waste collectors practise it. The segregated waste is then sold to vendors at a very nominal price.
- **Lack of vision in waste recycling and reuse:** The city lacks vision to implement waste reduction, recycling, and reuse practices. SMC manages the transportation of waste to the landfill site, where most of the vehicles are diesel-operated. Therefore, all the vehicles have direct emissions as per their every kilometre trip with less efficiency.
- **Delay in setting up the C&D waste system:** There is a gap in terms of the quantity of C&D waste processed and generated . As per the SWM DPR, the city has already planned and begun the process for C&D waste structures on the ground but very little has been implemented. That is the impact of a lot of C&D waste and other inert materials sent to the landfill.
- **No provision for E-Waste:** The city is facing challenges to implement basic segregation practices at source. The also city does not have the capacity to make provisions for e-waste collection and the associated processes.

19.6 RECOMMENDATIONS

19.6.1 Sectoral Aspiration

"Zero emission through efficiently managing municipal solid waste with various initiatives of waste to energy, recycle, and reuse practices in the city".

19.6.2 Sectoral Strategy

1. **Strategy SW-1:** Achieve 100% segregation of waste at source and promote community-based organic waste management by 2030.
2. **Strategy SW-2:** Zero landfill approach towards waste management with focus on reduce, reuse, recycle and recover by 2040.
3. **Strategy SW-3:** Adopt sustainable and inclusive practices for waste management and fuel usage by 2030

19.6.3 Strategy-wise Actions

Table 19-5: Strategy SW-1: Achieve 100% segregation of waste at source and promote community-based organic waste management by 2030.

Action description	Stakeholders	Indicators
Strengthen the community-based organic waste management so that it can become a complimentary system to the existing centralised wet waste management system in the next 4-5 years. This can be done by taking up a series of interventions and actions, as given below: • Promote a minimum of 3 levels of waste segregation: Wet waste, Dry waste and hazardous waste. • Provide training to the workers involved in waste collection and rag pickers for sorting, aggregating, and recycling dry waste. • Promote composting of wet waste at home, building societies, public and private institutes, hotels, hospitals, and hostels • Distribute home composting kits in selected wards as a pilot to increase the uptake of composting activities and generate awareness. • Set up compositing pits in parks and gardens, enable composting of garden waste • Set up Organic Waste Converter (OWC) infrastructure at every ward level with community support • Promote zero waste wards or society with citizen incentives for the segregation efforts through rebates in property tax or solid waste tax. Organise Best Society award competition for segregation at source, and support in community OWC operations. **Best practices:** **Alappuzha** embarked on a project called Clean Home Clean City that focussed on source segregation as the first and foremost step towards effective waste management. **Panaji** has worked over the last 15 years to achieve 99% segregation. Primary segregation was done in two or four bins by the households. **Mysuru:** The game changer for Mysuru was the zero-waste management plants in each zone that received segregated biodegradable fractions of solid waste from five wards on average. **Timeframe: 2030**	Lead: SMC Support by: Education institutes, Experts, NGOs, SHGs and other related departments. **Finance:** Swachh Bharat Mission fund; SMC budget; CSR; Multinational funding MLA	**Output:** No. of societies or institutes adopted management of wet waste through composting No. of awareness programmes conducted Reduction in waste generation (%) Wet waste composted (%) No. of parks with composting pits for garden waste No. of manpower trained; No. of OWC installed. **Outcome:** Improvement of waste segregation at source (%) Waste reduction to transfer station (%) Segregated waste collected (%) Organic waste processing at the community level (%)

Table 19-6: **Strategy SW-2: Zero landfill approach towards waste management with focus on reduce, reuse, recycle and recover by 2040**

Action description	Stakeholders and Finance	Indicators
Strengthen the existing centralised bio-methanation and composting processes by facilitating supply of segregated wet waste by undertaking key actions and interventions as given below: • Promote segregation of waste at source to ensure supply of segregated organic waste from residential, hotels, restaurants, and APMC market to the centralised site. • Identify and mandate Bulk Waste Generators (BWGs) to manage their own waste, and undertake composting and bio-methanation at their level • Promote IEC activity for citizens and stakeholders creating awareness on wet waste segregation, and provide training to the waste collectors for wet waste management **Timeframe: 2025-35**	Lead: SMC Support by: SBESPL, SBM, Consultants, NGOs, SHGs etc. Finance: SMC funding; SBM funding; Development bank; NCAP, CSR	**Output:** No. of BWGs identified and processing waste Quantity of compost and biogas generated; No. of societies/ institutes engaged **Outcome:** Emissions reduced (%) Wet waste going to landfill reduction (%)
Strengthen the centralised dry waste management by facilitating supply of segregated dry waste by undertaking key actions and interventions as given below: • Promote segregation of waste at source to ensure supply of segregated dry waste from residential, hotels, restaurants, and APMC market to the MRF facilities. • Identify and mandate BWGs to manage their own waste and mandate them to send dry waste to the designated MRF facilities. • Increase MRV/MRF centres for collection, segregation, and transfer of recyclables to the recyclers. • Promote IEC activity for citizens and stakeholders creating awareness on wet and dry waste segregation, and provide training to the waste collectors for wet and dry waste segregation • Implement city-level policy, enforce a bylaw for green procurements and a ban on single-use plastic (SUP) in government buildings, and carry out waste audits. Jamshedpur has proved to be a model of material recovery by establishing Dry Waste Collection Centres (DWCCs) to manage its non-biodegradable waste. Panaji: In 2021, the city implemented 16-way segregation at source. Along with this, several technologies and initiatives for waste management were adopted. **Timeframe: 2025-35**	Lead: SMC Support by: Bio Energy, SBM city cell, Consultants, NGOs, SHGs etc. Finance: SMC funding; SBM funding; Development bank; NCAP, CSR	**Output:** Quantity of dry waste collected and processed No. of MRV/ MRF centres operational No. of societies/ institutes engaged **Outcome:** Dry waste recycled (%) Dry waste diverted from landfill/ incineration (%) Employment generated in the waste sector
Prepare a detailed plan to implement the Extended Producer Responsibility (EPR) mandate in collaboration with the private players Pune has appointed NEPRA Pvt. Ltd for material recovery from dry waste and support in EPR.	Lead: SWM dept, Informal workers/ ragpickers, private operator Finance: Swachh Bharat Mission, NCAP, CSR, PPP	**Output:** SMC adopts a mandate for EPR

Action description	Stakeholders and Finance	Indicators
Take up the following initiatives and actions to comprehensively manage the C&D waste: • Set up a system for data collection and monitoring of C&D activities in the city at ward or zonal level • Set up C&D waste management for collection, transfer, and recycling facility for waste processing with desired capacity on PPP-based or other business models. • Enforce C&D Waste management rules for efficient execution of duties by waste generators, service providers, and the local authority. • Adopt better construction management practices aimed at the reduction of C&D waste by 30% North Delhi: The C&D waste plant is currently scientifically processing 2,000 TPD of mixed C&D waste and converting it into aggregates, which in turn is converted to ready-mix concrete, cement bricks, hollow bricks, pavement blocks, kerbstones, concrete bricks, and manufactured sand, thereby reducing the consumption of virgin construction raw material and minimising the environmental hazard due to C&D wastes. **Timeframe: 2025-30**	Lead: SMC Support by: Outsourcing agencies, consultants, experts, waste processors, technologists Finance: SMC funding; SBM funding; Development banks; Amrut scheme; PPP based	**Output:** No. of C&D waste plants implemented. Quantity of C& D waste collected and make reusable as bricks, concrete, etc. **Outcome:** Emissions reduced (%); Dry waste diverted from landfill/ incineration (%)

Table 19-7: Strategy SW-3: Adopt sustainable and inclusive practices for waste management and fuel usage by 2030

Action Description	Stakeholders	Indicators
Use recent technologies for efficient waste management - • Carry out route optimisation for efficient transportation of primary and secondary waste to reduce through GIS-based tracking • Carry out 100% surveillance of waste movement in the city (including formal and informal systems), monitoring/tracking/record keeping of waste recovered by the informal sector (especially at waste management facilities)	**Lead:** SWM Dept. - SMC **Support:** Transport dept, rag pickers, private contractors etc	**Output:** No. of trips reduced **Outcome:** VKT reduced
Improve the living standard of waste pickers by - • Conduct surveys, and register the existing rag pickers to form an informal sanitary workforce • Provide better work conditions to waste collection workers (social security, medical health check-ups), especially women (better lighting, security and washrooms at Integrated facilities and MRF facilities).	Lead: SMC, NGO, and Civil partner organisations, Health dept Finance: SMC own sources, NCAP, Swach Bharat	**Outputs:** No. of informal sanitary waste workers registered No. of health check-ups in a year **Outcome:** Qualitative reporting on improved quality jobs
Promote tri-cycle-based dry waste collection to promote NMT in waste transfer. **Timeframe: 2030**	Finance: SMC funding; SBM funding; Mayoral / Corporator, MLA or MP grants	**Output:** No. of tricycles used for dry waste collection **Outcome:** Emission reduced (%), Diesel cost reducted (%)

DR.BABASAHEB AMBEDKAR UDYAN
Photo credit: Pravin Gaikwad

20. RECOMMENDATIONS- URBAN GREENING & HEAT RISK

20.1 SECTORAL OVERVIEW

Being a part of the semi-arid region, Solapur receives an average rainfall of 725 mm. Semi-arid regions are often thought of as being particularly vulnerable to climate change. Semi-arid ecosystems are highly dynamic, with bursts of productivity in the wet season in good years and very low productivity in dry years, often leading to temporary or longer-term land degradation. Such climatic conditions are known to be climatically stressed with high temperatures, lower rainfall, and longer dry seasons.

Increasing urbanisation (and by effect, concretisation), higher densities, and the depletion of the city's green cover have resulted in the urban heat island effect, creating pockets of extreme heat exposure across the city.

The assessment of urban heat risk under Vulnerability Assessment (VA) is done by analysing non-spatial and spatial parameters. Non-spatial parameters include air temperature and night-time Land Surface Temperature (LST). The spatial analysis of heat risk uses MODIS night-time LST data at the district level to study LST difference between urban areas and the rural peripheries and day-time LST data from Landsat (USGS) that helps identify local areas more exposed to heat stress.

In the VA, a few key observations were made regarding the rising urban heat risk in the city:

The annual air temperature trend analysis shows that annual mean air temperatures rose by 0.1°C per decade between 1975 and 2021. The baseline temperature for the city, 27.7° C, was also the annual average temperature between 1981 and 2010. In total, 22 years were warmer than the baseline average in the period between 1975 to 2021.

- Under the Seasonal Air Temperature Trend, monsoon shows relatively the most rapid increase in temperatures, followed by winter and then summer, which implies that the monsoon season is seeing more high-temperature days than the other two seasons.
- An increasing trend of 8.7 hours every year is getting added to the time the city spends in extreme heat waves. The years 2010, 2016, and 2019 were three of the hottest in this period, with 53, 50, and 49 days classified as extreme heat wave, respectively.
- Heat Index: The combined number of days in the categories of 'caution' and 'extreme caution' are increasing at the rate of one day per year. Despite a perceived temperature range of 26°C -32°C or 32°C -39°C is not unusual for the city of Solapur, the increasing trend needs attention and causes problems to the micro-climate of the city.
- LST (UHI): In the case of Solapur, a rising trend of 0.03 degree Celsius per year in the monthly mean night-time LST has been observed in the last two decades i.e. from 2001 to 2021.

20.1.1 LST Hotspots

The built-up areas within the city are the main contributors of UHI, and these areas have higher population density as compared with the periphery. Hence, the LST within built-up areas is considered here. In the built areas of the city, the average LST during the pre-monsoon period remained in the 33°C - 37°C range, as shown in Figure 20-1 In the post-monsoon duration, the LST ranged from 23°C to 31°C for the city, with evidence of greater spatial differentiability pushing some areas to higher LST than others. A persistent example of soaring LST is the Solapur airport, a classic example of high surface temperatures that host a large area with bare soil and asphalt/concrete runways. During summers, the LST in and around the airport can rise to 45°C.

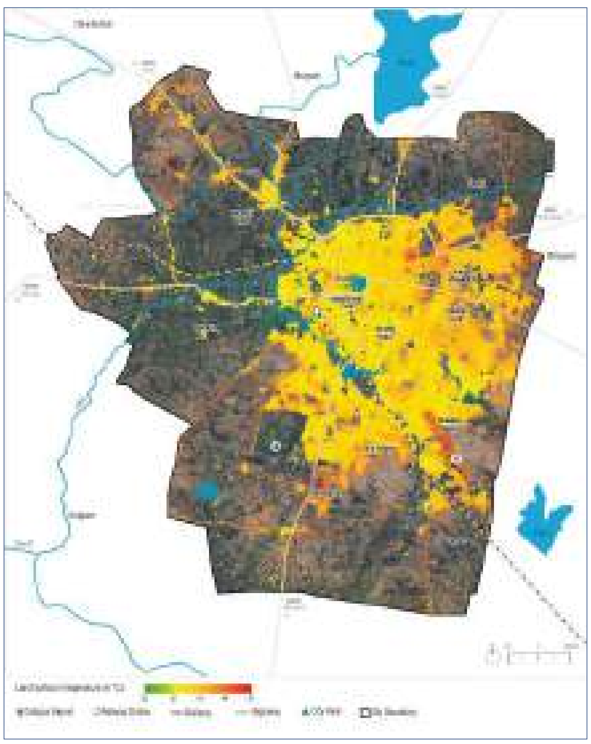
20.1.2 Correlation between LST and Vegetation

The presence of vegetation can influence the LST of an area. Vegetation and LST have an inverse correlation. The presence of vegetation is mapped through Normalised Difference Vegetation Index (NDVI) using Landsat satellite data.

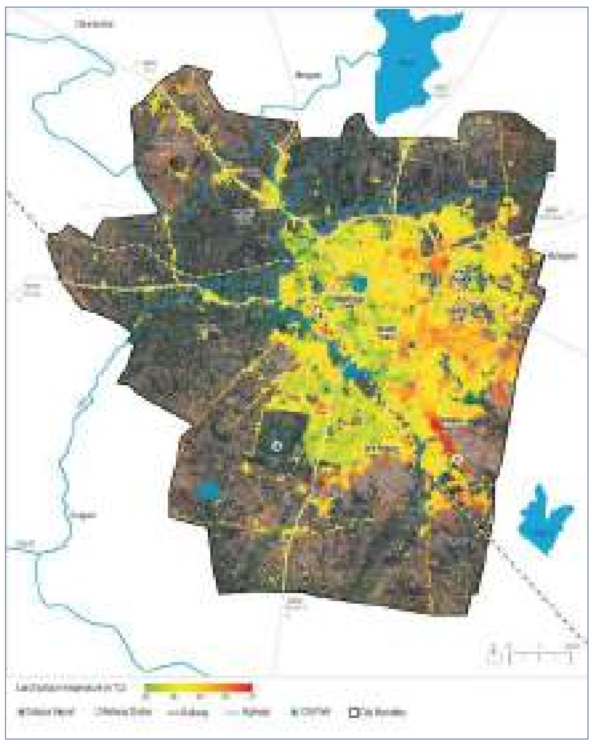
The city has large agricultural land parcels within the corporation boundary. Due to these seasonal crops, in the Rabi months (October, November, and December), the areas with cropland showed higher vegetation and lower LST. However, these effects are seasonal and do not contribute towards lowering the LST throughout the year.

Figure 20-1: **Mean Land Surface Temperature for pre and post monsoon (2019-2021)**

a) Pre monsoon summer months (April & May)



b) Post monsoon winter months (October – December)

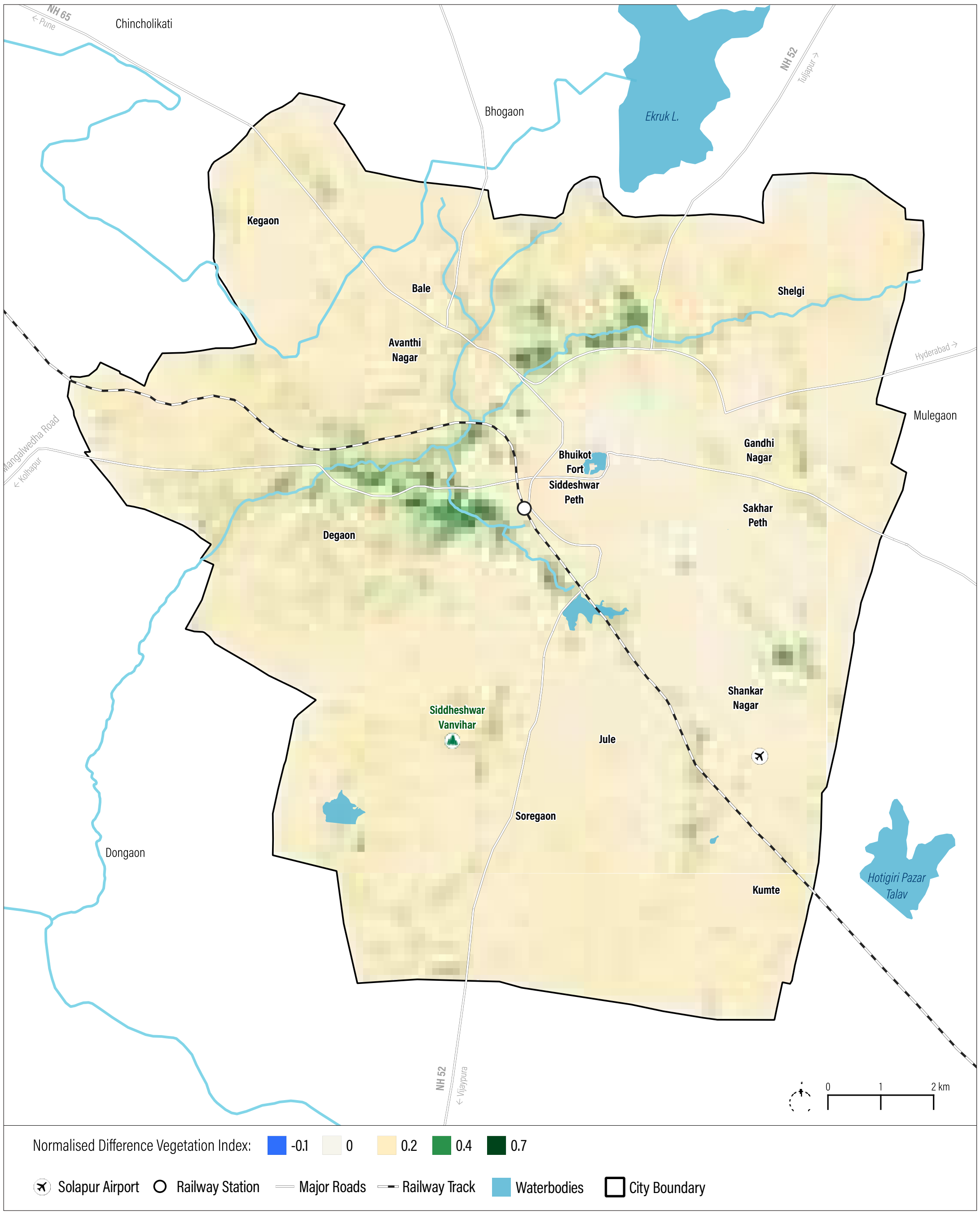


Source: WRI Analysis using Landsat 8, USGS, 2022

The green areas maintained near Bhuikot fort and Mahatma Gandhi Zoo are at lower LST due to the higher vegetation than the surroundings but have very less effect on the overall microclimate of the area.

The city LST values for post-monsoon months reduce by 31% as compared with the temperature values during pre-monsoon.

Figure 20-2: Mean NDVI for all months (2019-2021)



Source: WRI India analysis, Landsat 8 data between 2019 – 2021

20.1.3 City Open Spaces

As per URDPFI, open spaces are classified into three. These are recreational spaces, organised green, and other common open spaces (such as vacant land, open spaces including flood plains, and forest cover) in plain areas.

As stated, the city has large plots of agricultural land within the SMC boundary with 28.5% i.e. about one-third of the city area within the municipal limit is built.

The open space types in the city have been sub-categorised as:

- Type 1: Other common open spaces: Agricultural land/Cropland, Fallow land, Scrubland, Undeveloped built/barren
- Type 2: Recreational spaces: Gardens and Parks, *Maidan* and playground, Zoo, Fort
- Type 3: Organised green: Biodiversity park, Tree plantation

In the case of Solapur, open and recreational spaces comprise 2.03 square km. and the area under biodiversity park, zoo and plantations is 3.03 square km, as per the Revised City's Development Plan (2019). So, the open space is 0.20 square metres/ person, which is lower than the URDPFI norm of 10-12 square metres per person.

The green area comprising gardens, parks, and plantations is 5.05 square km, which is 2.89 % of the city area and 17.68 % of the built area of 28.5 sq.km. Additionally, the cropland, fallow land, scrubland, and barren land comprise 104.07 sq.km area, which is 58% of the city area.

The categorisations are made to be able to distinguish the type of interventions and actions basis the jurisdiction or authorities that manage the area. For instance, in Solapur, the biodiversity park is under the jurisdiction of the District Forest Office (DFO), the gardens and parks are with the Gardens Department, the Sports Department manages the upkeep of the playgrounds and indoor stadium, and the Social Forestry Department is responsible for the tree plantation activities in areas under their jurisdiction.

Table 20-1: Subcategories of Open spaces

Type	Area (sq.km)	% of SMC area
Cropland, Fallowland, Scrubland, Barren	104.071	58%
Open/Recreational	2.034804	1.13%
Biodiversity Park/Plantation (City Greens)	3.035577	1.69%

Refer to land use map Figure 2-2
Source: GIS data, SMC

Table 20-2: Details of Open spaces sub-categories within SMC

Department	Jurisdiction	Area/land under dept.	Roles
Gardens	City limits	43 gardens	Maintenance of gardens, Recharge pits, tree plantation (under SMC), recreational spaces
Sports	City limits	39 playgrounds + 1 sports centre)	Maintenance of playgrounds and indoor stadium
Social Forestry	City limits	0.17 sq. km (2 locations)	People-based tree plantation in barren/fallow lands, road side plantations, environmental awareness
District Forest Office	District + City	1.96 sq. km (Siddheshwar Vanvihar) Maldhok Bird Sanctuary: Deccan_thorn_scrub_ forest	Various species of trees and grasses have been planted, Miyawaki sites (location), Seed ball workshop, bird watching, painting competition, plantation[49]

Source: SMC data (2021)

There are altogether 37 gardens / parks in the SMC area, which are maintained by SMC. Of these, Mahatma Gandhi Bag located near Solapur fort is considered as a city-level park. The others are scattered across the city and serve mainly as neighbourhood parks. Additionally, 12 gardens are developed as part of AMRUT. There are 39 playgrounds in the city.

The major recreational/play areas in the city are Indira Gandhi cricket stadium located near park maidan. The maintenance of the stadium, which is spread across an area of 6 acres, is the responsibility of the SMC. Another stadium called Jila Krida Sankul (District Play Ground) within the SMC area is managed by the District Sports Authority.

Although agriculture is practised in Solapur city, data on details of the agriculture practices within the city has never been collected. A substantial proportion of land also remains undeveloped/ barren and agriculture practices have been discontinued for the purpose of construction, etc. There is a need for further introspection needs to be done in this regard.

20.1.4 Access to Public Recreational spaces

Public recreational spaces like parks, gardens, playgrounds ;and *maidan*s act as cushions during floods and as temperature dampening resources at both neighbourhood and city levels. Proximity to such spaces reduces long-term exposure to both higher air pollution levels and high surface temperatures. On the other hand, greener areas have greater carbon sequestration potential and are needed in any climate-resilient city.

Although the per capita open space availability is low, the accessibility to public recreational spaces is comparatively higher. The accessibility analysis conducted as a part of VA revealed that 65.1% of Solapur's population has access to public recreational spaces within the threshold values distance of 1 km within 10 minutes, while 34.9% does not have access to any parks, gardens, playgrounds, maidans within 1 km. Higher density areas in and around Sakhar Peth, Rajiv Nagar, Old Rangraj Nagar, Ashanagar, Shankar Nagar, and Dyaneshwar Peth lack ease of access to such facilities (within 10-minute walkable distance or 1-km service radius) Refer to annex 2-21 for map

20.1.5 Linkage between trees and LST

Treeless urban green spaces are overall less effective in reducing LSTs, and their cooling effect is approximately 2-4 times lower than the cooling induced by urban trees.

20.2 CARBON SINKS

In Solapur, cropland, fallow land, scrubland, and barren land constitute 104.07 square km, which is most of the land area of. On the other hand, open and recreational spaces cover 2.03 square km area and the area under biodiversity park, zoo and plantations is 3.03 square km as per the city's revised Development Plan 2019. The built area is 28.5% of the area under SMC.

To calculate the carbon sequestration potential for 3,50,000 trees, the Removal factor for trees outside forest (ToFs) and trees within the biodiversity park under protected forests has been considered.

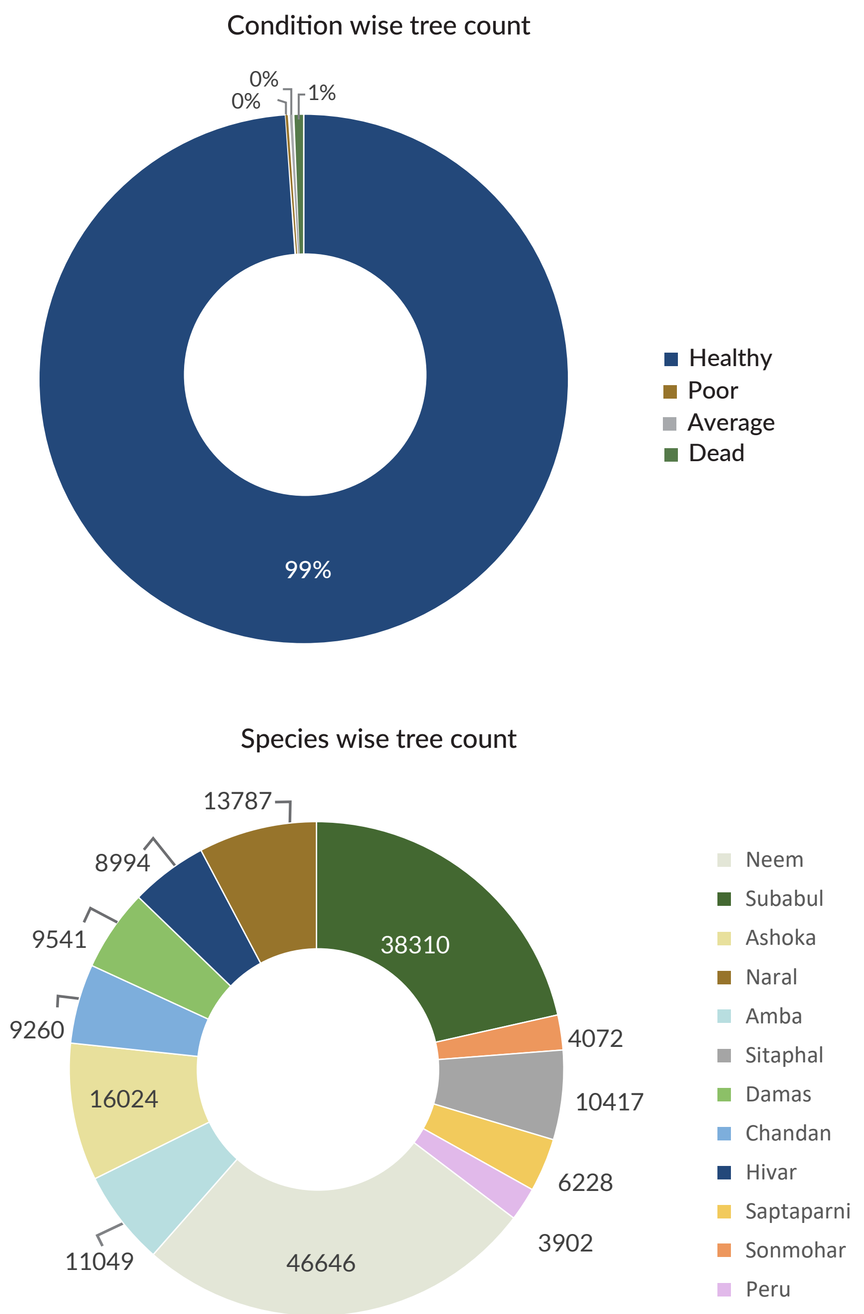
The Ekrukh lake in Hipparga village is an artificial lake close to Solapur city, around 8 km towards the north-east. The water reservoir formed by an earthen dam on the Adela River has a capacity of 3,330 M.Cu.Ft and is 7,200 feet long and 72 feet high. It has three canals. Besides water for irrigation and domestic use in villages, the lake supplies drinking water to Solapur city. However, the lake is outside the city limits and, therefore, not considered for calculation the carbon sequestration potential. However, the lake plays a huge role in maintaining the microclimate of the city.

- Removal Factor for ToF in Solapur = 2.8 MgC/ha/year
- Removal Factor for forested area in India = 0.299 MgC/ha/year
- The assessment from the typologies of vegetation in Solapur for the current year shows that in protected forests 4.108328 MT of CO_2 is removed. In TOF, 824.6408025MT of CO_2 is removed in a year

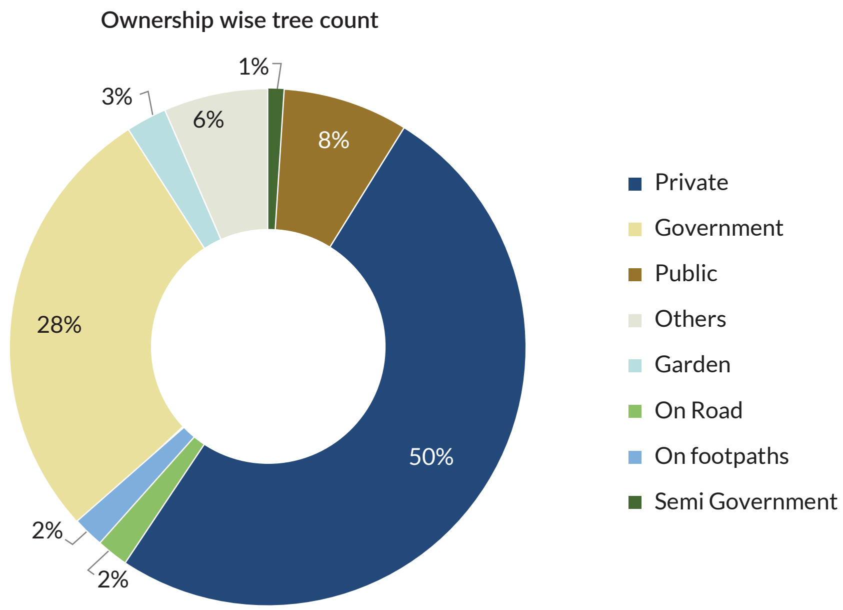
Note: The calculation is done for 350000 of 500000 trees in the SMC.

- The tree census for the city also collected data on tree conditions, tree species, and ownership, as shown in the graphs (Figure 20-3).
- The total number of tree species are 258 and the rare species number 36.
- The species-wise number of trees are Subabul 52989, Neem 45245, Naral 15576, Sitaphal 13440, Amba 12148, Damas Tree 12087, Ashoka (D) 10812, Chandan 9676, Saptaparni 8994, and Ashoka 7024.

Figure 20-3: Metrices from Tree Census (2022)



Source: Tree Census (2022), SMC



20.3 KEY GAPS AND CHALLENGES

- **Inadequate data for monitoring heat / temperature rise:** IMD requires data from two stations to be considered before declaring heat wave and extreme heat wave. However, that was not possible in the case of Solapur as data from only one station was available and, hence, this requirement was not considered.
- **Lack of and access to recreational spaces:** As per the URDPFI norms, there is a huge deficit in the area required for parks and playgrounds, and the identification of land for recreation in the core city is a challenge. The current space provision is 0.20 square metres per person, which is lower than the URDPFI norm of 10-12 square metres per person.
- **Maintenance of green spaces:** Both city-level and neighbourhood parks needs upgrading. Public gardens needs adequate maintenance in the absence of which there is a fear that unused parks and gardens in the high vicinity of the traffic areas to being converted to parking spaces since they are no longer used for recreational purposes .
- **Lack of financial and other resources:** The financial assessment of the corporation states that only 2% of the total revenue is spent on the preservation of parks and gardens. This may be due to the scarcity of water in the city.

20.4 ON-GOING INITIATIVES

1. **Tree Census:** The tree census has been done for 350,000 out of 500,000 trees in Solapur. It is an On-going activity undertaken by the Environment Dept at SMC. Each tree has been sampled, and information on girth (cm), height (m), canopy diameter, condition, ownership, GPS location, ward numbers, age and family has been captured. This information is useful for calculating the carbon sequestration potential and spatial ward-level analysis for area under trees.

2. **Tree plantation activities/ urban forestry:** With the help of SMC Officers, NGOs, NPOs,

private institutes, environment organisations, citizens, etc., SMC has planted more than 10,000 local indigenous trees in and around Solapur city through various programmes. SMC and the Forest Department with public engagement have developed dense forestation at the Hon'ble Collector's house, Siddheshwar Vanvihar, SRPF Camp, and Nehru Nagar ground. SMC has also planted and conserved 2500 trees on the dividers between the roads under this campaign.

3. **Proposed Biodiversity Park –** Tourist Place at Kegaon, Solapur: SMC with public engagement has developed a 47-acre land allocated for picnic as a Biodiversity Park. As of today, 14,500 endemic trees have been planted here. Also, this park includes a natural lake body and several newly developed watering holes for birds and wild animals. Trees have been specially protected and are irrigated through drip. An alpine rock garden has also been created in this park. This garden will attract tourists and provide a tranquil city life.

Figure 20-4: Vanvihar/ National Park

The SMC has reserved 47 acres of land for Miyawaki plantation. The estimated budget is INR 14 crore.

Figure 20-5: Miyawaki plantation sites

4. **SMC is planning to develop Nakshatra garden and an ayurvedic park at Bhogaon.** A zoo and three nurseries already exist in the SMC.

- **Ayurvedic Garden:** Land used by a garbage depot has been reclaimed and an ayurveda garden, children's park, and ayurveda nursery have been developed by SMC. Under Majhi Vasundhara Abhiyan, about 50,000 trees have been planted within city limits and more than 500 heritage trees have been identified and conserved.

5. **Tree bank:** The initiative gathers trees from donors with the purpose of conserving it. Under the Majhi Vasundhara Abhiyan citizens of Solapur city and SMC employees have been planted more than 50,000 various types of trees in SRPF camp, Siddheshwar Forest & city areas.
6. **Awareness drives**

- Cyclothon 2022- competition on 1 January 2022
- Green school/college competition for increasing green cover (2 lacs)

7. **Rainwater harvesting:** 2% concession in tax
8. **People Biodiversity Report (PBR):** Solapur Municipal Corporation has prepared a PBR report of the city area and submitted the same to the Forest Department of the Govt of Maharashtra on January 31, 2021.

20.5 RECOMMENDATIONS

20.5.1 Sectoral Priority

"Increase open spaces and their accessibility within developed/ built-up areas. Reduce heating effect through greening measures, and increase heat resilience".

20.5.2 Strategies and Actions

Key strategies are as follow:

Strategy UG-1: Increase per capita recreational areas by enhancing green cover and other recreational spaces, and in turn improve surface permeability for groundwater recharge to 30-40% by 2030.

Figure 20-6: Reclaimed land converted to Ayurveda garden

Image source: SMC (2021)

Strategy UG-2: Enhance, maintain, and preserve tree cover in the city, and increase the healthy green cover to 10-15% by 2030

Strategy UG-3: Reduce heating effect through greening measures by 2040

Strategy UG-4: Increase awareness and sensitization to help restore, maintain, and enhance the city's biodiversity ecosystem

Table 20-3 Strategy UG-1: Increase per capita recreational areas by enhancing green cover and other recreational spaces, and in turn improve surface permeability for groundwater recharge to 30-40% by 2030.

Action description	Stakeholders & Financing	Monitoring Indicators
Priority Action: Increase per capita recreational areas (gardens, parks, playgrounds) on the basis of norms in the revised DP 2041, and plan and provide for new recreational areas in areas with lack of access to spaces around Sakhar Peth, Rajiv Nagar, Old Rangraj Nagar, Ashanagar, Shankar Nagar, and Dyaneshwar Peth Integrate public open recreational spaces (such as gardens, parks) with artificial recharge pits or percolation pits for groundwater recharge. **Time frame: 2030**	Lead: Gardens dept.SMC Support: Sport dept., Town planning dept Finance: NCAP, SMC Budget, AMRUT, CSR	**Output:** % increase in per capita recreational areas (%) (green cover and other recreational spaces) **Outcome:** Reduction in land surface temperature at hotspots (degree Celsius), Increase in groundwater recharge (%) Increase in per capita green cover in low-income areas (%) Population with improved access to open/recreational spaces (%)
Priority Action: Adopt critical measures for sustainable management of green spaces, including the following: Considering water scarcity in Solapur, use treated wastewater from STP for watering green spaces through tankers or dedicated pipelines • Waste management and composting system for garden waste management • Introduce newer sources of funding, such as CSR, for the maintenance of greens, and construction and maintenance of percolation pits in the green spaces. **Time frame: 2025**	Lead: Gardens dept-SMC Support: Volunteer groups, NGOs Finance: SMC Budget, AMRUT, CSR	**Output:** No. of public spaces jointly maintained and co-owned, No. of composting pits set up, Quantity of secondary treated wastewater utilised for gardening (Litres per day), **Outcome:** Increase sense of ownership of the public spaces, Amount of waste composted (kg per day), Decrease reliance on water from the water supply system (%)

Table 20-4 Strategy UG-2: Enhance, maintain, and preserve tree cover in the city and increase the healthy green cover to 10-15% by 2030

Action description	Stakeholders & Financing	Monitoring Indicators
Priority action: Enhance, maintain, and preserve the tree cover in the city through the following initiatives • Complete the tree census, use the data for estimation of carbon sequestration potential and mapping the biodiversity • Increase the number of greens through reserved space for carrying out undisturbed plantation activities • Mandate the use of native species for tree plantation activities • Capacitate the officials to measure and analyse the carbon sequestration potential basis requirement **Time frame: 2025**	Environnent Dept, DFO, Social forestry cell, Gardens dept, NGOs, Civil society organisations Finance: DFO, Municipal budget, AMRUT, External grants, CSR	**Output:** No. of trees mapped, No. of additional parameters in tree census data collection, Area (in hectares) of land reserved, Officials capacitated (%) **Outcome:** Increase in green cover (%), Increase or decrease in tree cover (based on old records) (in sqkm), Change in carbon sink capacity (%)
Priority action: Document, map, and preserve biodiversity within Solapur city through • Identification, mapping, documentation, and scientific management of urban forests and rich biodiversity areas within the city • Demarcation of these areas as biodiversity zones and • Updating the People's Biodiversity Report (PBR) regularly through a dedicated app-based system and dashboard • Create awareness programmes among citizens and students, and promote research on local flora and fauna **Time frame: 2025**	Environnent Dept, DFO, Social forestry cell, Gardens dept, Town Planning Dept, Land Dept, NGOs, Civil society organisations Finance: SMC budget, AMRUT	**Output:** Documentation of biodiversity in the city, No. of new native species planted **Outcome:** Native species conserved and preserved (%), Citizen participation in conservation and preservation measures

Table 20-5: Strategy UG-3: Reduce heating effect through greening measures by 2040

Action description	Stakeholders & Financing or Funding mechanism	Indicators
Priority Action: Prepare a Heat Action Plan (HAP) for Solapur city based on the guidelines of the Government of India and learning from HAPs of other Indian cities like Ahmedabad and Bhubaneshwar with a focus on the following areas - • Building on heat mapping under the vulnerability assessment, further probe into the heat hotspot areas within the built fabric and undeveloped areas in the city • Upgrade the monitoring station for recording air temperature data to measure 'heat' and 'extreme heat' days in the city • Consider greening efforts and tree lining along major road corridors, integrate landscaping with storm water drains for increasing permeability • Deploy budgeted NBS solutions in slum and low-income neighbourhoods experiencing extreme heat stress • Early warning systems and precautionary measures for relief • Increase albedo of roofs and pavements – based on LST hotspots areas • Train and capacitate health workers, caregivers in documenting, identifying, and treating heat-related illness **Time frame: 2027**	Disaster Management Dept, Health Dept, PR dept, Gardens, Roads dept, SWD, buildings dept Finance: SMC Budget, NCAP, AMRUT, CSR	**Output:** No. of air monitoring station recording air temperature data No. of health warnings issued in summer months No. of heat hotspots/ areas identified No. of workshops, awareness drives organised No. of trees planted across identified corridors **Outcome:** Spatial variability in heat and extreme heat days experienced (record temperature difference) Coping mechanisms adopted Measures taken to mitigate the heat No. of people (including health workers) trained and capacitated on heat measures
Priority Action: Create an enabling environment for the mitigation of heat risk through • Maximising utilisation of undeveloped and barren lands, especially in areas exposed to high heat for small-scale greening purposes, and adopt tree lining to reduce exposure to bare soil • Amend building regulations for newer developments to integrate green roofs and farming at terraces to incentivize greening measures • Document urban farming practices and changes in cropping patterns within city premises **Time frame: 2026**	Land, Town Planning, SMC, Land/ farm owners, Gardens Dept, Environment Dept, Water dept Finance: SMC budget, NCAP, AMRUT, CSR	**Output:** Reduction in undeveloped/ barren land (%) No. of greening initiatives in the city **Outcome:** Reduction of water-intensive cropping patterns, ground water monitoring

Table 20-6: Increase awareness and sensitization to help restore, maintain, and enhance the city's biodiversity ecosystem

Action description	Stakeholders & Financing	Indicators
Priority action: Increasing awareness and sensitisation to help restore, maintain, and enhance the city biodiversity ecosystem through • Involve citizens in afforestation and regeneration activities • Develop a city dashboard to access information regarding urban greening and heat island to monitor hotspots at a city level • Facilitate the development of interactive tools, knowledge share about tree type, etc. – Innovation and uptake for information dissemination • Reduction in tree felling activities for infrastructure development roads **Time frame: Continuous**	Environment Dept, IT Dept., Health Dept. Educational institutes, Roads, Gardens Dept. DFO, Social Forestry Dept. Finance: SMC budget, NCAP, AMRUT, CSR	**Output:** City-level dashboard No. of tools, knowledge share platforms designed by the SMC, No. of tree conserved/preserved. No. of activities and social awareness drives **Outcome:** Type of user group accessing and using the information Maintenance and upgradation of information and data base Reduction in number of tree felling incidences. Area increase in tree plantation (%)

INDIRA GANDHI STADIUM
Photo credit: Abhishek Dulange

21. RECOMMENDATIONS- WATER RESOURCE MANAGEMENT

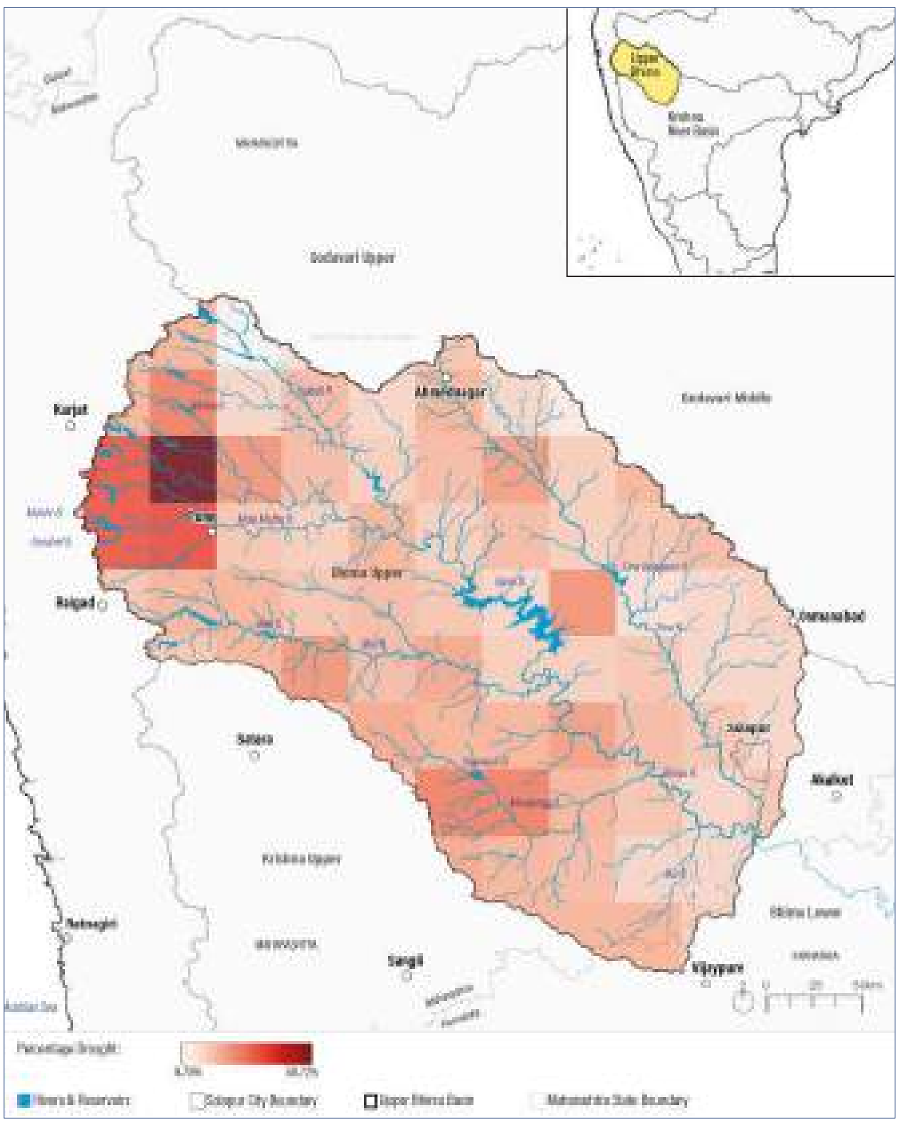
21.1 SMC WATER SUPPLY SYSTEM

21.1.1 Sectoral overview

Solapur city is a dry area, which receives erratic and inadequate rainfall. It receives water from three sources - Ekrukh Tank near village Hipparga about 7 km north of the main city, Bhima River at village Takli about 40 km south of the city, and Ujani Dam reservoir about 100 km west of the city.

The major source of water is the Ujani Dam, which receives water from five upstream dams located near Pune City. The water availability largely depends on the rainfall in the catchment areas of upstream dams located in the Pune region.

Figure 21-1: Location of Ujani Dam and its catchment from Solapur city



Source: WRI India analysis

21.1.2 Water demand and supply

The estimated demand for water in Solapur city is around 191 MLD (2020), and the projected demand for the years 2035 and 2050 is 250 MLD and 298 MLD, respectively[50]. The water supply is around 118 MLD (2019-20), which is around 62% of the demand. In the current situation, SMC supplies water once in four days. Water is supplied to each area at different times on specified dates as per the water supply schedule. Water supply is neither continuous nor is it distributed based on demand. As per the water supply chart, the storage reservoirs are filled a day before water is to be supplied. In some areas, it has been observed that, water is supplied using bypass pumping arrangements and these areas get more water than other areas. The average water supply hour for each area varies between 2 and 2.5 hours[51].

The reasons for inadequate supply levels are high water losses i.e., unaccounted for water (UFW) at 55%, inadequate allocation from sources, substantial evaporation losses in the Ujani Dam, inadequate rainfall within the Solapur catchment area, and water supply distribution network-related issues. The water treatment capacity is 213 MLD.

In 2020, the gap in water supply was around 49 MLD. This gap will be addressed by 2035 when the On-going source augmentation scheme (110 MLD) capacity becomes operational.

To ensure the provision of daily supply of water to Solapur city, the following two phases are planned[52]:

- Phase-1: From Ujani dam to Solapur city a supply of110 MLD, out of which 40 MLD will be treated at the Pakhani WTP and the remaining 70 MLD will be treated at the Soregaon WTP. The tender has been published, and the issuing of the work order is in process.
- Phase-2: Improvement in the distribution system for Solapur city is planned. A DPR has been prepared and submitted for approval.

21.2 ON-GOING INITIATIVES

Details of the On-going source augmentation project are as follow:

- The objective of the project is to lift raw water from Ujani Dam to meet the water demands of Solapur City for the year 2035.

Table 21-1: Water demand and supply scenario in Solapur city

Indicator / Year	2018	2020	2035	2050
Population	10,64,372	10,73,253	12,70,231	14,65,028
Daily water demand, MLD	183	191	250	298
Current water sourced, MLD	142	142	250	220*
Gap, MLD	41	49	0	78

Source: Presentation on water audit of Solapur city – 2022

- The project is designed to supply 110 MLD raw water from Ujani Dam to WTP at Pakni and Soregaon.
- The project will be developed on Design-Build-Maintain-Operate-Transfer (DBMOT) basis.
- It is being funded by SMC through Corporate Social Responsibility (CSR) funds from National Thermal Power Corporation (NTPC) as well as Solapur City Development Corporation Limited (SCDCL).
- The tender has been published, and issuing of the work order is in process.

SMC began a water audit study in 2020 and completed it in November 2022. The key findings emerging from the study are as follow:

- In the absence of metering, there is no reliable data on actual NRW levels. However, as per the study, the estimated NRW is 59%, which is very high.
- The percentage of metered connections (4.7%) is very less.
- A major output of this study is to provide a Bill of Quantities (BoQ) estimates for the construction of proposed Elevated surface reservoirs (ESRs), Supervisory Control And Data Acquisition (SCADA) system, laying of feeder mains and of the distribution network in the entire city, as per the Maharashtra Jeevan Pradhikaran State Schedule of Rates (MJP SSR 2021-22) for improvement of the existing water supply scheme amounting to approximately INR 977 crore.

Projects under AMRUT 1.0

- Underground Drainage Scheme for Solapur Municipal Corporation Area Under AMRUT Mission (2017-18)[53] is aimed towards laying and testing the Sewage Collection System, construction of Sump and Pump house and construction of an STP Cap.20.00 & 15.50 MLD based on MBR Technology) in State of Maharashtra Valued at INR 174,38,45,985.
- Refurbishment of WTPs and civil and mechanical works.
- Under AMRUT 2.0 SMC has proposed the following activities: preparation of hydraulic modelling and master plan creation. Project components included improvements to storage, transmission and distribution network, installing the SCADA system, carrying out water audit, provision of 24x7 water supply and NRW reduction.

SCDCL's key projects identified under SCP related to improving the water supply system of Solapur city are as follows-

- Developing Ujani- Solapur water supply scheme of 110 MLD capacity
- Rejuvenation of Siddheshwar Lake and Develop and maintain the Siddheshwar Lakefront under Smart Cities mission, Solapur.
- Carrying out a water audit
- Improvements to the water distribution system (Dayanand - Ujani bypass) and developing water supply scheme for 3 villages[54]
- Development of Command & Control Centre, developing smart kiosks

- Temporary flow measurements using Ultrasonic flow meters in selected areas
- Construction of Utility Ducts
- Construction of tertiary treatment plant and installation of SCADA system for Sewage Treatment Plants (STPs)
- Operation of secondary STP at Degaon along with associated SPS, and Design, Build, Finance, Operate and Transfer the system for Tertiary Treatment and Reuse of Tertiary Treated Wastewater (UF+RO) for NTPC's Power Plant at Fatatewadi near Solapur on PPP

21.3 KEY GAPS AND CHALLENGES

- The reasons for inadequate supply levels are inadequate allocation from sources, substantial evaporation losses in the Ujani dam, inadequate rainfall within the Solapur catchment area and issues related to the water supply distribution network and water management.
- In the absence of metering, no reliable data on actual NRW levels is available. However, as per the 2022 water audit study, the estimated NRW is 59%, which is very high.
- The percentage of metered connections (4.7%) is very less.
- Rainwater harvesting needs to be a priority for the city.

21.4 GROUNDWATER MANAGEMENT

21.4.1 Sectoral overview

Geologically, Solapur city is covered by Deccan basalt. There is no continuity in groundwater flow, mainly at a greater depth. The shallow aquifers get recharged during monsoon, but due to urbanisation and development associated with it, these are also not replenished fully. There is no aquifer and groundwater level map available at the city level. There are six ground monitoring wells in Solapur district, but none of them are located inside Solapur city.

Groundwater is overexploited due to a demand-supply mismatch within SMC areas. There are 3,270 tube wells, 306 bore wells, and 4 open wells in Solapur city, which highlights the dependency on groundwater. Very few efforts have been taken towards water conservation and rainwater harvesting.

In 2010, it was roughly estimated that there were 10,000 bore wells drilled in the city area, of which nearly 60% were seasonal[55]. It is estimated that nearly 3 MLD of water is made available through groundwater resources. With consecutive drought years and increased extraction of groundwater, more than 60% of the bore wells have been modified to low or no yield. SMC has recorded the locations and status of about 341 borewells owned by the government, but there have been gaps in the data as there are no records of private borewells. A detailed assessment and mapping of groundwater aquifers and a simultaneous mapping of borewells, tube wells, and open wells are crucial for framing groundwater strategy and actions.

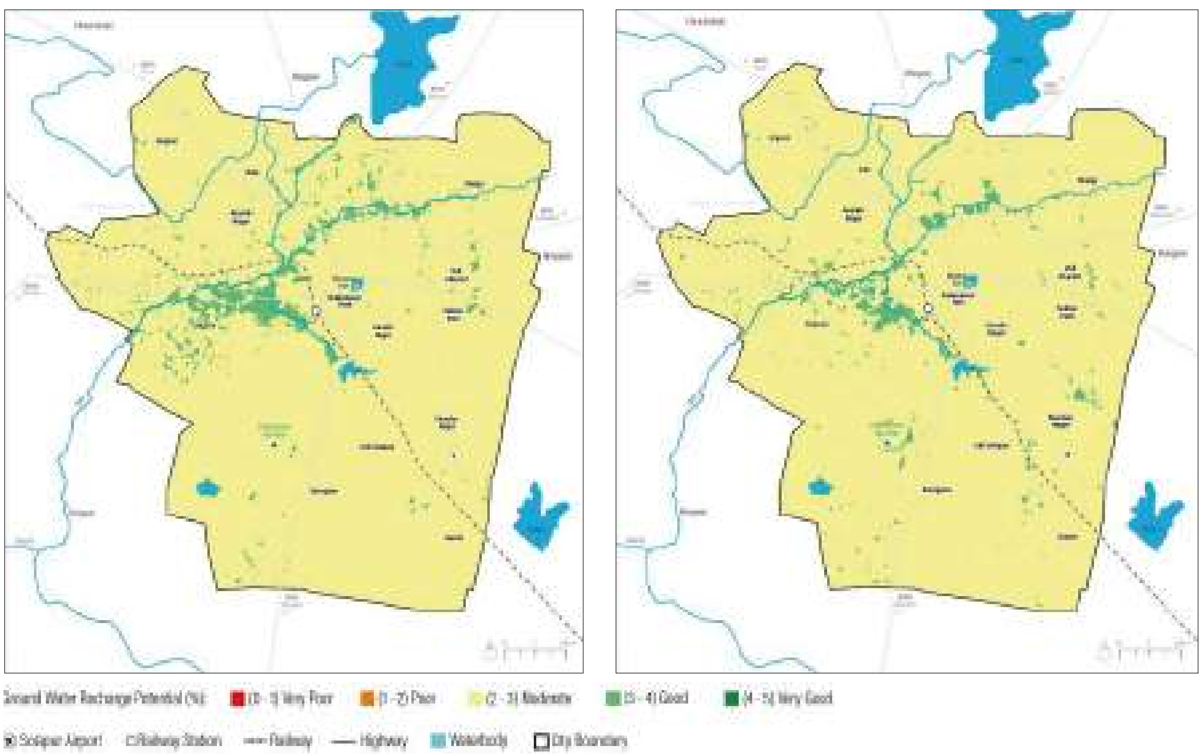
The impact of climate change on groundwater is emerging as a major challenge. The increasing variability in rainfall could mean more frequent and prolonged periods of droughts and floods. The effects of climate change on groundwater may result in a long-term decline in groundwater storage.

The groundwater recharge potential (GWRP) within the SMC area is estimated using three parameters – average annual rainfall (using IMD gridded daily rainfall), the slope of the terrain (obtained from topography/DEM), and the conditions of the vegetation, soil, and land use (represented by NDVI).

Solapur city exhibits a 'moderate' GWRP throughout its limits while the recharge potential improves to 'good' around the water bodies. The extent of the good recharge potential has decreased in the western part of the city as many new developments have cropped up in land that was used for agriculture in the year 2000. It can also be seen that as compared with the year 2000, the areas towards the south of the city have shown good recharge potential in 2020. This is attributed to the increase in farming activities in the periphery of the city. Nearly 11% of the population residing in the city live in areas with decreased GWRP.

There are no On-going initiatives related to groundwater development within the SMC area.

Figure 21-2: **GWRP within SMC area for two timestamps, two decades apart**



Source: WRI India analysis

21.4.2 Key Gaps and Challenges

The key challenges are as follow:

- No observatory wells located within city limits
- No data on city-level aquifer maps and groundwater levels and annual groundwater extraction
- No data available on private borewells and yield of public bore-wells and tube wells
- No On-going initiatives related to groundwater development within the SMC area

21.5 WASTEWATER MANAGEMENT

21.5.1 Sectoral overview

The estimated sewage generation in the SMC area is around 94 MLD (2021) assuming 80% of the water supply (118 MLD) by SMC. However, apart from the piped water supply, there is a substantial amount of groundwater usage as well. Therefore, the actual sewage generation will be upwards of 100 MLD.

21.5.2 Wastewater generation and treatment infrastructure

There are three Sewage Treatment Plants (STPs) with a total treatment capacity of 102.5 MLD, and the current treatment capacity utilisation is 42.92 %. Currently, there is no gap in treatment capacity (102.5 MLD) as compared with 94 MLD of sewage generation. However, by 2035, a gap of ~68 MLD in terms of treatment capacity will arise.

21.5.3 Wastewater recycling and reuse potential

The existing sewage treatment capacity is 102.5 MLD, and the utilisation is 89.35 MLD. The treated wastewater is discharged into a *nalla* (stream) near STP. Given that Solapur is a water-scarce region, there is an opportunity for recycling of wastewater and reuse for non-potable purposes as an alternative to the freshwater supply to these non-potable usages.

The National Thermal Power Corporation Ltd. (NTPC) is a large bulk potential buyer, and it has recently developed a 1,320-MW coal-based thermal power plant at Fatatewadi, about 20 km from Solapur city. The plant needs a large quantity of water and is dependent on the Ujani dam as a source of freshwater supply. There is an opportunity to supply treated wastewater from Degaon STP with 75-MLD capacity to the NTPC

Table 21-2: Wastewater generation and treatment in Solapur city

Indicator / Year	2018	2020	2035	2050
Population	10,64,372	10,73,253	12,70,231	14,65,028
Daily water demand, MLD	183	191	250	298
Supply, MLD	118	118	212.5	187
Esti. Sewage generation, MLD	94	94	170	150
Treatment capacity, MLD	102.5	NA	NA	NA

Source: Estimation based on the presentation on the water audit of Solapur city – 2022 plant. SMC can work out a reasonable selling price for secondary treated water to at least recover the O&M cost of the Degaon STP, which is INR 37 million/ annum (translates to INR 1.6 / kl). Doing this will accelerate the reuse of around 65 MLD of wastewater and divert an equal quantity of fresh water that was otherwise used as NTPC's process water.

SMC has an understanding with the NTPC plant wherein the latter has agreed to use the recycled wastewater from Solapur city instead of fresh water and divert the fresh water to the city.

Other key potential demand centres for wastewater recycling and reuse are as follows:

- There are 32 gardens of various sizes in Solapur city, including 13 developed as part of the AMRUT scheme. These gardens cover an approximate area of 100 acres. The secondary treated water from STP or recycled water with further treatment can be used for watering these gardens. Thus, it will help in conserving freshwater sources.
- In the case of multi-storied constructions and gated communities, internal dual piping for toilet flushing shall be made mandatory. It shall also be mandated for high-end users, such as hotels, malls, and industries.
- Such building communities and groups of housing implementing dual piping shall also ensure on-site treatment of wastewater to the water reuse standards of the nation or as per national/ international best practices.
- Supply of treated wastewater to non-potable users, such as process water for textile industries, horticulture, gardens, and toilet flushing at public toilet complexes, bus stands and railway stations, shall be explored.
- SMC may provide incentives on the quantity of wastewater treated and reused for which separate metering may be necessary.
- Incentives may be provided to customers (in water tariff, property tax etc.) for the recycling and reuse of treated wastewater.

1. On-going initiatives

Under AMRUT 1.0:

- A sewerage scheme was begun in 2018 at a project cost of INR 180.24 crore.
- The scheme included the construction of an STP at Desainagar, a 297-km sewerage network, and the setting up of a pumping station at Degaon.

Other projects:

- SMC has taken the initiative to increase the BoD level through the biocultural process of capturing good quality of methane. It has begun the energy audit of the STPs and is planning to implement a water reuse agreement with NTPC by the end of the year 2023.

21.6 KEY GAPS AND CHALLENGES

The key challenges are as follow:

- Only 60% of wastewater is received at the inlet of the STPs.
- Data on the use of septic tanks in terms of their coverage and the quantity and quality of wastewater treatment is unavailable.

- Apart from Degaon STP, SMC does not have a plan for the installation of the methane capture system at the remaining STPs.
- There is a need for automation systems such as SCADA in all STPs to effectively control, monitor, and manage the STPs.
- Given that Solapur is a water-scarce region, SMC should focus on the recycling of wastewater and its reuse for non-potable purposes as an alternative to the freshwater supply to these non-potable usages.

21.7 RECOMMENDATIONS

The points below indicate broad thematic focus areas for this sector/ broad sub-sector.

- Increase availability of raw water/ treatment capacity, water supply coverage and system efficiency
- Reduce water losses (Unaccounted for Water or UFW)
- Effective groundwater management through mapping, conservation, and management
- 100% collection and treatment of the wastewater
- Opt for the generation of energy from STPs
- Recycle and reuse domestic wastewater for non-potable purposes

21.7.1 Sectoral Priority

The following table presents the overall vision for the sector for Solapur City with action tracks:

Sub-sector		Strategy
Water supply system management	Strategy-WS1	Extend the formal piped water network to improve water access/ address intermittent water service
	Strategy-WS2	Adopt measures to reduce UFW from 55% to 15%, and NRW management through governance, technological and smart interventions
	Strategy-WS3	Adopt and implement supply-side management measures, such as optimisation of consumer demand, behaviour change, and awareness
Groundwater management	Strategy-GW1	Map the aquifers within SMC areas, and implement measures for aquifer rejuvenation and management
	Strategy-GW2	Promoting rainwater harvesting
Wastewater Management	Strategy-WW1	Collect and treat 100% of the wastewater generated within SMC through a combination of centralised and decentralised wastewater management systems
	Strategy-WW2	Capture methane from STPs by improving the system at Degaon STP and installing a new system at the remaining STPs
Wastewater recycling and reuse	Strategy-WR1	Explore opportunities for wastewater recycling, and supplyto NTPC plant for processing
	Strategy-WR2	Explore opportunities for wastewater recycling and reuse for non-potable purposes

21.7.2 Strategy-wise Actions

Table 21-3: WS-1, 2 & 3 - Key Strategies and Action for Waster Supply System in Solapur

Action description	Stakeholders and Financing	Indicators
Priority action: Ensure 100% water supply coverage by implementing key components, such as completing the 110-MLD parallel pipeline project, extending the piped network, and setting up storage reservoirs to cover the uncovered areas with proper pressurised supply, consumer metering and implementing automation systems like SCADA for better monitoring and control. **Timeframe: 2025**	**Lead:** SMC **Supporting:** NGOs, citizen groups Finance: SMC budget, State/ central schemes such as AMRUT	**Output:** City area and the population covered by water supply (%), Connections metered (%) **Outcome:** Amount of water saved due to metering and SCADA system, economic benefits to families in terms of their time saved in fetching water due to assured water supply, increase in water revenue for SMC
Priority Action: SMC need to set up an NRW Cell with the mandate to plan, develop, implement, and monitor an action plan for the reduction of unaccounted for water (UFW) from 55% to 15%, reduction of NRW, conduct periodic water audits, and undertake leakage mapping and repairs in a phased manner. In September 2022, SMC has already completed the water audit through which it estimated UFW and NRW levels of the water supply system of Solapur city. The outputs of the water audit are expected to be used to address some of the interventions proposed under the NRW study carried out under CBUD by SMC. The NRW Cell shall be given the responsibility of implementing various actions/measures proposed as per the water audit study either internally or through the appointment of external contractors. Energy audits need to be mandated at prescribed intervals for the efficient functioning of electro-mechanical equipment in the system. **Timelines:** 2024	**Lead:** SMC **Supporting:** NGOs, citizen groups, Pvt. Vendors Finance: SMC budget, State/ central schemes like AMRUT 2.0	**Output:** Reduction in water losses (UFW), Increase in water revenue for SMC **Outcome:** increase in efficiency in transmission and distribution network, financial recovery, NRW reduction

Action description	Stakeholders and Financing	Indicators
Priority Action: **Use Information and Communication Technology (ICT) to collect widespread and near-real-time data from multiple infrastructure systems -** (i) Adopt the automation systems such as SCADA-based that allows the utility a graphical insight into the flow, level, pressure & efficiency monitoring along with insights into possible issues on day day-to-day. (ii) Install Internet of Things (IoT) enabled SMART metering – bulk metering and consumer metering to effectively measure, monitor, and control the flow (iii) Develop a mobile app for citizen grievance and feedback (iv) Integrate the above components to the Command-and-Control Center (CCC) or through a dashboard to effectively monitor the system **Case examples:** Solapur used an automation system (SCADA) for STP and Pimpri Chinchwad city established a SCADA system for bulk water supply and sewerage systems in 2010. **Timelines: 2024**	**Lead:** SMC **Supporting:** Pvt. Operators, NGOs, citizen groups Finance: SMC budget, State/ central schemes	**Output:** Population covered each year (%), No. of programmes conducted **Outcome:** Water saving, Reduction in wastage of water
Priority Action: Adopt the following key approaches (strategies) to reach the target audiences and achieve the overall communication objectives: 1) Internal communication: Implement internal communication activities to address staff concerns in SMC, and build support for reforms and utilise the staff in disseminating information on the reform. 2) Public participation mechanisms: Establish mechanisms that serve as information-sharing to engage leaders/ decision makers and implementation partners. 3) Multi-media information campaign: Develop and implement a branded, phased, multi-media communication programme to increase knowledge on the objectives and benefits of the reform to motivate key stakeholders to adopt positive Water Supply and Sewerage Services and Water Resource Management practices. 4) Media advocacy: Leverage the media as a partner in the dissemination of accurate and holistic reform messages. **Timelines: Continuous**	**Lead:** SMC **Supporting:** NGOs, citizen groups	**Output**: No. of events conducted disaggregated by target audience **Outcome**: The city is able to take up more water-sensitive reforms.

Table 21-4: GW-1 & 2 - Key Strategies and Actions for Groundwater Management in Solapur

Action description	Stakeholders and Financing	Indicators
Priority action: Delineate, map, and protect the aquifers by delineating and managing groundwater recharge and discharge zones. **Timeframe: 2026**	**Lead:** SMC and GSDA **Supporting:** NGOs, Geological dept of Solapur University, Institutions Finance: SMC budget, Corporate Social Responsibility (CSR), Institutional own funding wherever the recharge zone is within institutional premises	**Output:** % of city's area mapped, % of recharge area to be protected, a protected area in Ha. **Outcome:** Quantity (MLD) of groundwater recharge
Priority action: Identify low-lying areas, lakes, and flood plains, and reserve them to store rainwater for better environmental conditions and for improving groundwater recharge. **Timeframe: 2024**	**Lead:** SMC **Supporting:** NGOs, GSDA, Institutes, Citizen groups, students from architecture and engineering colleges Finance: SMC budget, Corporate Social Responsibility (CSR)	**Output:** City's area mapped (%), Area to be protected (in Ha) **Outcome:** No of pilots for recharge of groundwater
Priority action: Identify potential sites for artificial ground recharge structures, delineate them, and take up pilot projects within the government and institutional premises. **Timeframe: 2024 and continue**	**Lead:** SMC **Supporting:** NGOs, GSDA, Citizen groups, Educational institutes Finance: SMC budget, Corporate Social Responsibility (CSR)	**Output:** City's area mapped (%), Area to be protected (in Ha) Rise in GW level (to be measured by putting Piezometer tubes) **Outcome:** Increase in unit meters rise in GW level
Priority action: Amend the Development Control Rules to make provision for the reservation of plots/land within recharge and discharge zones. **Timeframe: 2025**	Lead: SMC Supporting: Builders Association, Arch Association, Consulting Civil Engineer's Association Finance: SMC budget, Corporate Social Responsibility (CSR)	**Output:** City's area mapped (%), Area to be protected (in Ha) **Outcome:** Amendment in DCR clause/s No. of buildings having RWH system in place
Priority action: RWH to be made mandatory. Incentives are to be provided on the quantum of water consumption avoided by the organized water supply system. SMC shall identify and reserve 2-5% of the development area for water bodies, either natural or constructed. **Timeframe: 2 years & continue**	**Lead:** SMC and GSDA **Supporting:** NGOs, Geological dept of Solapur University, Institutions Finance: SMC budget, Corporate Social Responsibility (CSR), Institutional own funding wherever the recharge zone is within institutional premises	**Output:** Quantity of water consumption avoided from the organised water supply system. **Outcome:** A system of Groundwater Table monitoring wells may be developed at the ward level.to be used for assessing the efficiency of RWH measures, and warnings against excessive exploitation of groundwater.

Table 21-5: WW-1 & 2 - Key Strategies & Actions for Wastewater Management, recycling and reuse in Solapur

Action description	Stakeholders	Indicators
Priority action: Collect and treat 100% of the wastewater generated within SMC through a combination of centralised and decentralised wastewater management systems. SMC shall capture data on the use of septic tanks in terms of their coverage and the quantity and quality of wastewater treatment. Wherever it is not feasible to implement the sewer system, explore the option of the decentralised system through scheduled desludging and treatment through the Faecal Sludge Treatment Plant (FSTP). Thus, SMC shall use a combination of centralised and decentralised systems to ensure 100% wastewater collection and treatment. **Timeframe: 2027**	**Lead:** SMC **Supporting:** NGOs, Institutions (bulk-wastewater generators), Urban Development Dept. of the GoM Finance: SMC budget, user charges for desludging, sewerage charge, GoM Grant and GoI schemes like AMRUT, Corporate Social Responsibility (CSR), institutional own funding within institutional premises	**Output:** Wastewater collected, treated, and disposed of safely (%) **Outcome:** Quantity of GHG emissions reduced, Improvement in sanitation-related service levels, reduction in water-borne diseases
Priority action: Carry out a detailed feasibility study of the STPs within the SMC area, and identify (i) areas of improvement in the case of the Degaon STP and (ii) the installation of a new system for remaining STPs. **Timeframe: 2025**	**Lead:** SMC **Supporting:** Technical Institutions **Finance:** SMC budget, CSR, institutional own funding wherever there is reuse potential within institutional premises	**Output:** Quantity of methane generated, and energy generated **Outcome:** energy savings within STP premises and savings in energy costs due to the use of energy generated from methane

Table 21-6: WR-1 & 2 - Key Strategies and Action for Wastewater Recycle and Reuse in Solapur

Action description	Stakeholders and Financing	Indicators
Priority action: Supply secondary treated wastewater from Degaon STP of 75 MLD capacity to the NTPC plant to further treat it and reuse it for its processes. NTPC has developed a 1,320-MW coal-based thermal power plant at Fatatewadi about 20 km from Solapur city. The plant needs a large quantity of water and is dependent on the Ujani Dam as a source of freshwater supply. SMC can work out a reasonable selling price of recycled/ secondary treated water to at least recover the O&M cost of the Degaon STP, which is INR 37 million/ annum (translates to INR 1.6 / kl). It will help reuse around 65 MLD of wastewater and divert an equal quantity of fresh water. SMC has reached an understanding with the NTPC plant wherein NTPC has agreed to use the recycled wastewater from Solapur city instead of fresh water and divert the fresh water to the city. **Timeframe: 2025**	**Lead:** SMC and NTPC **Supporting:** Industries Dept. and Urban Development Dept. of the State Government of Maharashtra Finance: Public Private Partnership (PPP), NTPC contribution, SMC budget, GoM Grant	**Output:** Quantity of wastewater recycled Quantity of wastewater reused, Net revenue to SMC from the sale of water **Outcome:** Saving potable water that was to be supplied to industries (%)

Action description	Stakeholders and Financing	Indicators
Priority action: Explore various options for recycling domestic wastewater, and reuse for non-potable purposes such as gardens (32 gardens including 13 gardens developed under the AMRUT scheme covering an approximate area of 100 acres), institutional/ industrial consumers, other non-potable users such as processed water for textile industries, horticulture, toilet flushing at public toilet complexes, bus stands and railway stations, etc. **Timeframe: 2025**	**Lead:** SMC **Supporting:** Universities/ institutions, garden dept., CREDAI, NGOs etc. **Finance:** SMC budget, Corporate Social Responsibility (CSR), institutional own funding wherever there is reuse potential within institutional premises	**Output:** quantity of wastewater recycled, the quantity of wastewater reused, net revenue to SMC from the sale of water **Outcome:** % of potable water that was to be supplied to various usages saved,

STATION ROAD.RAILWAY LINES
Photo credit: Pravin Gaikwad

22. RECOMMENDATIONS - AIR QUALITY

22.1 SECTORAL OVERVIEW

Air pollution risk assessment under the Vulnerability Assessment (VA) framework includes temporal analysis using data from CAAQMS and manual stations established in the city as well as spatial analysis based on satellite imagery. There are seven Central, state, and city-led monitoring stations in Solapur maintained under different programmes, as mentioned in Table 5-1 (Chapter 5).

Air pollution monitoring includes the study of the concentrations of physical and chemical compounds. Chemical compounds include gases such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), tropospheric ozone (O_3) and carbon monoxide (CO), while the physical compounds include the dust particles PM_{10} and $PM_{2.5}$. Non-attainment cities were classified on the basis of PM_{10} concentration. In Solapur, Respirable Suspended Particulate Matter (RSPM) levels also known as PM_{10} were above the annual limit established by the Central Pollution Control Board (CPCB), which shows non-attainment.

- **NO2** is majorly emitted when fossil fuels (coal, oil, gas, or diesel) are burnt at high temperatures, mainly from the transportation sector two-wheeler, freight vehicles, etc.
- **SO2:** Toxic gas is produced during the combustion processes associated with coal, lignite coal, petroleum products, and wood. In the residential sector, the consumption of coal for cooking and water heating needs, non-regulated burning of open waste, and intermittent landfill burning can be associated with SO_2 emissions.
- **CO** is emitted from fossil fuel and biomass burning in the transportation sector, industries, residential sector, and MSMEs. Low income groups still do not use LPG and PNG as fuels.
- **$PM_{2.5}$ and PM_{10}** are primarily caused by road dust resuspension, followed by transport and industries and construction activities.

The temporal analysis of different air pollutant levels (annual averages for SO_2, NO_x, PM_{10}) for Solapur city has been carried out from 2004 to 2021 to assess the city-wide and station-wise variations using data from three manual stations: Niyojan Bhawan, Walchand Institute of Technology (WIT) Campus, and Solapur Municipal Council (SMC) premises. As per the analysis, NO_2 levels in the city are nearing the threshold of 40 µg/m^3 and PM_{10} shows high values that cross the annual safety threshold of 60 µg/m^3. However, SO_2 levels were much below the stipulated regulatory limit of 50 µg/m^3. In the case of CO, 22% of the days are above the threshold of 2 mg/m^3. The winter months typically show spikes in CO values. The level of O_3 was inconclusive due to data gaps.

The spatial analysis using data from the Sentinel satellite for NO_2, SO_2 and CO includes the study of the spread of concentration of each pollutant in the region of interest, except $PM_{2.5}$ for which the data from the Atmospheric Composition Analysis Group at the Washington University in St. Louis, USA, is used. Also, note that spatial data is not available for O_3 and PM_{10} /RSPM. The spatial analysis concluded:

- NO_2 is mainly concentrated in the central parts of the city, around Siddeshwar Peth where traffic is expected to be high due to the higher concentration of activities. The second most prominent hotspot to the southeast is located over the Solapur thermal power plant, which is outside the SMC boundary. Moreover, the Source Apportionment study carried out by the Indian Institute of Technology - Bombay (IIT-B) and National Environmental Engineering Research Institute (NEERI) for the city of Solapur in 2017 identifies vehicles (96%) and brick kilns (4%) as major NO_2 contributors.
- SO_2 is concentrated in the area around Shelagi where the APMC market is located and between Sakhar Peth near MIDC. As per the Source Apportionment study, the major contributors are brick kilns (97%), industries (2%), and bakeries (1%).
- With regard to CO, there have been a few instances of fire (most likely, stubble burning) outside the city boundary between March and April, 2020, which may explain these elevated concentrations of CO. As per the source apportionment, vehicles (38%), bakeries (33%), industries (13%), domestic (6%), and crematoria (3%) contribute to CO emissions. This might be owing to the use of coal and wood as fuel.
- $PM_{2.5}$ and PM_{10}: Under these pollutant categories, the major sources are industries (30-36%), bakeries (20-25%), open eateries (24- 35%), and vehicles (7-8%). The pollution levels also coincide with the type of fuel usage.

The MIDC area is located towards the eastern side of the city. Some areas with high concentration levels of $PM_{2.5}$ are a group of industries in the region where the Kolhapur Road exits the city boundary. This region hosts a stone crushing site (contributing to the highway maintenance work), and a waste material treatment plant. Similarly, the north-western hotspot near Chincholikati is also located over a small industrial area. $PM_{2.5}$ concentrations were also observed around the airport where the Shri Siddheshwar sugar factory is located and around the Degaon sewage treatment plant.

22.2 ON-GOING INITIATIVES

1. Air Quality Monitoring

- Installed four more air quality monitoring stations under NAMP during the last two years

2. Policy

- Formulated Action Plan for control of air pollution in Solapur in 2019[56]
- Micro action plan for non-attainment city Solapur published in 2021
- Source Apportionment study was conducted in 2017

3. Other initiatives

Identified 20 junctions as air pollution hotspots for a hotspot management plan

Ban on open waste burning in the city

22.3 KEY GAPS AND CHALLENGES

1. **Monitoring, Institutional Co-ordination and Capacity building**

From 2004 to 2019, only three stations were established in Solapur, of which 1 was continuous and 2 manual. Recently, four new stations have been established. Given that, the insufficient number of air quality monitoring stations, limited data in terms of granularity and limit in data capture points over the years of hindrance in capturing the air pollution concentrations at a local level. Most of the stations are operated manually, and the data captured is at times inconsistent. Moreover, RSPM or PM_{10} is monitored across six stations, but $PM_{2.5}$ is monitored in three stations. Lack of capacity and awareness in terms of data capture and methods have been observed as some key gaps.

2. **Linking data to health impacts**

Given the use of unclean cooking fuel in both residential and commercial establishments, there is a lack of understanding of the exposure to health risks, especially in the case of non-attainment cities with high exposure to particulate matter. No efforts have been made to track the secondary fuel data use in the city's low-income residential areas or slum neighbourhoods.

3. **Future estimate emissions**

The city's expansion will lead to PM emissions from the construction sector. A regular check on an array of construction-related activities in the city is necessary. Moreover, Solapur airport isn't fully functional. However, as the city grows and develops, emissions from the construction sector might be a cause for concern.

4. **Diversify the activity mapping**

Most of the hotspots identified by the city for undertaking a hotspot management plan are limited to traffic junctions and traffic congestion spots. There is limited understanding of the authorities in identifying nuanced activities, such as open waste or stubble burning, building construction activities, bakeries and residential areas using unclean cooking fuel, and brick kilns, that add to the poor air quality in the city.

22.4 RECOMMENDATIONS

Key Strategies are as follows:

Strategy AQ 1: Strengthening Air Quality Monitoring: Improve monitoring of air quality station data ; and create avenues for decentralised data collection to strengthen data gathering, monitoring, and information dissemination by 30% by 2030.

Strategy AQ 2: Reduction of air pollution levels by 20-30%: Target the reduction of air pollution levels by 50% through mainstreaming targeted actions in the transport, non-exhaust emission (NEE) and waste management sectors by 2030.

Strategy AQ 3: Air pollution-related activity Mapping: Identify and monitor current and future activities (apart from transport and waste) that contribute towards the city's high emission levels and take measures to regulate them.

- Track 3(a): Emissions from thermal power plant
- Track 3(b): Cooking fuel use at residential and commercial establishments

(especially, bakeries/ open eateries)

- Track 3(c): Crematoria
- Track 3(d): Industries (2 components: MSMEs/textiles and brick kilns)

Strategy AQ 4: Disseminate information on the risk and impact of air pollution on human health; address air pollution through a multi-sector approach

22.4.1 Strategy-wise actions

Urban air quality monitoring has been traditionally the remit of expensive and complex reference instruments set-up. However, low-cost censors have been assessed for their viability in monitoring ambient air quality, including both gaseous and particulate matter (PM) pollutants. Deploying portable sensors can also help understand the spatial variability of air pollution in the city. Although CPCB does not recommend the use of sensors for regulatory decision-making, the network of sensors can help identify activity-based pollution hotspots in the city.

Based on CPCB's norms for the number of monitoring stations[57], Solapur city has about seven air quality monitoring stations, four of which meet the norms. However, not all the stations are equally distributed across varying land use and population density. However, low-cost sensors can be installed at high-density activity areas to monitor the concentration of the pollutants.

Table 22-1 Strategy AQ-1: Improve air quality monitoring station data; and create avenues for decentralised data collection further strengthening data gathering, monitoring, and information dissemination by 30% by 2030.

Action description	Stakeholders and Financing	Indicators
Maintenance and upgradation (from manual to automated) of at least three air quality monitoring stations to be integrated with meteorological analysers capable of monitoring wind speed, wind direction, humidity, temperature, etc **Timeframe: 2023-2024**	SMC, MPCB Finance: NCAP	**Output:** No. of automated stations for AQ monitoring **Outcome:** Increase in frequency and quality of the data collected
Include monitoring of ozone (O_3) to understand quantifiable impact of ground-level ozone formation in heavy traffic zones **Timeframe: 2025**	SMC, MPCB Finance: NCAP	**Output:** No. of monitoring stations that track O_3 **Outcome:** Track possible causes of ozone emissions
Identification of air pollution hotspots within SMC by adopting a scientific method for hotspot identification **Timeframe: 2024**	SMC Finance: SMC budget, NCAP	**Output:** Number of hotspots identified **Outcome:** Formulate actions for hotspots identified

Action description	Stakeholders and Financing	Indicators
Install air quality monitoring sensors in identified high-density activity areas for generation of monitoring data (for non-statutory purpose) **Timeframe: 2024**	SMC, Waste sector, Industries, Building and Construction units Finance: SMC, Research grants	**Output:** No. of sensors installed by year **Outcome:** Identify hotspots, and formulate actions for abatement of identified hotspots
Train research and academic institutions in sample collection, analysis, and monitoring of stations. **Timeframe: continuous on a bi-yearly basis**	SMC, Academia/ research institutes Finance: NCAP	**Output:** Number of research institutes, or academia involved in the study **Outcome:** No. of people capacitated
Use satellite monitoring for linkage of the numeric data on air quality to spatial data and land use, major activities in the city for identifying emerging hotspots **Timeframe: 2027**	SMC, GIS dept, IT, Academia, and Research institutions Finance: Research grants	**Output:** No. of areas identified with probability of high pollution levels **Outcome:** Measures to address the hotspots identified from satellite imagery
Engage innovation hubs/start-ups in testing low-cost pollution monitoring devices as a pilots **Timeframe: 2030**	SMC, IT, entrepreneurs Finance: CSR	**Output:** No. of pilots **Outcome:** Newer technologies and methodologies adopted to understand air pollution intensity in the city
Create a city dashboard for real-time monitoring **Timeframe: 2024**	IT, PR, SMC Finance: NCAP	**Output:** Creation of a city dashboard hosted at SMC website **Outcome:** Information dissemination to the public
Capacitate the department to analyse data and disseminate information to the public **Timeframe: 2024**	PR, SMC, Educational Institutes Finance: NCAP	**Output:** No. of officials trained, capacitated **Outcome:** Frequency of monitored data disseminated to the public
Issue warning signs and triggers, especially during winter months due to relatively low wind and higher inversion duration, through formulating a Graded Response Action Plan (GRAP) **Timeframe: 2027**	PR, SMC, Educational Institutes Finance: NA	**Output:** No. of warning signs issued against days where pollutant cross threshold in a year **Outcome:** Population exposed to air pollution risk and hazards are aware, and take appropriate measures.
Use of print media, social media platforms, radio and TV for city-related AQI information **Timeframe: continuous**	Media, PR, SMC Finance: NA	**Output:** No. of articles, radio announcements made on a weekly/ monthly basis **Outcome:** Citizens are aware, and take health precautionary measures on extreme air pollution days.

2. Sectoral Strategy AQ 2: Reduction of air pollution levels by 50%: Non-Exhaust Emission, Traffic Hotspots, Waste related

While setting up a target of 50% reduction in air pollution, the focus is on sectors such as transport, non-exhaust emissions, traffic hotspots, and waste. The strategies and actions for the transport sector are comprehensively covered as part of a separate assessment of the transport sector in this CAP document. However, the sector also aligns with air pollution because of emissions affecting air quality. As a part of the assessment of the transport sector, the following strategies are proposed:

Under Strategies 1-4, in Table 18-2 the provisioning of increased use of mass transit inadvertently refers to the curb in private vehicle use, thus reducing emissions. Moreover, the conversion of fuel from diesel or petrol to comply with the latest BS-VI norms or gas-based CNG/ LPG or to EV adoption also addresses the issue with respect to emissions. Similarly, increasing NMT penetration through the provision of better infrastructure also addresses the issue of emissions related to the transport sector. Strategy Action 3 in Table 22-2 also addresses the same by making way for EV penetration in the market. The mitigation actions are more likely focused on reducing targeted emissions through switching to EVs and enabling an increase in the share of public transport and NMT.

This section on air pollution reduction strategies focuses on the following areas in addition to the transport sector:

- 2(a) Non-Exhaust Emission (NEE) or resuspension of dust particles of Particulate Matter (PM)
- 2(b) Spatial hotspots identified (as a part of Vulnerability Assessment (VA) and traffic junctions)
- 2(c): Crop burning/ Waste/ Landfill burning

Non-exhaust Emission (NEE) or resuspension of dust particles of PM from road dust in SMC is a major concern for health and is directly dependent on vehicle kilometres travelled (VKT) and road condition. The average trip length for four-wheelers is 5.7 km and that for two-wheelers is 5.4 km (CMP, 2016). Therefore, as the city expands, more distance needs to be covered which will also result in higher $PM_{2.5}$ and PM_{10} emissions.

NCAP has set a tentative national target of a 20% - 30% reduction of air pollution in 132 non-attainment cities by 2024, taking 2017 as the base year. The ‘non-attainment cities’ are those that failed to meet the national ambient air quality standards during the years 2011- 2015 and are required to formulate city-specific action plans in order to reduce air pollution. Solapur is in the list of non-attainment cities.

Table 22-2 Track 2(a): Non-Exhaust Emission (NEE) or resuspension of dust particles of PM – Transport

Action description	Stakeholders	Indicators
Increase of PUC centres for monitoring tailpipe emissions **Timeframe: 2026**	RTO, Traffic police Finance: Municipal budget, NCAP	**Output:** No. of PUC centres established and operational in the city **Outcome:** Change in pollutant concentration from vehicular emission (%)
Strengthen policy on Abatement of older vehicles **Timeframe: 2028**	RTO Finance: NA	**Output:** No. of older vehicles scrapped **Outcome:** Reduction in number of old vehicles (%)
Provide better quality road network within SMC area **Timeframe: 2024**	PWD, Roads department Finance: Municipal Budget, NCAP	**Output:** Km of roads reconstructed **Outcome:** Reduction in potholes (%)
Regular cleaning of road dust, use of Sprinkler Systems, and Mechanical Sweepers **Timeframe: 2025**	PWD, Roads Department Finance: Municipal Budget, NCAP	**Output:** No. of sprinkler systems installed, mechanical sweepers procured **Outcome:** Reduction in dust emissions (%)
Green buffers along major traffic corridors **Timeframe: 2027**	Gardens Department Finance: NCAP	**Output:** No. and species of greens planted along km of roads **Outcome:** Improvement in AQI level
Blacktopping of metaled roads, pavement of road shoulders **Timeframe: 2024**	PWD, Roads Department Finance: Municipal Budget	**Output:** km of roads **Outcome:** Reduction in dust emissions (%)

Table 22-2 Track 2(b): Spatial hotspots identified (as a part of VA and traffic junctions) – Transport

Action description	Stakeholders and Financing	Indicators
Efforts towards reducing traffic hotspots basis AQI traffic areas in 8 junctions by installing water fountains and other appropriate measures. **Timeframe: 2024**	SMC, MPCB, Traffic police Finance: NCAP	**Output:** Working document on actions to reduce air pollution hotspots in the city **Outcome:** Reduction in dust emissions (%)
Blackspot mitigation, reduce traffic congestion for improved road safety and NMT access at 15 junctions **Timeframe: 2026**	RTO, Traffic police, Roads Department Finance: NCAP, Maharashtra State Transport Department	**Output:** No. of traffic junctions designed **Outcome:** Improved sense of pedestrians safety at junctions
Recognising LOW Emission Zones (LEZs)[58] area-based (E.g. Siddeshwar Peth) **Timeframe: 2026**	SMC, Zone Officer, Traffic police Finance: NCAP	**Output:** No. of LEZs, No of ICE vehicles banned/restricted **Outcome:** Improvement in AQI level

Action description	Stakeholders and Financing	Indicators
Identify hotspots apart from traffic junctions from an agglomeration of major activities with the municipal corporation **Timeframe: 2025**	SMC Finance: NCAP	**Output:** No. of air pollution hotspots identified **Outcome:** Pilots test solutions to mitigate the identified hotspots

The NCAP includes about 19 steps to control emissions from vehicular pollution and 6 to control air pollution from resuspension. The 19 action points cover steps such as banning of vehicles, issuing PUC, retrofitting particulate filers in existing vehicles, awareness campaigns, and fuel conversion. The micro action plan has provided action codes for every targeted action related to the improvement and strengthening of the PUC programme, clean fuel and fuel quality, strengthening of public transport, and traffic congestion. The Source Apportionment study mentions actions on restriction of entry of commercial vehicles, retrofitting of diesel particulate filters in 4-wheeler PT, maintenance of 2W and conducting public awareness campaign . Actions for the transport sector has been most extensively drafted across all verticals. Basis the SA and VA analysis, there is a set of activities that also lead to air pollution-related emissions .

Track 2(c) Crop burning/ Waste/ Landfill

Similar to the transport sector, the waste sector too has mitigation-related actions and proposed targets. The five action tracks within the waste management sector are as follow:

- Achieve 100% segregation at source, and conduct the community-based organic waste management
- Reduce waste sent into the landfill
- Incinerate less incineration, recycle more, and reuse dry waste
- Reduce waste-related transport activities and fuel switches for vehicles
- Implement C&D waste processing and e-waste management facilities in the city

In addition to the actions proposed under solid waste management, the issue of landfill fires has persisted over the years. On May 12, 2022 SMC recorded a major landfill fire. The fire that started around May 5, 2022, became intense over the days, and fire services were present at the premises to combat the fire. From our interaction with the authorities, the fire incidents seem to occur every year during summer (April and May) for the last 10 years (exact dates not recorded) due to methane generation, but the intensity is low. The strategies are targeted towards recording these fire instances in the city.

As listed in the micro action plan, the provision of water supply from the nearest sewage plant and the clearance of legacy waste is an action plan for reducing landfill fire. However, there are no detailed actions on the clearance of legacy waste. On the issue of waste burning, awareness drives for control of the burning of agriculture waste and crop residues are action points under the micro action plan.

Track 3: Air pollution-related activity Mapping

Strategy AQ-3: Identify and monitor current and future activities (apart from transport and waste) that contribute towards the city's emission levels and the steps to regulate these activities for cleaner air in the city by 50% by 2030 and 70% by 2050

Sectoral Action Track 3(a) Emissions from Thermal Powerplant

NTPC is located 15 km outside the city in the villages of Fatatewadi, Ahirwadi, and Hotgi in South Solapur taluka towards the south-east of the city. The plant has a capacity of 1320 MW[59] power generation . There appears to be a concentration of NOx towards the southeast direction, towards the NTPC plant. However, the jurisdiction of NTPC is outside the city limits and, therefore, outside the scope of CAP. The NTPC's Environmental Clearance (EC) discusses the possible emissions of PM, SO2, NOx, and CO2 and the actions necessary to curb these.

However, the city should continuously monitor the possible emissions of PM, SO2, and NOx on a regular basis. Wind direction and speed must be monitored especially if the emission fumes are towards the city's direction of growth and expansion either by installing a monitoring station or sensors.

Table 22-3: Crop burning/ Waste/ Landfill: Track wise actions and their implementation

Action description	Stakeholders and Financing	Indicators
Monitor hazard in terms of recording instances of landfill fire and stubble burning in summer and winter months and take appropriate measures to monitor air quality levels in the city on such days **Timeframe: 2025**	SMC, Solid Waste, Fire and Environment Departments Finance: NCAP	**Output:** No. and frequency of landfill fire events in a year, AQI levels for gaseous and PM **Outcome:** Reduction of instances in a year (%), Decrease in pollutant concentration compared to other days (%)
Formulate a plan towards closure of the dumping site/ scientific closure of the landfill **Timeframe: 2030**	Solid Waste, Environment Department, SBESPL Solid Waste, Environment Department Finance: Municipal Budget	**Output:** Comprehensive Plan on landfill closure **Outcome:** Working document on targeted action to address the issue of legacy waste in landfill

Sectoral Action Tracks 3(b) and 3(c) on the uptake of clean fuel for cooking in domestic and commercial sectors and, subsequently, crematoria are addressed towards behavioural change attributes in the community. These action points are mainly pointed towards medium and long term, while the increase of LPG adoptions in the population can be achieved in the short run by 2025. Targets regarding clean fuels in crematoria are particularly difficult to achieve due to the associated community sentiments. However, these are sectors that are included in the micro action plan and source apportionment of the city.

Table 22-4: NTPC Environmental Clearance lists the measures to curb gaseous and PM emissions

<table>
<tr><th>Measure</th><th></th><th>Components</th></tr>
<tr><td>Emissions from the combustion of fossil fuels from stationary or mobile sources</td><td>Yes</td><td rowspan="2">Stack emissions shall comprise PM, SO_2, NO_x and CO_2 due to the combustion of coal. To mitigate these emissions and to ensure compliance with revised environmental norms of air emission, the following measures are envisaged:
PM: ESP has been designed to meet the limit of PM < 30mg/Nm^3
SOx: FGD has been installed for limiting SO2 emissions within 100mg/Nm^3
NO_x: NO_x emissions from the steam generator shall be controlled by employing low NOx burners & denox system (LNB) limiting NOx values within 100mg/Nm^3</td></tr>
<tr><td>Emissions from production processes</td><td>Yes</td></tr>
</table>

Table 22-5: Sectoral Action Track 3(b): Domestic and Commercial (Bakeries/ open eateries) Cooking fuel

Action description	Stakeholders and Financing	Indicators
Increase uptake of clean cooking fuel usage through subsidising LPG cylinders in low-income vulnerable population **Timeframe: 2027**	Slum department, SMC Finance: PMUY	**Output:** No. of HHs with LPG cylinder used as the primary fuel **Outcome:** % increase of LPG uptake in low-income and vulnerable HHs
Undertake a sample survey to track secondary fuel usage in vulnerable neighbourhoods by evaluating susceptibilities, resilience capacities, and financial resources of vulnerable communities. **Timeframe: 2024**	SMC, Zonal/Ward officers, Slum department Finance: PMUY	**Output:** No. of HHs using unclean fuels for domestic purposes **Outcome:** % shift of HH to reduce or give up usage of unclean cooking fuel % change in PM reductions
Increase PNG uptake in HIG and MIG households neighbourhood by 30% **Timeframe: 2025**	SMC, Maharashtra Natural Gas Ltd Finance: SMC	**Output:** No. of HIG HHs with PNG connections **Outcome:** Increase in PNG Uptake
Inventory of bakeries and open eateries and their fuel type- spatial concentrations **Timeframe: 2024**	SMC, Food department Finance: SMC	**Output:** Spatial concentrations and details of the type of bakeries **Outcome:** Adoption of sustainability practices by bakeries and open eateries
Install pollution amelioration measures like scrubbers (APCDs) in exhaust systems in bakeries. Adopt eco-friendly ovens. **Timeframe: 2025**	SMC, Bakeries Association, MPCB Finance: NCAP	**Output:** No. of bakeries with installed scrubbers No. of bakeries able to equip eco-friendly ovens **Outcome:** Adoption of sustainability practices by bakeries and open eateries
Identify Sustainable practices for bakeries/open eateries in terms of fuel usage, waste management. Etc. **Timeframe: 2025**	SMC, bakeries association Finance: NCAP	**Output:** Working document on actions to shift to sustainable practices **Outcome:** Adoption of sustainability practices by bakeries and open eateries
Calculate $PM_{2.5}$ emission – exposure level for open eat-out joints **Timeframe: 2024**	SMC, Policy, and Research Institute Finance: NCAP	**Output:** Daily PM concentration levels **Outcome:** Reduction targets set by the associations (%)
Mandate the use of LPG/electricity in bakeries and eateries **Timeframe: 2027**	SMC	**Outcome:** Bakeries and other eateries adopted clean fuel (%) **Outcome:** Adoption of sustainability practices by bakeries and open eateries

Action description	Stakeholders and Financing	Indicators
Increase awareness of the impact of unclean cooking fuel on one's health, implement policies and interventions in a more defined manner **Timeframe: 2025**	SMC, Environment Dept, Slum départements, NGOs	**Output:** No. of awareness programmes undertaken towards the transition to a cleaner cooking fuel **Outcome: Adoption of sustainability practices by bakeries and open eateries**
Mandate all bakeries to obtain a licence, and check for unlicensed establishments **Timeframe: 2024**	SMC	**Output:** Closure of unlicensed establishments
Ensure the promotion and use of cleaner fuel (i.e., LPG) instead of coal-fired *chulhas*, *tandoors* or firewood in hotels and restaurants **Timeframe: 2025**	Hotel/Restaurants Association, SMC	**Output:** No of hotels and restaurants adopting cleaner fuel **Outcome:** Adoption of sustainability practices by bakeries and open eateries
Joint workshop and sector consultations with bakeries, restaurants, hotels, and open eat-out associations to discuss an action plan **Timeframe: 2024**	Bakeries, Hotel/ Restaurants association, SMC, MPCB Finance: NCAP	**Output:** To document grievances and shortcomings for the adoption and update of cleaner fuels. **Outcome:** Adoption of sustainability practices by bakeries, hotels, and open eateries

Track 3(c): Crematoria

There are a total of 18 crematoria in Solapur city, of which 16 are wood-based and 2 are electric. According to the NCAP, an average of 2-3 corpses are cremated per crematorium per day.

Table 22-6 Crematorium: Track wise actions and their implementation

Action description	Stakeholders and Financing	Indicators
Conversion of wood-based crematoria to electric **Timeframe: 2030**	Electricity Department, SMC Finance: NCAP, SMC Budget	**Output:** No. of wood-based crematoria converted to electric **Outcome:** Increase of usage electric crematoria (%)
Assessment of quantity of wood used as a fuel (per day/per week) **Timeframe: 2024 and continuous**	SMC Finance: NCAP, SMC Budget	**Output:** Quantity (in kg) estimation of monthly use of wood in the crematorium **Outcome:** Estimate emissions from fuel usage in the crematorium
Incentives towards the use of electric crematoria and awareness drives **Timeframe: 2024 onwards**	SMC Finance: NCAP, SMC Budget	**Output:** No. of awareness drives undertaken **Outcome:** Change of behaviour and perception towards the use of electric crematoria

As a part of the micro action plan for Bakeries and Crematoria, LPG has been proposed for use in hotels and *dhaba*s and renewable fuel/oil/electricity/gas, etc. in crematoria.

The micro action plan includes actions for increasing the number of LPG connections among the low-income strata, the shifting of fuel in all hotels and bakeries to LPG and electric connections, and the implementation of underground LPG lines for domestic use under the SMART City Mission.

Track 3(d): Industries (2 components: MSMEs/textiles and Brick kiln)

There are two industrial areas within SMC, the Hotgi Road industrial estate that houses small-scale industries and the MIDC industrial area at Akkalkot Road. The latter has an area of 216.48 ha. Based on an inventory of all industrial units in Akkalkot MIDC, 73% of the units are found to be textile units that manufacture *chaddar*s, terry towels and napkins. A total of 657 units are functioning in the MIDC area, the breakup of which is provided in Table 22-9.

A total of 141 small and medium-scale enterprises function in this estate, generating direct employment for 2,000-3,000 persons, as informed by the estate society. Apart from direct employment, the estate is supporting 10,000-15,000 dependents of the employees working in the industrial estate. In addition to textiles, the *beedi* industry is another dominant industry, which is employing about 80,000 people of which a majority are women.

The status of these industries is not clearly known. While Solapur has been incremental in manufacturing Solapur *chaddar*s, many of these power looms have shut down[60]. There has been a change, from the manufacturing of products from *chaddar*s to uniforms, however textile as an industry continue to dominate. There have been claims on the deterioration of the *beedi* industry due to health and safety issues.. The power loom and *beedi* industry claim to provide employment to the migrant population from surrounding rural areas and the states of Karnataka and Andhra Pradesh. Solapur district is also home to sugar industries. The city has several sugar industries as sugarcane is produced here as a crop.

Table 22-7: Number and Type of Industrial Units

Sr No	Type of Unit	Number of units	% of total
1	Fabrication	6	0.91%
2	Engineering and Pharmacy	18	2.74%
3	Chemical	17	2.59%
4	Electrical/Tiles/Tyre/Pharma	140	21.31%
5	Textile Units	476	72.45%
	Total	657	100%

Source: Revised City Development Plan 2041 (2019)

Table 22-8: MSME and textile industries Track wise actions and their implementation

Action description	Stakeholders & Financing	Indicators
Regular update on the inventory for industry type in SMC **Timeframe: 2024 and continuous**	SMC, MIDC, MPCB Finance: NCAP, SMC Budget	**Output:** No. of agri-based, manufacturing industries, heavy industries in SMC **Outcome:** Change of industry typology in Solapur city/ region
Track industrial fuel usage, and devise mechanisms to shift to alternate cleaner fuel **Timeframe: 2030**	MIDC, MPCB Finance: NCAP, SMC Budget	**Output:** Industries categorised into fuel type **Outcome: Adoption of cleaner fuels by industries**
Establish one monitoring station near Akkalkot MIDC **Timeframe: 2025**	MPCB, SMC Finance: NCAP	**Output:** Monitoring station established **Outcome:** Regular monitoring of gaseous and PM emissions
100% reduction in the operation of Diesel Generators sets through uninterrupted power supply **Timeframe: 2028**	Power company Finance: NCAP	**Output:** Reduction in the operation of DG sets (%) **Outcome:** DG sets phased out for commercial purposes
Industries Associations, MPCB, and SMC should collaborate to explore the possibilities of enhancing resource consumption efficiency in the industries of the SMC area. **Timeframe: 2025**	MPCB, MIDC, SMC	**Output:** No. of industrial associations capacitated **Outcome:** Industrial associations adopting sustainability measures

The clean air action plan discusses the banning of new industries in city limits as well as the installation of air pollution control systems. It also calls attention to regular audit of stack emissions as a part of its actions and strategies. In addition, reducing air pollution loads from industries, C&D, brick kilns, DG sets, and commercial-residential cooking are also a part of the plan.

Brick Kilns

Table 22-9: Brick Kilns Track wise actions and their implementation

Action description	Stakeholders and Financing	Indicators
Identify brick kiln sites and do regular monitoring, including a check on use of fuel type and unauthorised units **Timeframe: 2025**	SMC	**Output:** No. of authorised and unauthorised brick kiln sites within and around 5km buffer outside SMC **Outcome:** % reduction of brick kiln operations
Improve kiln technology, undertake conversion of natural draft brick kilns to induced draft **Timeframe: 2025**	SMC, MIDC, MPCB	**Output:** No of brick kilns with upgraded technology instalments **Outcome:** Improved sustainability measures adopted by brick kilns

Action description	Stakeholders and Financing	Indicators
Reduce air pollution at kilns by installing air pollution control devices (APCD) **Timeframe: 2025**	SMC, MIDC, MPCB	**Output:** No. of brick kiln with upgraded technology instalments **Outcome:** Improved sustainability measures adopted by brick kilns

The clean air action plan focuses on the identification of brick kilns and their regular monitoring, including the use of designated fuel and closure of unauthorised units within SMC. While the source apportionment lists the shifting of natural draft brick kilns to induced draft, it is crucial to consider the banning of operational Brick kilns in the city area to achieve emission reduction.

Building Construction and Demotion

While C&D-related actions are proposed as a part of the mitigation sector under solid waste management, the actions related to air quality management strategy focus on the adoption of better practices for redevelopment and construction related activities.

Table 22-10 Building & Construction: Track wise actions and their implementation

Action description	Stakeholders and Financing	Indicators
Identification of quarrying site(s) and related activities within a 5 km radius outside the SMC boundary **Timeframe: 2024**	SMC, MPCB, Building & Construction associations	**Output:** Map the No., locations and operational hours of the activities **Outcome:** Actions and measures in place to reduce the impact to the surroundinga area
Enforcement of C&D Waste rules[61] for the efficient undertaking of duties by waste generators, service providers and the local authority. **Timeframe: 2027**	SWM Finance: NCAP, Swachh Bharat Mission	**Output:** % area affected by the suspension of dust from C&D **Outcome:** Emissions reduction and reduced exposure from the suspension of dust particles.
Adopt better construction management practices aimed at reduction of PM by 30% **Timeframe: 2030**	SMC, MPCB, Building & Construction associations Finance: NCAP	**Output:** No. of sites complying with C&D norms **Outcome:** Emissions reduction and reduced exposure from the suspension of dust particles.
Conduct target workshop with C&D industry **Timeframe: 2024**	SMC, MPCB, Building & Construction associations	**Output:** No. of industries capacitated **Outcome:** To document grievances and address issues with regard to adoption of sustainable practices in the sector
Create a detailed inventory of the projects (residential, commercial, transportation, physical infrastructure, redevelopment) work in SMC **Timeframe: 2024**	Building and Construction dept of SMC, RERA website	**Output:** List to be updated on a quarterly basis, especially during high pollution level days **Outcome:** Ban on activities on certain days in winter months to reduce pollution effects

The clean air action plan makes no mention of quarry sites in the city. However, it does list the measures related to the enforcement of C&D rules in SMC. The micro-action plan lists the actions related to the transportation of construction materials, enforcement of CPCB guidelines, etc. The Source Apportionment Study lists certain measures to control dust from construction activities using enclosures, fogging machines, and stringent implementation barriers. Also greening and landscaping to be done at major arterial roads and national highways listed under major polluting stretches.

Track 4: Disseminate information

Table 22-11 Track 4: Disseminate information on the Risk and Impact of air pollution on human health; address air pollution through a multi-sector approach

Action description	Stakeholders	Indicators
Carry out multi criteria pollutant hotspot analysis- based on activity mapping **Timeframe: 2025**	SMC Finance: NCAP	**Output:** No of hotspots identified **Outcome:** Actions and strategies to mitigate the identified hotspot
Set up a mechanism to track hospital admissions/ cases for respiratory illness such as asthma, bronchitis, acute respiratory infections **Timeframe: 2025**	Health department, Educational institutes Finance: NCAP	**Output:** No. of cases of extreme respiratory illness **Outcome:** Tracking respiratory illness over a period of time
Conduct a health risk assessment to identify the communities exposed to air pollution-related activities including vulnerable sections of the population – children and elderly **Timeframe: 2025**	Health department, Educational institutes Finance: NCAP	**Output:** No. of vulnerable people across zones or wards. **Outcome:** Monitoring and frequent health-related interventions among targeted groups.

23. INCLUSIVITY & CO-BENEFITS IN CLIMATE ACTION PLANNING

23.1 ENSURING INCLUSIVITY AND EQUITY IN THE CAP PROCESS

Achieving the goals of the Paris Agreement requires a collective, sustained long-term effort and more inclusive climate action. The process of formulating the CAP for Solapur was in line with the framework used to develop the Mumbai Climate Action Plan and C40 Cities' Climate Action Planning Framework. However, besides formulating the GHG inventory for cities and setting targeted actions for 2050, the Solapur CAP has aligned its inclusivity and equity considerations by adopting the inclusive planning guidance of C40 Cities and WRI.

The roadmap to Solapur's inclusive CAP aligns with the city's existing needs to address climate action in the form of consultations with stakeholders and workshops for capacity building as well as to validate the actions and targets by 2050. Under the needs assessment and through an extensive Vulnerability Assessment, communities and areas that are prone to more risk have been identified. Interactions with NGOs, civil society groups and ground truthing were carried out to understand challenges in the adoption of climate-sensitive strategies.

Inclusive climate Action Planning (ICAP) facilitates local governments to access climate-related risks and identify actions that are consistent with the country's climate goals. Inclusivity can be achieved by engaging relevant stakeholders in the policy-making process. Inclusivity can be thought of in terms of processes, policies and impacts . In terms of process, primary consultations were held with the NGOs, civil society stakeholders and those working in the environment space, including the District Forest Office, on various initiatives related to greening. These considerations are reflected in the accessibility analysis of green spaces. Moreover, consultations were also held with the transport and solid waste management departments at the SMC to understand the various initiatives carried out under these sectors.

In terms of policy considerations, relevant documents such as NCAP, city's Source Apportionment study, Development Plan, etc. were referred. Solapur CAP aligns with national programmes and polices such as the NCAP, Swachh Bharat Mission and CSCAF through the five sectoral actions targets identified within these. Moreover, the actions and pilot projects are aligned with the municipal budget, XV Finance Commission and NCAP budget. The cities participation in MVA ensures the local bodies to take environment-related actions incorporating the five elements Earth, Air, Water, Energy, and Enhancement. The impact analysis considers the assessment of risks by identifying hotspots attributed to LST, flooding or waterlogging, and air pollution and overlaying them with the most vulnerable population in the city. The impacts of climate change, especially extreme weather events, are felt disproportionately by the poor and the marginalised. The assessment of impacts is done from a multihazard lens, where, in the case of Solapur, heat hotspots, traffic congestion hotspots, and decreased GWRP levels were studied. Analysis concludes, 3.4% of Solapur's population is vulnerable to both, above average LST and decreased GWRP, the majority of which resides in the eastern part of the city. Risk assessment has taken into account the city's historic trends and current situation, based on available scientific evidence from 1975 till date. Basis the historical trend, the major climatic risks identified were that of heat risk, water scarcity and GW depletion, and air pollution.

Inclusive CAP can advance the development outcomes in cities in the domains of environment, health and wellbeing, education and skills, economic prosperity, essential public services, civil society, and governance and institutions. These aspects are mainly referred to in terms of action tracks. For instance, health and wellbeing are addressed through increased monitoring and evaluation of air pollution monitoring stations in the city. Education and skillset development are to be addressed through actions in the waste sector, which also employs women staff for waste segregation and management activities. Similarly, the usage of unclean fuels for domestic purposes is tracked through the indoor air quality analysis. Through this, actions on mobilising adoption of clean fuels adoption for domestic purposes, and commercial use (bakeries, open-eat outs, crematoria in the case of Solapur) have been focused upon. With respect to economic prosperity in the city, an increased share and access to public transport and NMT infrastructure, will result in increased expenditure towards transport , leading to an increased share of women participating in the workforce.

CAP requires input from a diverse network of groups with an interest in or influence on climate action. An inclusive, collaborative process for climate action planning is as important as the CAP itself as it builds widespread community and political support, fosters credibility, and strengthens the plan.

23.2 CO-BENEFITS IN CLIMATE ACTION PLANNING

The Fifth Assessment Report of the IPCC defines co-benefits as being "the positive effects that a policy or measure aimed at one objective might have on other objectives thereby increasing the total benefits for society or the environment. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices, among other factors. Co-benefits are also referred to as ancillary benefits" [62]

Climate action planning have added co-benefits in addition to climate risk mitigation and adaptation outcomes. It has wider social, economic and public health related co-benefits that impact the people and environment.

Mitigation

Co-benefits of climate change mitigation are the benefits related to mitigation measures which reduce GHG emissions or enhance carbon sinks.

Climate change mitigation policies can lead to lower emissions of co-emitted air pollutants. For instance by shifting away from fossil fuel combustion the reduction of methane can bring benefits in terms of limiting global temperature increase as well as improving air quality which in turn benefit the health and economic well-being of the people.

Adaptation

There are some synergies or co-benefits between adaptation and mitigation, one of which is the inclusive benefits of public transport system. It has implications both in terms of reduction of GHG emissions as well as increase resilience in case of disasters. Reduced air pollution from transport improves health. It also improves resilience in terms of accessibility to the public transport network and opportunities for employability as a social and economic benefit. Active lifestyles and increased exposure to urban green spaces provides both physical and psychological benefits.

The social, economic and health related co-benefits are outlined below:

Social- Some actions emphasise on equity and inclusivity with a focus on vulnerable areas and communities. This has been addressed through prioritisation of action in hazard prone areas, strengthening information dissemination and increased awareness campaigns. Focus on vulnerable groups such as women, children, elderly and urban poor is also ensued.

Economic- Employment through green jobs, financial incentives to switch to sustainable practices, savings on public expenditure such as lowered travel cost with public transport or switching to cleaner appliances, and opportunities for vulnerable groups such as women are some of the economical benefits through climate action planning.

Public health- The overall mental and physical health and well-being is addressed through increased access to green spaces and protected biodiversity, cleaner air and safety of citizens with reduced exposure to climate risks amongst other measures

Figure 23-1 : Illustration of the co-benefits under increase in green spaces

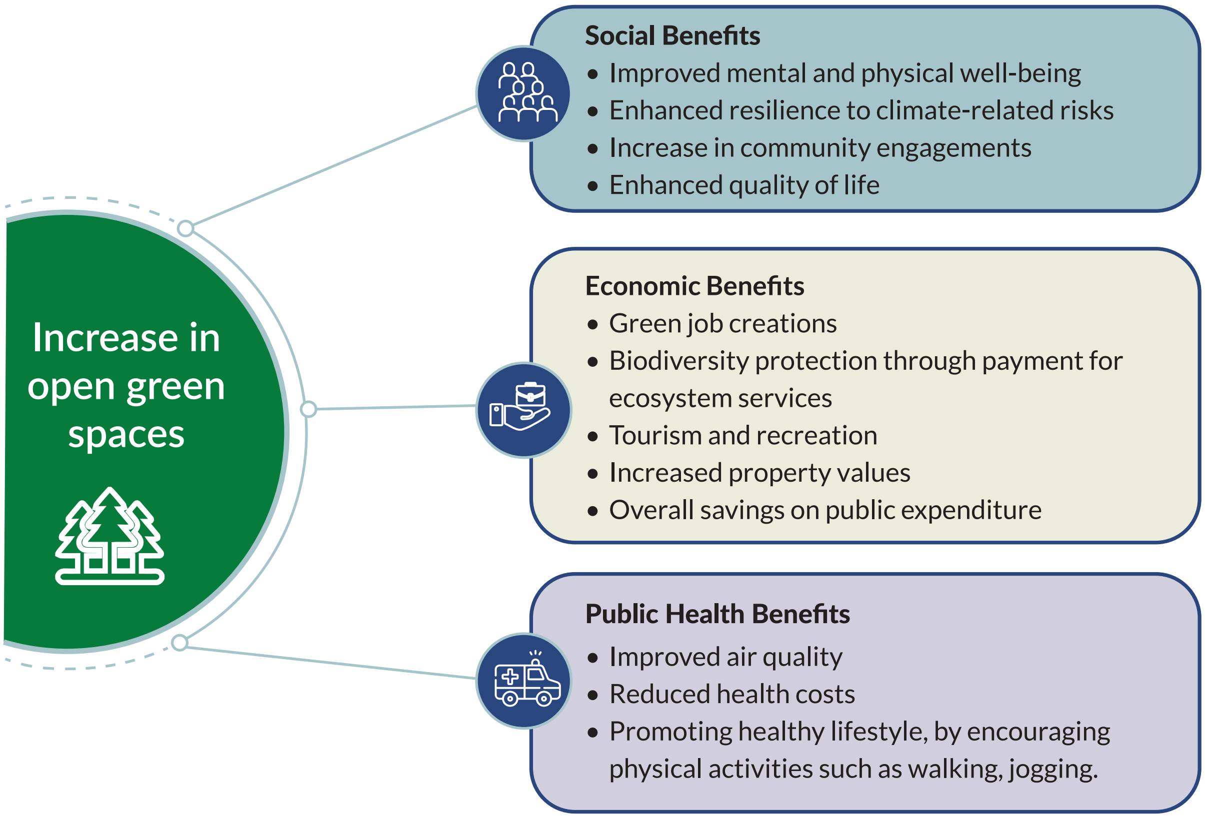
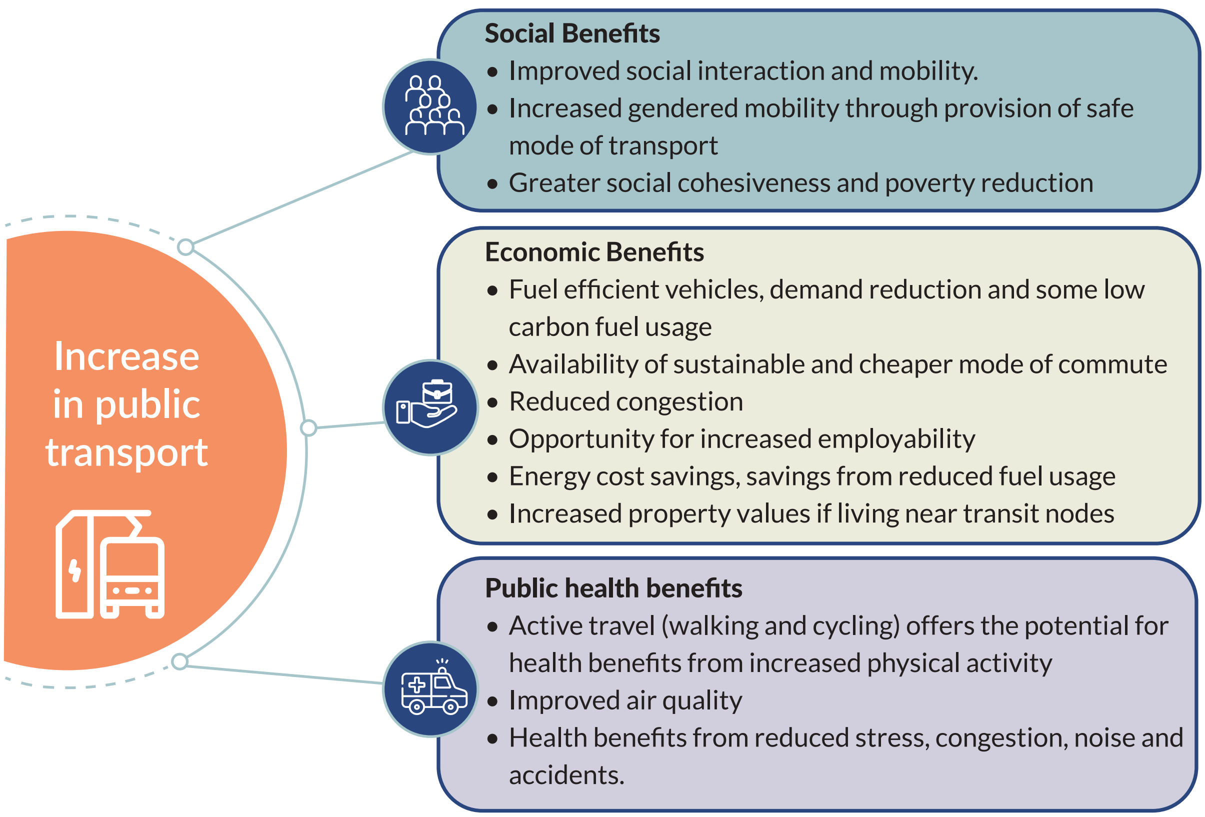
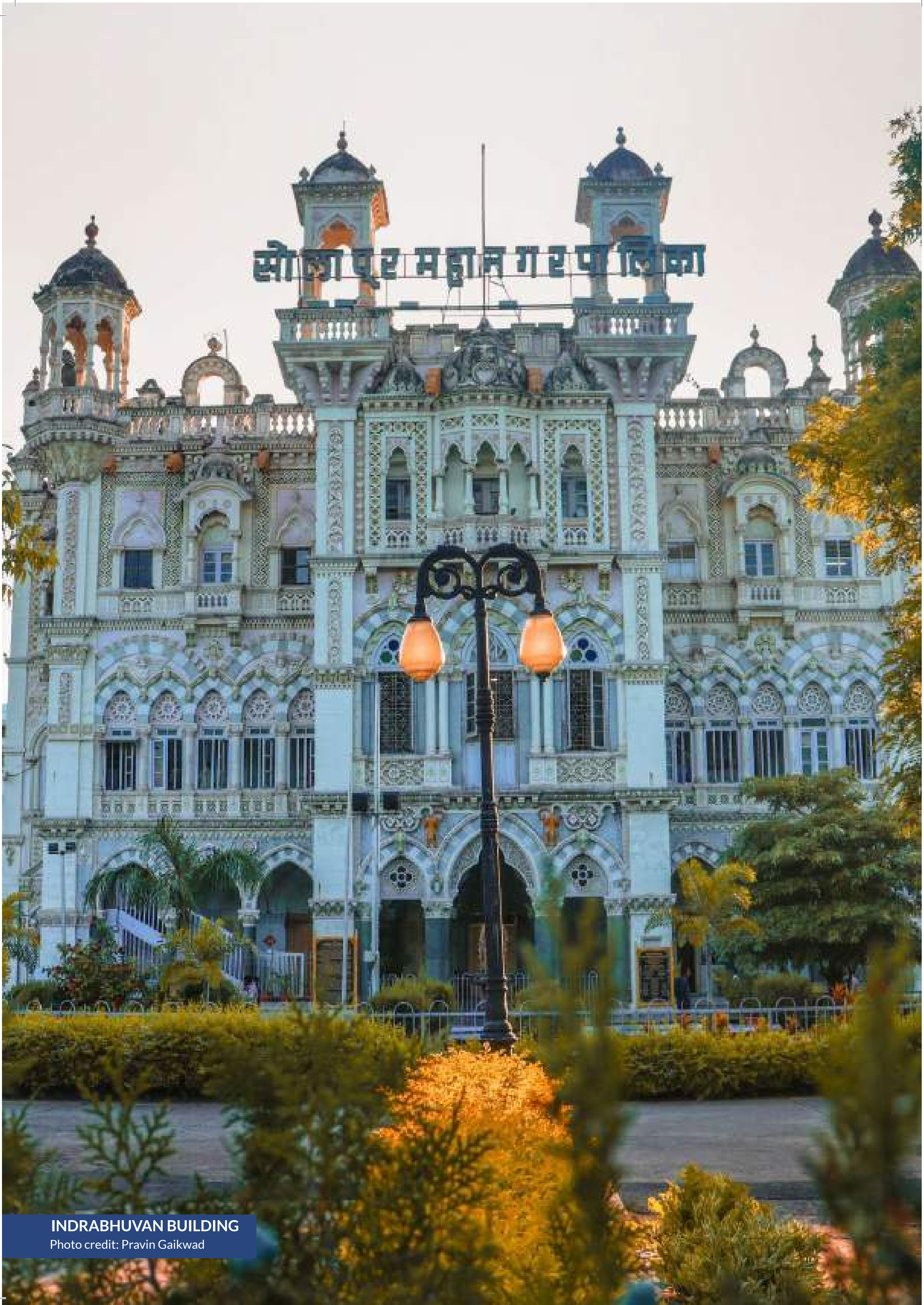


Figure 23-2: Illustration of the co-benefits under increase in public transport mode share





INDRABHUVAN BUILDING
Photo credit: Pravin Gaikwad

24. GOVERNANCE & INSTITUTIONAL STRUCTURES

24.1 ORGANISATIONAL STRUCTURE

24.1.1 Existing Organisational Structure within Solapur City

Solapur Municipality (municipal council) was established on August 01, 1852. The governing structure of SMC consists of political (elected) and administrative wings. The political wing is an elected body of councillors headed by the City Mayor. The Municipal Commissioner heads the administrative wing and is responsible for strategic decisions, operational planning, and management of the Corporation.

Table 24-1: Agencies involved in Solapur city administration

S.N.	Name of agency	Role/ sector	Solapur CAP Sector
1	Solapur Municipal Corporation (SMC)	City administration managing - water supply, sanitation, solid waste management, roads and bridges, development plan, streetlights, etc.	Air Quality, Buildings & Energy, Greening & Biodiversity, Transport, Solid Waste Management, Water, Urban Heat
2	Regional Transport Office (RTO)	Vehicle Registration	Sustainable Transport, Air Pollution
3	Oil companies	Sale of petrol, diesel and CNG	Energy & Buildings, Air Pollution
4	Maharashtra State Electricity Distribution Company Limited (MSEDCL)	Electricity distribution and supply	Energy & Buildings
5	Maharashtra State Power Generation Company (MAHAGENCO)	Electricity generation	Energy & Buildings
6	Groundwater Survey & Development Agency (GSDA)	District Ground water management	Water Resources Management
7	Traffic police	Traffic management	Sustainable Transport
8	Indian Meteorological Department (IMD)	Rainfall and temperature data	Disaster Risk & Mitigation, Urban Heat, Air Quality
9	Maharashtra Pollution Control Board (MPCB)	Control and regulation - Air, Water and land pollution	Air Quality, Solid Waste Management, Industries
10	Forest Department	Social forestry program and greening measures	Greening & Biodiversity
11	Disaster Management Authority	Preparation and response during disasters	Disaster Risk & Mitigation
12	Smart City Office, Solapur	Management of infrastructure projects	Sustainable Transport

24.1.2 Agencies that support Solapur city Administration

The organisational set-up of SMC consists of a Deliberative wing, which comprises of elected representatives of the city, and an administrative wing comprising appointed representative responsible for infrastructure and service provision. Additionally, there are parastatal agencies that come outside the purview of SMC and provide services, technical data, and support to the city. These agencies have planning, implementation, and regulatory roles. The City Municipal Corporation is the nodal agency. The list of agencies and sectors is presented in Table 24-1.

Elected wing

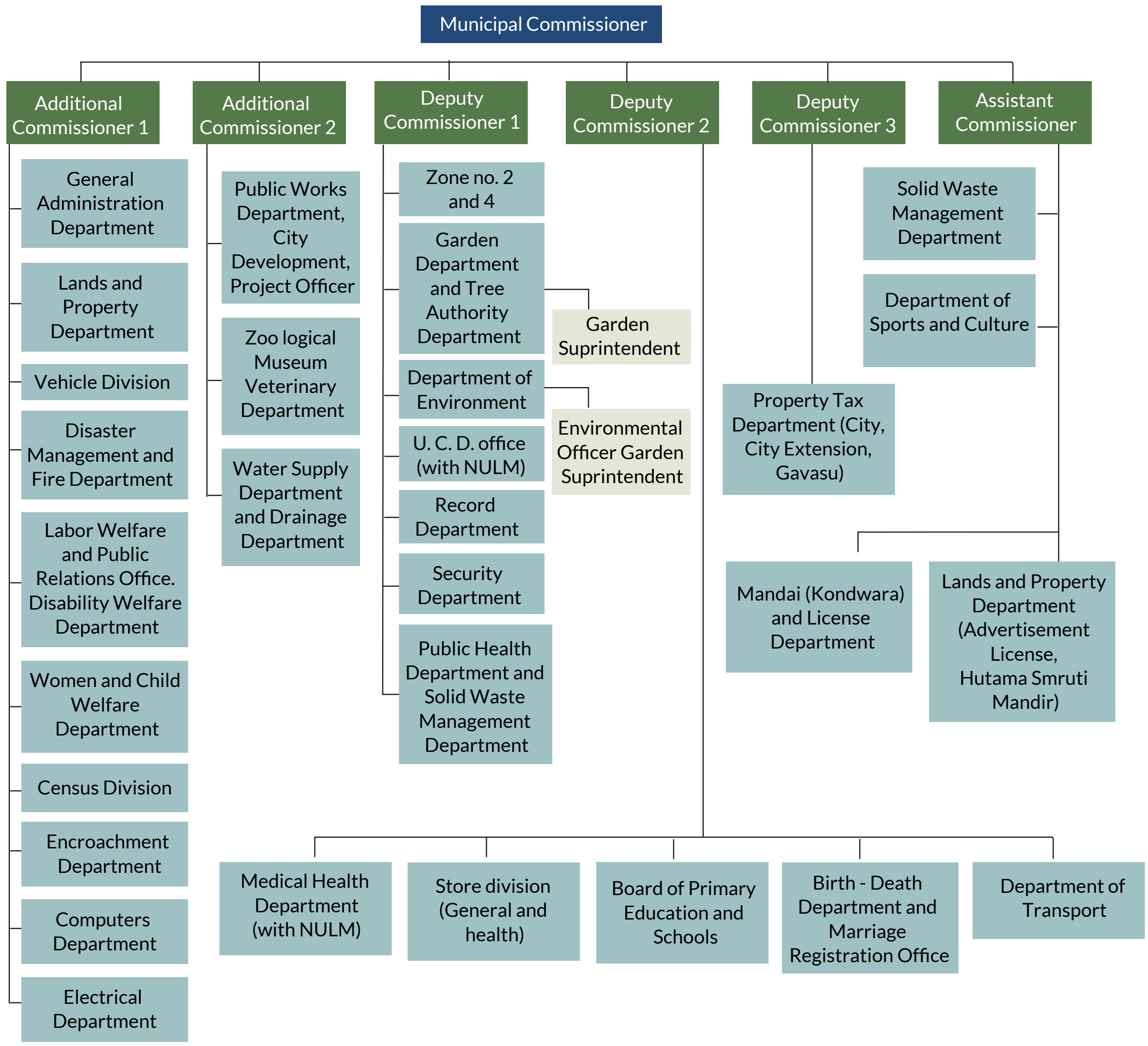
The elected wing of the corporation is represented by the elected members from each of the 98 electoral wards in the city. The group of all the elected members and five members from the non-elected political parties form a General Board (GB) of the Corporation. The members of the GB select a 16-member Standing Committee headed by a Chairman who is selected by members of Standing Committee.

Administrative wing

- The administrative or the executive wing of the SMC is headed by a Municipal Commissioner appointed by the State Government, whose term is usually for three years.
- There are two Additional Municipal Commissioners who oversee various departments.
- There are two Deputy Municipal Commissioners and four Assistant Municipal Commissioners who provide assistance to the SMC in general administration and civic infrastructure works, such as water supply, electricity, public transport and roads.
- The Municipal Corporation is organised into eight zones for effective service delivery and management under the purview of zonal officers. The executive wing of the SMC is organised into 11 major functional departments.
- The Environment Department reports directly to the Deputy Municipal Commission. The major functions of the Department include working on the nexus of waste management, air pollution under NCAP, and greening under Majhi Vasundhara Abhiyan.

Solapur city is divided into 26 administrative wards and 8 zones. The city is authorized to build roads, provision of water supply, collection of waste, etc within the Municipal Corporation limits and impose taxes on properties falling in its jurisdiction.

Figure 24-1: Organisational structure of SMC



Source: SMC (2022)

The Solapur Municipal Transport (SMT) is the agency involved in the management of public bus transportation in the city. Being the district headquarters, Solapur houses the head offices of the district-level agencies, such as Zila Parishad, District Collector, and Regional Transport Office (RTO).

24.1.3 Institutional Barriers

- SMC is in charge of providing infrastructure and services such as water supply, sanitation, storm water drainage, solid waste management, public transportation, open spaces and public health. While the environmental concerns are managed by the individual departments with no concentrated efforts towards larger impact on climate, The Environment Department plays a limited role with regard to waste and air pollution.
- Currently, the Environment Department is focussed on projects under the NCAP, which may be multi-sectoral. The department in its current functioning has limited expertise to address and implement cross-sectoral projects due to the lack of either institutional capacity or, in some instances, funding mechanisms.
- Currently, the Environment Department does not have adequate budget allocation for administrative and project related works; and its institutional capacity also needs to be built to oversee various functions related to environment management within SMC area.
- To implement the Solapur CAP, it is important that one department that has institutional and technical capacity as well as the ability for strong interdepartmental coordination to take ownership, provide advice on key amendments to statutory regulations, and liaise with parastatal agencies, as required.

24.1.4 Proposed institutional arrangement for Department of Environment and Climate Change

It is proposed that the current Environment Department headed by the Deputy Municipal Commissioner be the nodal coordinating agency for the Solapur CAP. In line with the Ministry of Environment and Climate Change as well as the changes instituted by the Government of Maharashtra, the newly named Department of Environment and Climate Change at the state level addresses issues pertaining to environment and accelerates climate action in Maharashtra. It is also proposed that the Environment Department in Solapur be expanded, strengthened, and renamed as the Department of Environment and Climate Change following official protocol. Their roles can be streamlined in terms of:

1. Strengthening the technical capacity
2. Meeting climate targets through adaption and mitigation strategies
3. Regulatory role
4. Cross departmental coordination

The proposed 'Department of Environment and Climate Change' (ECC) would be headed by Deputy Municipal Commissioner who would be reporting to the Additional Municipal Commissioner.

As the Department of ECC overlooks all development projects under its purview, it is important to create an environment and climate change cell that is focused on the implementation of the Solapur CAP. The Environment and Climate Action Cell (ECAC) would play a critical role in data management and research, coordinate with other interdepartmental and parastatal agencies, and support the projects and programmes pertaining to the environment, as well as monitor the outcomes and outputs of the Solapur CAP. The ECAC will comprise two verticals, as shown in Figure 24-3.

Figure 24-2: Proposed changes in the Environment Department

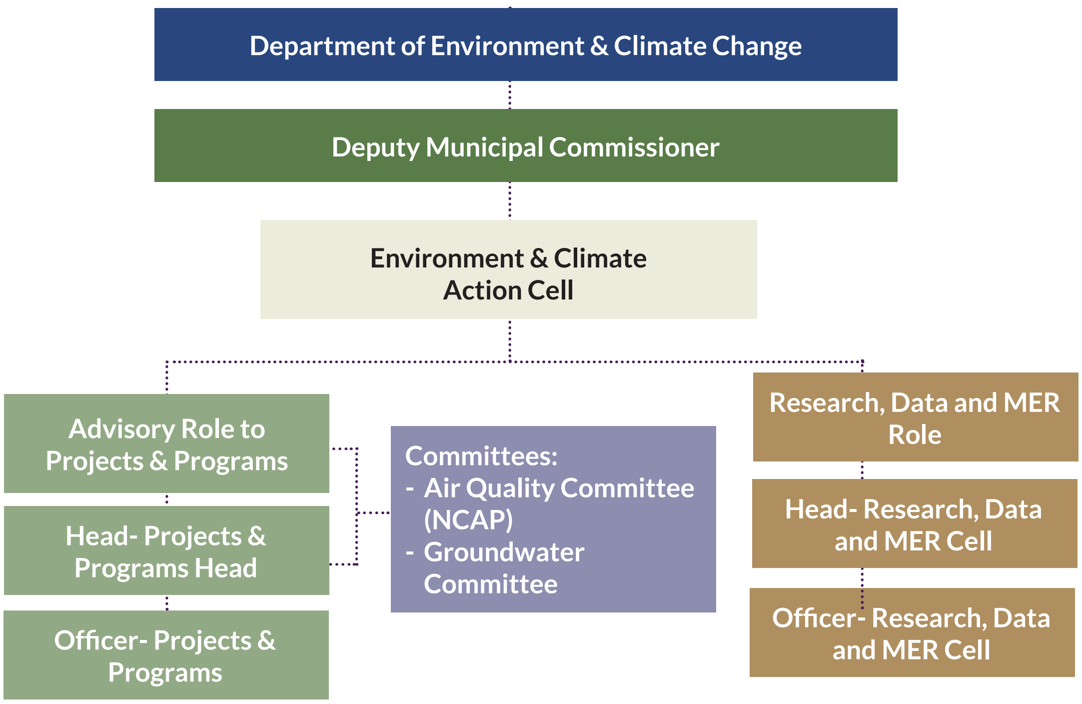


Figure 24-3: Two Verticals proposed for Environment and Climate Action Cell

Data Management, R&D, Monitoring and Evaluation	Projects & Programs
Create data repository	Technical and Institutional capacity to execute projects
Develop guidelines for projects aligned with climate goals	Coordination with other departments to mainstream climate action
Take localised actions based on data	Streamline projects & programs with available funding
Monitoring and Evaluation	
Monitor outputs and outcomes of Solapur CAP	
Report progress of the Solapur CAP	

Source: WRI India analysis

The ECAC will carry out two functions:

- Advisory role in projects and programmes: Support for all environmental aspects of the implementation of various national, subnational, and externally funded projects and programmes, as well as in climate-related budget, schemes, and grants.
- Research, Data and Monitoring Evaluation & Reporting (MER): Collect and analyse data related to climate change, monitor implementation of CAP, etc.

This Cell can be headed by the Deputy Municipal Commissioner and supported by a team.

25. FINANCING ARRANGEMENTS

25.1 SMC - SECTOR-WISE BUDGET ALLOCATION

The SMC budget has two major heads - revenue and capital. In this section, the SMC's budget for 2023-2024 has been analysed with data from Financial Year (FY) 2019-20 to FY 2022-23. The FY20, FY21, and FY22 numbers are actuals whereas the FY23 numbers are revised budget estimates.

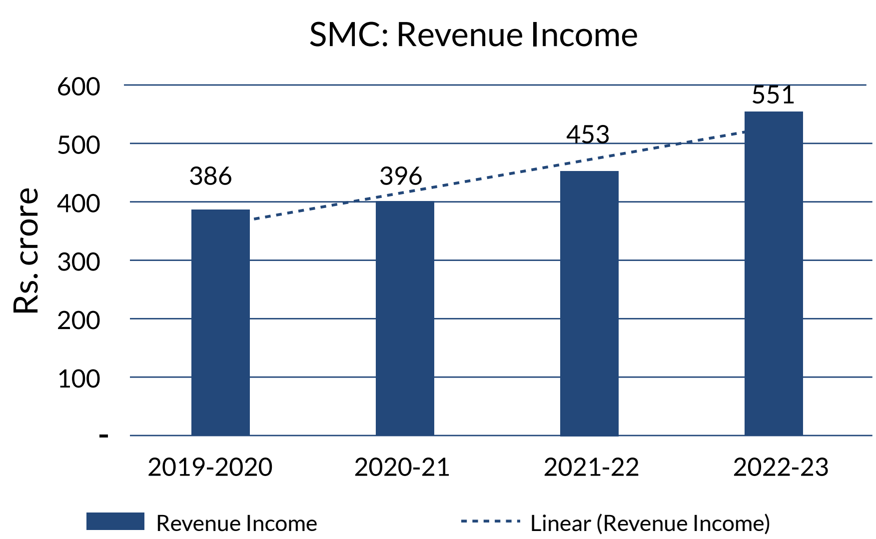
25.1.1 Revenue account

The trend of revenue income during FY20-FY23 is shown in Figure 25-1. There is very little revenue surplus. During this period, the revenue income and expenditure grew at a compounded annual growth rate (CAGR) of 13%.

The share of revenue income in the overall income ranges from 51% in FY 2019-20 i.e., FY21 to 70% in FY23. Thus, the revenue expenditure is fully and capital works partly funded with the revenue income.

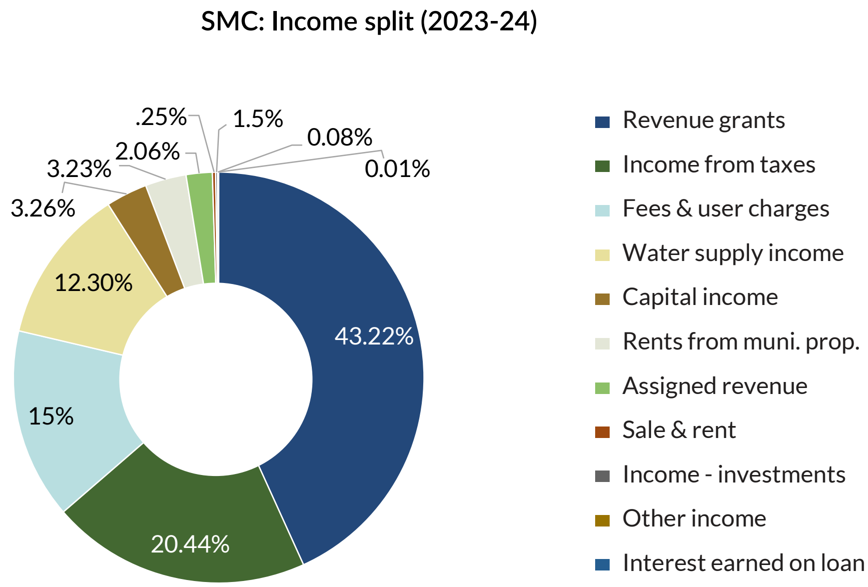
The share of various activities/ sectors within SMC's revenue income and expenditure are presented in Figure 25-2 and 25-3.

Figure 25-1: SMC: Revenue income and expenditure growth trends



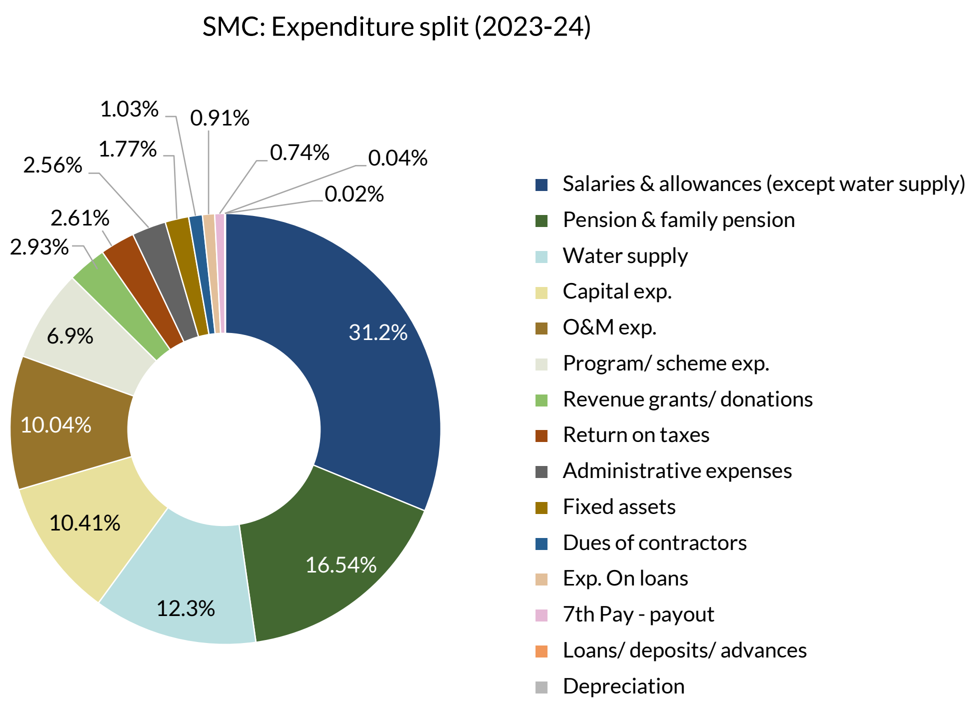
Source: SMC budget 2023-24 (FY 2022-23 are revised estimates) and WRI India analysis

Figure 25-2: SMC: Income – break-up



Source: SMC budget 2023-24 (FY 2022-23 are revised estimates) and WRI India analysis

Figure 25-3: SMC: Expenditure break -up



Source: SMC budget 2023-24 (FY 2022-23 are revised estimates) and WRI India analysis

The key observations are as follow:

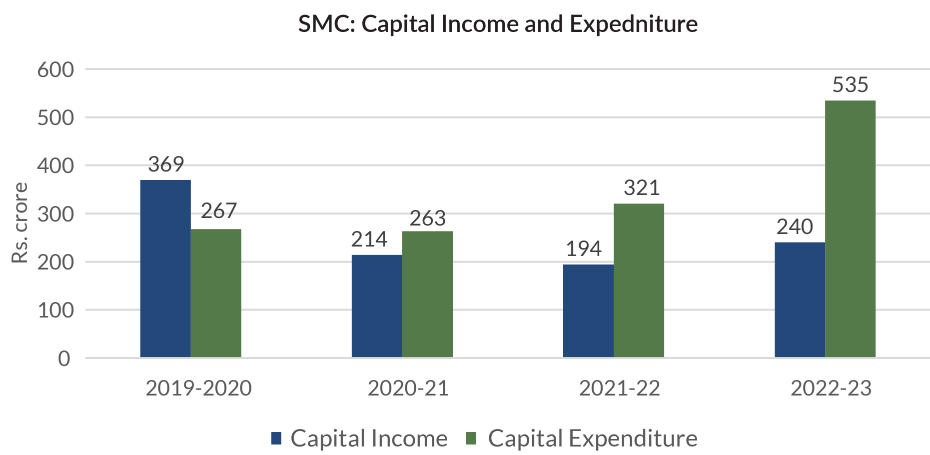
- The three major sources of income for SMC are revenue grants (43.22%), followed by municipal taxes (20.44%), and charges and user fees (15%).
- The three major sources of expenditure for SMC are salaries & allowances (31.20%), followed by pension & family pension (16.54%), and water supply expenditure (12.30%).

25.1.2 Capital account

The capital account comprises capital income and expenditure. The capital income comprises (a) works taken up from the revenue income transferred to capital account and (b) funds received under State and Central schemes which in turn comprises 61% (FY23) to 73% (FY20) of the total capital income.

During FY20-FY23, the capital expenditure grew at a CAGR of 26% whereas during FY20-FY22, it grew at a CAGR of 6.3%. This highlights that the SMC needs to plan for improving its income and, at the same time, manage the capital expenditure in a judicious manner. It should also leverage its balance sheet so that it can fund more capital works based on existing income streams.

Figure 25-4: SMC: Capital income and expenditure growth trends



Source: SMC budget 2023-24 (FY 2022-23 are revised estimates) WRI India analysis

The key observations are as follow:

- The capital works in SMC are largely funded through the State and Central Government grants. For example, SMC has received INR 45 crore under AMRUT in FY22, INR 35 crore as part of XIV/XV Finance Commission grant, and INR 19.6 crore under Lokshahir Anna Bhau Sathe Nagri Yojana.
- The capital works in SMC are also funded through revenue income transferred to capital account, which includes construction of buildings, roads, streetlights, drainage works, etc.
- The total capital income in FY20 was INR 369.44 crore, which has decreased to INR 239.9 crore in FY23.
- In FY20, under Development Charge, SMC received INR 18.73 crore, which has increased to INR 20.12 crore in FY22.
- SMC maintains a separate water account. The expenditure on water supply has increased, from INR 47.41 crore in FY20 to INR 64.83 crore in FY23.

25.2 FINANCING AND INSTITUTIONAL ARRANGEMENTS

Currently, the SMC implements the capital project through the funds transferred from revenue income and scheme grants and manages and maintains the assets through revenue expenditure. The major capital works are taken up through the capital income as revenue surplus is less.

It is worth noting that SMC has access to various State and Central capital grants that are linked to areas related to climate action. For instance,

- SMC received INR 126.3 crore in FY20, INR 56 crore in FY21, and INR 35.14 crore in FY22 under the Fourteenth and Fifteenth Finance Commission grants.
- Additionally, under the State Government scheme called Nagarothan, SMC has received INR 4.94 crore in FY21, INR 9.42 crore in FY22, and INR 15 crore in FY23. It also received INR 10 crore in FY20 and INR 25.26 crore in FY21.
- Under the National Clear Air Program (NCAP) in FY 2022-2023, INR 10.70 crore were used for air pollution related work, building awareness, roads maintenance, and plantation activities. Furthermore, under NCAP, for FY 2023-2024, INR. 17.62 crore has been sanctioned, of which INR 8 crore has been distributed in FY23 and INR 10 crore budgeted for FY24. (SMC, 2023)
- Under AMRUT YOJNA 1 for 2018-19, a sum of INR 150 crore was disbursed for drainage, of which 75% is being utilised for civil works and INR 67.86 crore for solar work, borewell recharge, and other civil works. (SMC, 2023)
- These grants represent significant funding sources for SMC, particularly in the areas of roads maintenance, waste management, and gardening sectors.

Furthermore, there is a need for reclassification, reallocation, and fresh allocation of the budget for climate actions, both for adaption and mitigation.

A few examples of where the funds are oriented towards climate actions are given below:

- SMC has spent INR 25 lakh (FY20), INR 6.32 crore (FY21), and INR 3.24 (FY22) crore on the conservation and beautification of Dharmveer Sambhaji Talav. There is scope to look at some of the priority actions proposed under CAP, such as the provision of groundwater recharge structures, increasing greening to reduce heat, and preserving biodiversity.
- In 2022-23, the budget allocated for the Road Department is INR 209 crores. There is scope to look at some of the priority actions proposed under CAP, such as traffic hotspot mitigation, junction improvement, and provision of rainwater recharge structures along the major roads. These actions can be adopted in road development works, and a part of the budget from the Road Dept can be reallocated to these initiatives.
- Similarly, funding for waste management is available under Swacch Bharat Mission and the Fifteenth Finance Commission. So, there is scope for convergence and prioritisation of the funds allocated for mainstreaming climate actions.
- Thus, there is a need to relook at the budget of SMC and identify areas of convergence, reclassification, and prioritisation. Based on this, a dedicated climate budget can be prepared so that the city can take climate actions on priority.

In terms of project structures and business model, SMC can explore various ways of developing and implementing projects.

25.3 NEED FOR CLIMATE BUDGET

Given the need for reclassification, reallocation, and fresh allocation of a part of the budget for climate actions, a climate budget is essential for Solapur to ensure that there are dedicated financial resources available to implement the Solapur CAP. It is also important to leverage such a budget as a governance tool to overcome the institutional barriers identified in the city's existing governance structure.

Although the budget will be anchored within SMC and activities that are directly under SMC's control will be prioritised, the ECAC and climate budget will ensure that the department within SMC or parastatal agencies assumes the responsibility to implement climate actions that lie within their control to ensure better coordinated outcomes. Through this engagement, the city will prepare a climate budget for FY 2024-25 with sector-specific emission ceilings, in alignment with the plan. The status of climate efforts and achievements will be tracked on a quarterly basis and reported annually. As part of the budget process, climate measures will be proposed, implemented, monitored, and reported regularly as per the Monitoring, Evaluation and Reporting (MER) process laid out in Chapter 26.

25.4 PILOT PROJECTS

While developing the draft of Solapur CAP, a list of pilot projects has been identified and discussed with SMC. The objective of taking up pilot projects is to demonstrate to SMC the process of implementation of the climate action strategies identified under the Solapur CAP. A list of such pilots is given in Table 25-1. WRI India will provide technical support to SMC on a few pilot projects from this list.

Table 25-1: Pilot projects identified under CAP

Project	Brief description
Eastern part of the city - increase groundwater and greening	• Eastern part of Solapur city has been identified as heat hotspot area and has depleting groundwater recharge potential. • In this part of the city, identify a pilot area, identify groundwater recharge areas along the natural stream, check potential for greening, activity mapping and reduction of emissions from these activities.
Traffic hotspots mitigation	• There are more than nine traffic hotspots within the city • One junction may be identified as a pilot area, and measures proposed to reduce pollution, dust, and urban heat island effect through junction improvement, greening etc.
Nature based solution (NBS) and greening at Kambar Talav area	• Kambar Talav has been identified as one of the areas within the city for groundwater recharge and greening. • In the study areas upstream and downstream of Kambar Talav, identify potential areas for pilots on Nature-based solutions (NBS), urban forestry, and lake restoration
Support in faster adoption of electrification of transport vehicles	• Support in preparing a detailed priority plan for procurement of EV buses, retrofitting of older buses, and retrofitting auto-rickshaws to CNG and cleaner fuel.
Wastewater recycling and reuse for NTPC thermal power plant	• Support in prefeasibility for domestic wastewater recycling and reuse of treated water for NTPC thermal power plant.
Use insights from VA analysis of Solapur CAP in various planning documents like DP	• Use insights from VA analysis of Solapur CAP as inputs for the DP, planning of mobility, water supply and sewerage, new playgrounds, and gardens, etc.

26. TRACKING PROGRESS

Climate risk management requires the systematic integration of climate resilience considerations with interventions (strategies, policies, plans, and programmes) at various levels i.e. national, sub-national, regional, city, community and individual across multiple stakeholders. It is important, therefore, to have a continuous Monitoring, Evaluation and Reporting (MER) structure in place to track the progress of the implementation of Solapur CAP . A crucial part of climate risk management is MER as it promotes accountability in implementation and make improvements based on the learnings. Monitoring is essential for tracking the progress of actions through continuous, systematic data collection. Evaluation is important for assessing the impact of actions, while reporting and learning enable transparency and data driven accountability amongst various stakeholders.

Effective MER frameworks support governments to develop co-operation in improving decision making under various uncertainties presented by climate change.

Monitoring is a continuous process that relies on systematic collection of data on specified indictors. The indicators indicate progress as per the use of allocated funds. Evaluation is the assessment of an on-going programme or policy. The aim is to measure efficiency and effectiveness and in turn measure impact. Learning requires the development of systems that act on the information from evaluative processes.

Over the last decade, there have been Central and State led climate centric initiatives and programmes. The CSCAF, NCAP, Swachh Bharat Abhiyan, and particularly the state-led Majhi Vasundhara Abhiyan. Reporting is done at the city level within these frameworks. The MER framework for the CAP work seeks to align with some of the indicators reported under the various programmes. For instance, the cities need to do a tree census under Majhi Vasundhara. The CAP utilises the information from the tree census conducted to calculate the sequestered carbon. The function of the CAP is to highlight crucial data sets in addition to aligning with the other State and Central frameworks.

26.1 MONITORING

The ECAC as part of the Department of ECC would play a critical role in data management and research, coordination with other interdepartmental and parastatal agencies, and providing support to the projects and programmes that pertain to the environment, and monitor the outcomes and outputs of the Solapur CAP. Defining clear objectives and indicators is key to framing the MER. The major tasks are listed:

- A Monitoring, Evaluation and Reporting (MER) cell in ECAC is to be formed.
- There has to be an update of the GHG inventory and the climate risk assessment every three years (next to be done in 2027).
- Annually monitor the progress of Solapur CAP against the targets set in the plan, report on a list of key performance indicators, communicate progress against indicators,

and develop a system to reflect on learnings against the key objectives and principles of the Solapur CAP.

- Additionally, the MER cell to prepare updated CAP every five years. (next to be done in 2029)

26.1.1 Key Performance Indicators

To track progress, key performance indicators (KPIs) have been identified across various sectors, which relate to the outcome indicators for each of the six priority action areas.

1. Water Management

Table 26-1: Water Management- Key Performance Indicators for key strategies/ priority actions

SN	Key strategies/ priority actions	Key Performance Indicators
1	Water Supply System Management	• Increase in metered piped water connections • Improved access to water supply • Reduction of water losses
2	Groundwater management	• No. of rainwater harvesting and groundwater recharge structures and the estimated quantity of water conserved
3	Wastewater Management, recycling and resuse	• Collection and treatment of waste water • Supply of secondary treated waste water to industries, NTPC, domestic and other non-portable use.
4	Wastewater recycling and reuse	• Quantity of wastewater recycled and reused for non-potable purposes • Gas captured at the STPs

2. Sustainable Mobility

Table 26-2: Sustainable Mobility- Key Performance Indicators for key strategies/ priority actions

SN	Key strategies/ priority actions	Key Performance Indicators
1	Public transport	• Percentage increase in overall public transport ridership • Increase in no. of buses per lakh population • Increase in public transport trips per capita per annum (disaggregated by gender and income level) • Percentage of population within 500 meters walk of public transportation option (bus stops)
2	Non-motorized transport	• Percentage change in NMT mode share • Percentage increase in kilometres of walking and cycling infrastructure

SN	Key strategies/ priority actions	Key Performance Indicators
3	Cleaner fuels and E-mobility	• Percentage of CNG or electric vehicles in the city, decreasing total annual fuel consumption from transport • No. of charging stations at public places set up and managed by the government and private sector • No. of vehicles taken benefits of subsidy for e-mobility under state and central schemes/ programs •
4	Sustainable freight	• Percentage of low-carbon road freight

3. Municipal Solid Waste Management

Table 26-3: Municipal Solid Waste Management- Key Performance Indicators for key strategies/ priority actions

SN	Key strategies/ priority actions	Key Performance Indicators
1	Decentralised waste management	• Organic waste convertor (OWC) infrastructure for treatment at the ward or zone level • Compost generated in TPD, biogas generated in kg/ day • Percentage increase in the number of HHs with decentralised system • Setting composting pits in parks and gardens
2	Source segregation	• Percentage segregated at source • Percentage reduction of open waste burning
3	Scientific disposal	• Percentage of legacy waste processed • Amount of gas capture
4	Livelihood	• No. of green jobs created • No. of woman employees/ workers

4. Air Quality

Table 26-4: Air Quality- Key Performance Indicators for key strategies/ priority actions

SN	Key strategies/ priority actions	Key Performance Indicators
1	Strengthening Air Quality Monitoring	• Upgradation of air quality monitoring stations from manual to automated integrated with metrological analysers. • Identification and monitoring of air quality hotspots

SN	Key strategies/ priority actions	Key Performance Indicators
2	NEE, traffic hotspots and waste	• Increased monitoring of tail pipe emissions and mitigating road dust • Traffic hotspot mitigation plan
3	Activity Mapping	• Increasing uptake of clean cooking fuels • Assessment on the quantity of wood, coal and other fuel types • Industrial fuel usage and enable shift to usage of cleaner fuel

5. Energy and Buildings

Table 26-5: Energy & Buildings- Sector wise Key Performance Indicators for key strategies/ priority actions

SN	Sectoral strategy/ priority actions	Key performance indicator
1	Support grid decarbonisation by increasing RE mix in the city	• Percentage increase in RE (MW) at government buildings and utilities • RE cell within the city • Percentage increase in localised energy generation (solar, wind etc.) via Renewable Energy (MW) sources • Strengthen waste to energy systems at STPs and SWM sites
2	Adoption of cleaner fuels in residential, commercial, and industrial users	• Transition of HHs or other users from coal/ fossil fuel to LPG/ PNG/ biogas • Transition of HHs or other users from LPG/ PNG to electric / solar • Transition of HHs or other users from low- income or vulnerable sections of the society from coal/ fossil fuel to LPG/ PNG/ solar/ biogas
3	Energy efficiency and energy conservation	• 100% Led streetlights, sensor based lighting within SMC premises and gardens

6. Greening and open space

Table 26-6: Greening and open spaces- Key Performance Indicators for key strategies/ priority actions

SN	Key strategies/ priority actions	Key Performance Indicators
1	Green cover and open spaces	• Increase in per capita green cover and open spaces • Increase in accessibility to green cover and open spaces
2	Urban Heat	• No. of heat hotspots identified and mitigated • Change in LST across wards, slums etc. • Maximise utilisation of undeveloped and barren lands

26.2 DATA MANAGEMENT

The process of developing CAPs requires a comprehensive data repository. Various data gaps have been highlighted as a part of sectoral actions and strategies. Socio-economic data and demographic differences at ward level were extracted from Census of India 2011, which is a decade old. Sector specific data was accessed through secondary literature and various government reports, such as the CMP, CDP, and NCAP.

1. Data for analysing climate risk assessment: The strategies and actions listed under CAP promotes collection of quality data through establishing better monitoring for data related to climate risks, such as pollutant concentrations, air temperature, rainfall variability (IMD station), and GW depletion.

- Setting up dashboards at the municipal level for information gathering and dissemination
- Use of open files to be integrated with the development planning process, so the data gets updated and used in the development plan process. This can be within the purview of the Town Planning Department.

2. Data for emission inventory requires co-ordination from various government departments, parastatal agencies as well as private players. The ECAC can play a role in gathering the data for updating the emission inventory and track the progress under CAP.

- (Re)create the framework for data collection under CAP.
- Integrate the CAP data collection framework with other reporting frameworks along with other tool kits such as the MVA and Swachh Survekshan.

3. Data for sectoral analysis can be within the scope of SMC departments and parastatal agencies. The CAP has established baseline data for the identified sectors. However, there are certain segments where baseline was not developed due to the lack of primary data. For instance, the ground water data (geo-codded locations of borewells, tubewells, monitoring wells, recharge zones) needs to be mapped in detail for assessment of the ground water table in coordination with the Ground Water Survey and Development Agency (GSDA). Similarly, for the air pollution sector data on use of wood, coal as a fuel need to be accounted for, which can under the purview of the District Collector Office along with the Environment Department at the SMC. There are multiple such data points as a part of the sectoral analysis under CAP.

26.3 EVALUATION

A comprehensive evaluation of the status of current actions within the CAP will be conducted once in five years. A proposed evaluation and reporting template is provided in Table 26-7. The evaluation process would be conducted by the Research, Data and MER cell in the newly formed ECAC. This cell would be supported by the Head of Departments, Chief Engineer, Garden

Superintendent, Executive Engineers of internal departments of the SMC, project managers under Smart city, and officers from various parastatal agencies such as GSDA, MSEDCL, and IMD.

The evaluation process will adopt a participatory approach, engaging external stakeholders and vulnerable communities affected by it, including civil society organizations (CSOs), NGOs, and research agencies. This collaborative effort aims to enhance the effectiveness of the Solapur CAP in improving the lives of vulnerable communities and promoting inclusivity. Through this process, the city will evaluate the inclusiveness of actions and the fair distribution of impacts. The outcomes of the evaluation will be openly published and shared with various stakeholders, ensuring transparency and enabling participatory review. Additionally, these evaluation results, coupled with the updated climate risk assessment and GHG inventory, can be utilised to revise the baselines, targets, and trajectories outlined in the CAP, facilitating accelerated action.

Strategy SM-1: Strengthen the public bus transport system to ensure that it is affordable, reliable, and sustainable and provides access to all by 2030.

Priority Action: Increase the bus fleet from the current number of 60 to 490 by 2031 by repairing and retrofitting existing buses, and procuring new CNG and electric buses i.e., using cleaner fuels.

Table 26-7: Sample of goal wise evaluation of goals and targets

Goal 1: Increasing the proportion of renewable energy in the grid mix			
Target 1: Grid Decarbonised through an increase in RE mix in the electricity generation with a target share of 42% by 2030, 56 % by 2040 and 67% 2050			
Output Indicator	**Target (year)**	**Current progress (year)**	**Source**
Residential PV on-grid connected electricity (%)	25% (2030)	0.7% (2027)	Electricity bills and energy audits of the municipal buildings and utilities
Goal 2: Increase share of public transport and NMT in the city			
Target 2: Strengthen the public bus transport system to ensure that it is affordable, reliable, and sustainable; and provides access to all by 2030			
Output Indicator	**Target (year)**	**Current progress (year)**	**Source**
No. of buses operational	490 (2031)	12% (2022)	Data from SMT
Increase accessibility to bus stops from 50% to 100%	100% (2030)	50% (2022)	Data from SMT, Primary mapping of bus stops

26.4 REPORTING

The Research, Data and MER cell under the newly formed ECAC would be responsible for monitoring the progress of the CAP. ECAC will be, responsible for monitoring Solapur CAP, will ensure that GHG inventory as well as the climate risk assessment is updated every three years to understand the city- and sector-wide impacts of CAP implementation.

Every year the Research, Data and MER Cell will prepare the Solapur CAP progress report, evaluating three levels of indicators – 1) at an aggregate city level, 2) as per KPIs and 3) as per outcome indicators listed across every action in the sectoral action plans. The CAP Progress Report can then be submitted to Climate Action Cell, GoM.

The list of indicators proposed for aggregate city-level progress assessment is presented below. These can be revised and updated as per the Department's decisions. Additionally, the Research, Data and MER cell will also prepare an updated CAP every five years to ensure the city meets its intended target for 2050.

Proposed indicators for aggregate city-level progress assessment

- GHG emission inventory: aggregate reduction across all actions in Solapur CAP, which would result in emissions reduction
- Climate risks and VA: Monitor the air temperature levels, air pollution concentration and the impact of heat and increased air pollution on people. Moreover, rainfall variability, depletion of ground water and water shortages needs to be assessed too.
- GHG inventory and the vulnerability assessment of the city every 3 years.
- Impact on people in terms of monitoring improved access, community health and assessment of livelihoods of the citizens.

Table 26-8: Proposed indicators for aggregate city-level progress assessment.

Sr No.	Indicator
1.	Total GHG emissions reduced – aggregate reduction across all sectoral actions mentioned in the CAP, resulting in emission reduction
2.	Total lives saved in vulnerable communities – estimated lives saved in risk-prone areas where adaptation actions are implemented
3.	Improved access to amenities, utilities, and services across all the communities in the city
4.	Overall community health improved – qualitative assessment of improved health in vulnerable/ exposed communities
5.	Total green jobs created – aggregated green jobs created across all actions in the Aurangabad CAP

**This is an indicative list to help the Department in drafting a detailed MER framework that builds on the outcome indicators and KPIs and helps communicate climate action impacts to a wide range of city stakeholders*

The reporting for the outcome and output indicators would be evaluated and reported by the Research, Data and MER cell under the newly formed Department of ECC in SMC. It would be their responsibility to update the progress on the KPIs every year. A sample format presented in Table 26-9 has been proposed.

Table 26-9: Proposed format for annual updating of KPIs

Output Indicator	Target year	Current progress (year)	Source
Procurement of e-buses	400 (2026)	100 (2024)	Data from SMT
Installation of solar PV in public buildings	100% (2040)	7% (2021)	Data from SMC
Increase access to public spaces	100% (2030)	65.1 % (2021)	Data from SMC

PARK STADIUM AND SHRI.SIDDHESHWAR MANDIR AERIAL VIEW
Photo credit: Chetan Ligade

27. CONCLUSION

Climate resilient development policies and plans need to aim to keep global warming below 1.5 °C as well as adapt to current and future impacts of climate change while also considering how countries can continue to improve wellbeing and ensure equity around the world. The decision-making process is very critical, for once we have hit 1.5 °C, some impacts of climate change will become irreversible, particularly in some sensitive ecosystems. This considerably limits the options for adaptation and human development.

Climate change cannot be solved with technical solutions. Instead, it needs integrated efforts across society and the world. The Indian state of Maharashtra is committed to achieving net zero by 2050, with Mumbai leading the way towards achieving reduction of GHG targets through the strategies and actions within MCAP. The Solapur Climate Action Plan serves as a roadmap of SMC's commitment to combat climate change and to increase the climate resilience of the city.

The Solapur Climate Action Plan aligns with the policies and plans developed at the national, state, regional, and city levels. Plans and strategies such as CSCAF, NCAP, and City Development Plan, provide a strong base for planning current and future strategies related to climate action in the city. Moreover, the institutional structures and financing mechanisms in Solapur's CAP are aligned to work towards policy reforms and regulatory amendments to mainstream climate actions with SMC's planning ethos.

Climate resilient development emerges from explicitly bringing together actions to adapt to climate change with actions to reduce greenhouse gas emissions, in order to advance sustainable development. The consultative processes conducted for identifying the climate and environmental risks, presenting the findings from the GHG Inventory and the sectoral actions and strategies included participation from leadership within SMC and various departments, external stakeholders, parastatal agencies and sectoral experts. However, the most important stakeholders are the city dwellers and their willingness to act in a personal capacity and at the household or community levels to help achieve the city's net zero targets, thus promoting sustainable development.

Annexures

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ANNEXURE 1: VA PROCESS METHODOLOGY

Annexure 1-1: Urban Heat Risk – Assessment parameters and attributes

Parameter	Vulnerability	Methodology	Data Source
Annual air temperature trend analysis and deviations	Positive relation	Annual air temperature trend, change-point detection, Annual air temperature anomalies and seasonal average temperature	NCEI, 1975-2021
Extreme heat events	Positive relation	Heatwaves and Heat index classification	NCEI, 1975-2022* (up to July*)
Land Surface Temperature	Positive relation	Night-time temperature trends from LST	MODIS LST Product, 2001-2022
		Average land surface temperature, seasonal variations, LST hotspots, , area under vegetation.	Landsat 8, 2019-2021; Census 2011

Source: WRI India Analysis

Annexure 1-2 Wards with highest heat impact in terms of percentage population

Ward no.	Population facing excessive heat (LST>=city annual avg.)	Percentage of population facing excessive heat (LST>= city annual avg.)
57	7287	97.62
28	7335	88.18
36	8914	83.62
32	13153	80.99
34	10274	80.17

Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

Annexure 1-3 Wards with highest heat impact in terms of percentage jobs

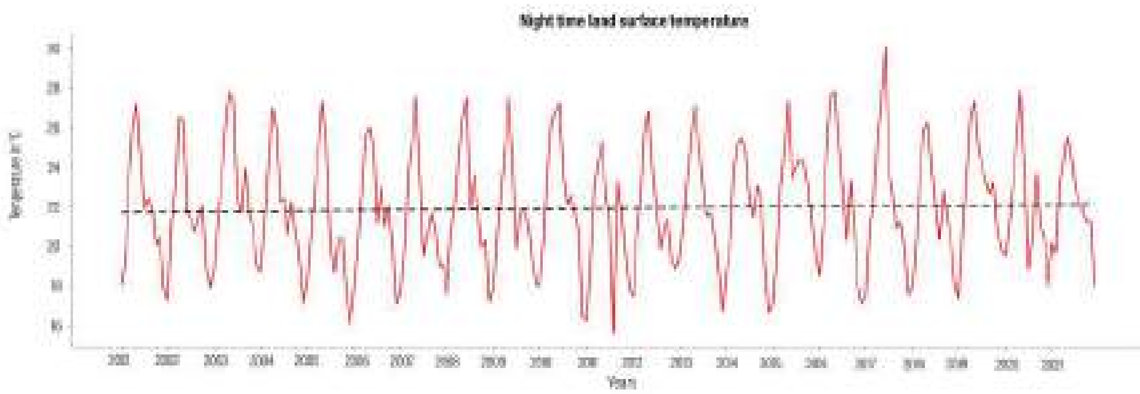
Ward no	Jobs facing excessive heat (LST>=33° C)	Percentage of Jobs facing excessive heat (LST>=33° C)
1	919	100
18	210	100
20	154	100
25	63	100
28	928	100
30	1062	100

Ward no	Jobs facing excessive heat (LST>=33° C)	Percentage of Jobs facing excessive heat (LST>=33° C)
34	7105	100
35	375	100
57	1108	100
71	173	100
74	72	100
76	38	100

Ward no	Jobs facing excessive heat (LST>=33° C)	Percentage of Jobs facing excessive heat (LST>=33° C)
97	307	100
36	4584	99.7
94	470	91.44
27	666	85.38
8	186	83.78

Source: WRI India using Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, DoE,2015

Annexure 1-4 Monthly mean night-time land surface temperature trend between 2001 & 2021



Source: WRI India analysis; MODIS Night time LST Product, 2001-2022

Annexure 1-5 Air pollution – key parameters

Parameter	Vulnerability	Methodology	Data Source
Concentration of gases	Positive relation	Time-series showing the annual mean	CPCB, MPCB
Concentration of physical pollutants	Positive relation	Time-series showing the annual mean	CPCB, MPCB
Percentage of sector wise contribution of various sources	Positive relation	Base year of study 2017	Source Apportionment study
Indoor air pollution	Positive relation	Bar chart showing $PM_{2.5}$ concentrations in the kitchen and living area for most common cooking fuels	Census 2011

Source: WRI India analysis

Annexure 1-6 Rainfall Variability- Assessment Parameters and Attributes

Parameter	Vulnerability	Method Used	Data Source
Long-term Rainfall trend	Positive Relation	50-year time series to measure the annual mean precipitation	Indian Meteorological Department
Extreme Rainfall Events	Positive Relation	50-year time series to measure the frequency, intensity, & duration of Extreme Rainfall Events (ERE)	Indian Meteorological Department

Source: WRI India analysis

Annexure 1-7 details cumulative counts of ERE reported at Solapur between 1970 and 2020 by duration, such as how long the single event lasted.

Annexure 1-7 Duration of Extreme Rainfall Events between 1970 and 2020, Solapur Observatory

Category/Duration	1 Day	2 Days	3 Days	4 Days	5 Days
Rather Heavy (35.6-64.4 mm)	178	5	1	1	0
Heavy (64.5- 124.4 mm)	54	2	0	0	0
Very Heavy & Extremely Heavy (>124.5 mm)	2	0	0	0	0

Source: WRI India using meteorological data from IMD

Annexure 1-8 Drought Risk-Assessment Parameters and Attributes

Parameter	Vulnerability	Method Used	Data Source
Probability of Drought	Positive Relation	70-year (1951 – 2020) time series to measure the probability of meteorological drought	Indian Meteorological Department
Water Stress	Positive Relation	Global data layer clipped to sub-basin boundary and symbolized using the same classes as used in the original global dataset	WRI AQUEDUCT
Stage of Groundwater Development	Positive Relation	The stage of groundwater development was obtained from various reports published in the past decade	Central Ground Water Board
Groundwater Recharge Potential	Negative Relation	Weighted average of average annual rainfall, slope of the topography and NDVI is used as an indicator of GWRP.	Indian Meteorological Department, Shuttle Radar Topography Mission, Landsat 7

Source: WRI India analysis

Annexure 1-9 Evolution of Stage of Groundwater Development in Solapur District.

Year	2009	2013	2017
Administrative Unit	**Stage of Groundwater Development**		
Akkalkot	54.09	51.83	55.8
Barshi	79.16	76.47	80.25
Karmala	77.6	70.43	72.14
Madha	78.53	78.11	81.92
Malshiras	101.53	100.29	101.31
Mangalwedha	84.37	77.23	79.94
Mohol	87.69	84.33	89.26
N.Solapur	64.17	63.13	67.79
Pandharpur	76.9	77.08	77.22
S.Solapur	61.83	58.07	60.73
Sangola	77.98	5.08	76.25
District Total	78.23	75.08	78.37

Source: CGWB report, 2019

Annexure 1-10 Indicators based on demographic context

Indicator	Description	
Literacy	Definition	Literacy indicator includes overall effective literates, effective female literates, and access to educational institutes, such as schools, for preliminary education.
	Rationale For Selection	Literacy is important for raising awareness regarding climatic hazards, and building resilience and capacities for preparedness for response activities during a disaster event. Higher levels of literacy (with the assumption that ease of access to schools offer an opportunity for the improved status of enrolments) lead to improved adaptive capacities by enhancing the opportunity to access stable jobs, thereby increasing socio-economic stability and reducing vulnerability to climatic hazards. Disaster responsiveness, knowledge of saving mechanisms, etc. are observed to be better in educated individuals and families.
Gender Profile	Definition	Gender profile is understood using the indicator of sex ratio.
	Rationale For Selection	Disproportionate impact on women and girls with increased care-giving tasks post disaster and unequal access to resources and services play crucial role of women in disaster response.

Indicator	Description	
Social Composition	Definition	Percentage of Scheduled Castes (SC) and Scheduled tribes (ST) population is estimated to understand the extent of social vulnerability on the basis of caste.
	Rationale For Selection	Caste also serves as an equity indicator to identify underserviced neighborhoods SC and ST population potentially have higher exposure, higher sensitivity and lower adaptive capacity.

Annexure 1-11 : Demographic Context — Assessment parameters and attributes

Indicator	Parameter	Methods Used	Data Source
Literacy	Effective Literacy Rate	(Total literate population above 6 years of age / Total population above 6 years of age) *100	Ward level: Census 2011 - Primary Census Abstract
	Effective Female Literacy Rate	(Total female literate population above 6 years of age /Total female population above 6 years of age) *100	
	Access to Schools	Population coverage computed within 1km of walking distance using service area polygons around school locations	NIC 2018, Census 2011
Gender Profile	Sex Ratio	(Total female population)/ (Total male population) *1000	Ward level: Census 2011 - Primary Census Abstract
Social Composition	Percentage of SC and ST population	(Total SC population + Total ST population) / (Total Population) *100	

Annexure 1-12 Indicators relative to socio-economic aspects

Socio-Economic Aspects		
Indicator	**Description**	
Access to Information	Definition	This indicator is measured as a function of ownership of a phone (landline, mobile or both), computer with Internet, television and/or radio/transistor. Access to these assets indicates access to related information/ news/ broadcasting significantly reducing vulnerability.
	Vulnerability to Climate-Induced Hazards	Ownership of information and telecommunication devices offers the opportunity to access regular live news updates, broadcast warning alerts, evacuation instructions as well as preparedness information in the event of a disaster. Information access enables awareness and better adaptive capacity, reducing vulnerability to disasters and slow onset events. Communication with a higher percentage of the population before and during such events can help authorities and communities be better prepared, efficiently manage evacuation plans and effectively carry out rescue operations.

Socio-Economic Aspects		
Indicator	**Description**	
House Ownership	Definition	Home ownership is understood based on Census data that indicates households that own the house they live in.
	Vulnerability to Climate-Induced Hazards	Home ownership increases one's willingness to invest in improvements to increase safety (against increasing climate risks like heat and extreme rainfall events) and resilience of property and associated assets. In case of other associated losses like job loss, income loss due to health impacts, and asset losses (like vehicles or electronics), having a safe living space to come back to is critical to retain a sense of social security and decreased vulnerability.

Annexure 1-13 Access to Information — Assessment parameters and attributes

Parameter Mapped	Relationship to Vulnerability	Methods Used	Data Source
Households owning Radio/ Transistor	Negative	Percentage of households having each of the specified assets	Ward level: Census 2011 – HH 14 table- Availability of Assets
Households Owning Computers with Internet			
Households Owning TV			
Households Owning Landline, Mobile and Both			

Annexure 1-14 House Ownership — Assessment parameters and attributes

Parameter Mapped	Relationship to Vulnerability	Methods Used	Data Source
House Ownership	Negative	Percentage of households having ownership of the property they reside in	Ward Level: Census 2011 HH14 table– Ownership Status

Annexure 1-15 Indicators reflective of Physical Environment Aspects

Physical Environment Aspects		
House Condition	Definition	Roof is the prime built envelope of the house with the highest area being exposed. House condition is defined here as a function of the roofing material used for its construction. Based on Census categories, households with roofing material that can be termed as ''temporary" with limited constructional durability are considered as vulnerable.
	Vulnerability to Climate-Induced Hazards	Houses with temporary roofing materials are potentially at greater risk during extreme weather conditions such as heavy rainfall, flooding, or extreme heat, due to their limited constructional durability.

Physical Environment Aspects		
Access to public recreational spaces	Definition	Recreational spaces include parks, gardens, playgrounds, and maidans affiliated with the government, freely accessible by the public, and non-ticketed.
	Vulnerability to Climate-Induced Hazards	Open spaces provide much needed space for play, active health, and mental relief. These spaces act as drainage areas during heavy rainfall events, reducing the risk of urban flooding. Green areas also play a pivotal role in reducing effects of urban heat. During disasters, these areas can also provide spaces for evacuation, rescue, and recovery. Populations with limited access to public recreational spaces are at greater risk and more vulnerable. During slow onset events such as extreme summers, properly shaded open spaces offer weaker and more exposed section of the society including those living in slums, with necessary respite from extreme indoor heat stress.

Annexure 1-16 House Condition — Assessment parameters and attributes

House Condition			
Parameter Mapped	Relationship to Vulnerability	Method used	Data Source
Households with Temporary Roofing Material	Positive	Percentage of households having temporary roofing material- includes Grass/ Thatch/ Bamboo/ Wood/Mud etc., Plastic/ Polythene, Stone/ Slate, and Galvanized Iron /Metal/ Asbestos sheets. etc.	Ward Level: Census 2011 HH14 table – Material of Roof

Annexure 1-17 House Condition — Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with > 33°C LST overlaid to ward areas	Landsat 8, Solapur Municipal Corporation, Census 2011

**Urban heat risk is assumed for areas with LST >32°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021*

Annexure 1-18 Access to Public Recreational Spaces — Assessment parameters and attributes

Parameter mapped	Relationship to Vulnerability	Method Used	Data Source
Access to Public Recreational Spaces	Negative	Proximity is used to evaluate access to these public recreational spaces. It includes include publicly accessible and non-ticketed parks, gardens, institutional playgrounds, and maidans. Ped shed of 10 minutes walkable distance was considered for parks, institutional playgrounds or maidans. Ped shed of 10 minutes walkable distance was considered for parks, institutional playgrounds or maidans.	Existing Land Use (2018) from Solapur Municipal Corporation, World Settlement Footprint 2019, Census 2011

Source: Bernard van Leer Foundation. (2018). A good start for all children: Annual Report. Retrieved from https://bernardvanleer.org/app/uploads/2019/04/BvLF-AnnualReport18-Digital-Pages.pdf

Annexure 1-19 Access to Public Recreational Spaces — Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with >33°C LST overlaid to gridded population density with limited access to public recreational spaces (unserviced population)	Landsat 8, Solapur Municipal Corporation, World Settlement Footprint 2019, Census 2011

**Urban heat risk is assumed for areas with LST >32°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021*

Annexure 1-20 Indicators relative to Infrastructure and Service Aspects

Indicator	Definition	
Access to Drinking Water	Definition	Access to drinking water is calculated as a function of the source of drinking water and its proximity. It is shown by illustrating wards that lack access to drinking water sources within premises and treated drinking water facilities.
	Vulnerability to Climate Induced Hazards	Sources are considered as a proxy for the quality of water and the proximity of that source, whether near or away from premises, are vulnerable to climate risks, such as flooding, water logging, pollution etc. During or after a disaster, households dependent on alternate water sources (which do not have a drinking water source within their premises), such as tankers or community taps, are vulnerable since physical access via roads may be impacted. On extreme heat-like situations, households with limited access to piped water are vulnerable to health impacts. During water stress in the city, these households do not receive tanker water or other sources, or procurement is very expensive, thereby restricting access to many. Lack of ease of access to reliable and potable water is important for public health as contaminated drinking water might cause health hazards and vulnerabilities increase during climate-induced disasters.

Indicator	Definition	
Access to Sanitation	Definition	Access to sanitation infrastructure is evaluated as a function of the proximity of latrine availability, sewage, wastewater disposal methods, and access to public toilets (with respect to slums). It is represented by illustrating wards that lack access to latrine availability within premises, treated sewage disposal, wastewater disposal methods, and serviceable/ unserviceable slum area of public toilets.
	Vulnerability to Climate Induced Hazards	Households without latrines located inside premises are dependent on public toilets, exposing them to health risks and ease-of-use issues, especially for women, children, and special needs population. These challenges increase manifold during extreme events when physical access is hindered. Unsanitary methods of sewage and wastewater disposal can pose serious health hazards, pollute surface and groundwater, escalate air pollution, and deteriorate living conditions during climate induced hazards, such as flooding. Usually, informal settlements are congested, with a higher population living in small built areas. They mostly belong to economically weaker sections and, at times, cannot afford to have latrines within their premises. Hence, public toilets function as sanitation facilities for them. However, during extreme events, such as that of flood or heat, physical access to such services gets restricted, making them more vulnerable.
Access to Clean Cooking Fuel	Definition	Access to clean cooking fuel is defined by the use of non-polluting fuels, which includes LPG/PNG, electricity, and biogas. It is represented by illustrating wards that lack access to these non-polluting fuels.
	Vulnerability to Climate-Induced Hazards	Several low-income households continue to rely on firewood, kerosene, and other fuel for cooking purposes. The use of such polluting cooking fuels increases harmful exposure and worsens indoor living conditions. Current trends of deteriorating air quality along with indoor air pollution increase health risks, making the population more vulnerable. Those living in smaller homes with kitchens not separated from living quarters are most at risk. Households dependent on wood for cooking either have to travel far or depend on the limited local natural resources available. Thus, those responsible for collecting fuelwood are more exposed to outdoor climate events.
Access to electricity grid	Definition	Access to electricity grid is represented by illustrating wards that lack access to the electricity grid and is estimated based on non-usage of electricity as the main source of lighting.
	Vulnerability to Climate-Induced Hazards	Lack of access to electricity, which is the main source of lighting, increases the risks of illegal connections. It cannot ensure stability and, therefore, the ability to resume connectivity after disasters once the grid is restored. It decreases the adaptive capacity of households.

Indicator	Definition	
Access to public transit	Definition	Access to public transit (in this case, bus stops) is measured by evaluating pedestrian access to them within 5 minutes.
	Vulnerability to Climate-Induced Hazards	Access to public transit (in this case, bus stops) enables access to jobs and resources, which can help improve household incomes. Women and children also have access to these networks, allowing them to opt for better jobs and education opportunities, thereby increasing adaptive capacity and reduction in vulnerability. During flood events, waterlogged streets hinder physical access to bus stops, disrupting regular access to mobility networks, opportunities, and basic amenities and impacting livelihoods. Population dependent on bus stops to access jobs and for personal needs are deeply impacted due to loss of working hours, reduced productivity, loss of income, and inability to access basic needs or health and emergency services. Vulnerability of poor households and end users further escalates during such events.
Access to emergency health care facility	Definition	All public and private hospitals with emergency in-patient facilities are considered. Access is defined as vehicular access within 8-10 minutes response time from a hospital.
	Vulnerability to Climate Induced Hazards	Having access to urban health facilities remains a basic essential service. Access to medical care is important for improving living standards and becomes even more critical during disaster events. Better access improves adaptive capacity by enabling timely medical assistance. Vulnerability of the population with limited access increases further during heat waves, flooding, or landslides, which may lead to higher mortalities or long-term health risks.
Access to emergency fire Services	Definition	Access to emergency fire services is defined as the response time (5-7 minutes response time) taken by emergency personnel to reach the incident location.
	Vulnerability to Climate Induced Hazards	Prompt emergency services with adequate coverage across the city increases adaptive capacity and ensure timely emergency response to vulnerable areas. Residents of high-density, informal settlements are most at risk during fire emergencies (since the risk of spread is highest due to high densities) and for rescue operations during a flood or other disasters.

Annexure 1-21 Access to Drinking Water – Assessment Parameters and Attributes – Lack of Access to drinking water

Parameter Mapped	Relationship to Vulnerability	Method Used	Data Source
Lack of access to treated drinking water	Positive	Percentage of households without access to treated drinking water- – including households with drinking water sources from untreated tap water, covered wells, uncovered wells, handpump, tube well/ borewell, springs, river/canal, tanks/ ponds/lakes and other sources	Ward Level: Census 2011 – Main source of drinking water and location of drinking water source
Limited ease of access to drinking water		Percentage of households without drinking water inside premises- including households with latrines near and away from premises	

Annexure 1-22 Access to Drinking Water - Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with > 33°C LST overlaid to ward areas	Landsat 8, Solapur Municipal Corporation

**Urban heat risk is assumed for areas with LST >32°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021*

Annexure 1-23 Access to Clean Cooking Fuel – Assessment Parameters and Attributes

Parameter mapped	Relationship to Vulnerability	Method Used	Data Source
Lack of access to clean cooking fuel	Positive	Percentage of households without access to clean cooking fuel- includes households using firewood, crop residue, cow dung cake, coal/lignite/ charcoal, kerosene, others as their fuel for cooking.	Ward Level: Census 2011 – Type of fuel used for Cooking[1]

Annexure 1-24 Access to Sanitation – Assessment Parameters and Attributes

Parameter Mapped	Relationship to Vulnerability	Method Used	Data Source
Limited ease of access to latrine	Positive	Percentage of households without latrine inside premises	Ward Level: Census 2011 – Number of households having latrine outside premises, Flush/pour latrine, Pit latrine, Night soil disposed into open drain, Service latrine[1]
Lack of access to treated sewage disposal methods		Percentage of households without access to treated sewage disposal methods- including households with Flush/pour flush latrines connected to systems other than septic and piped water sewer system, pit latrine without slab/ open pit, service latrine with night soil disposed into open drain, service latrine with night soil removed by humans and service latrine with night soil serviced by animals.	
Lack of access to treated wastewater disposal methods		Percentage of households without access to treated wastewater disposal methods — outlets connected to open drainage or no drainage	
Access to Public toilets (with respect to slums)	Negative	Slum area coverage within 5 minutes walking service area polygons around public toilet locations	Solapur Municipal Corporation 2022

Annexure 1-25 Access to Electricity Grid– Assessment Parameters and Attributes

Parameter Mapped	Relationship to Vulnerability	Method Used	Data Source
Lack of Access to Electricity Grid	Positive	Percentage of households without access to electricity as main source of lighting- includes households using Kerosene, other oil, any other as their main source of lighting and households with no lighting	Ward Level: Census 2011 – Main Source of Lighting[1]

Annexure 1-26 Access to Public Transit (Access to bus stops) – Assessment Parameters and Attributes

Access to Bus Stops			
Parameter Mapped	**Relationship to Vulnerability**	**Method Used**	**Data Source**
Access to Bus Stops	Negative	Population coverage within 5 minutes walking service area polygons around bus stop locations**	Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

***Access to public recreational spaces is mapped using service area polygons that are for analyzing access within 1 km. It has been considered based on pedestrian accessibility standards within 10 minutes walkable distance (Bernard van Leer Foundation, 2018).*

Annexure 1-27 Access to Emergency Healthcare services – Assessment Parameters and Attributes

Parameter Mapped	Relationship to Vulnerability	Method Used	Data Source
Access to Hospitals (in patient facility)	Negative	Population coverage within 8 minutes drivetime service area polygons around hospital locations	Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011, Google API

Annexure 1-28 Access to Emergency Healthcare services- Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with >33°C LST overlaid to gridded population density with limited access to hospitals (unserviced population)	Landsat 8, Solapur Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

**Urban heat risk is assumed for areas with LST >32°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021*

Annexure 1-29 Access to Emergency Fire Services – Assessment Parameters and Attributes

Access to Emergency Fire Services			
Parameter Mapped	**Relationship to Vulnerability**	**Method Used**	**Data Source**
Access to Fire Stations	Negative	Population coverage within 5 min drivetime service area polygons around fire station locations	Solapur Municipal Corporation 2021, World Settlement Footprint 2019, Census 2011

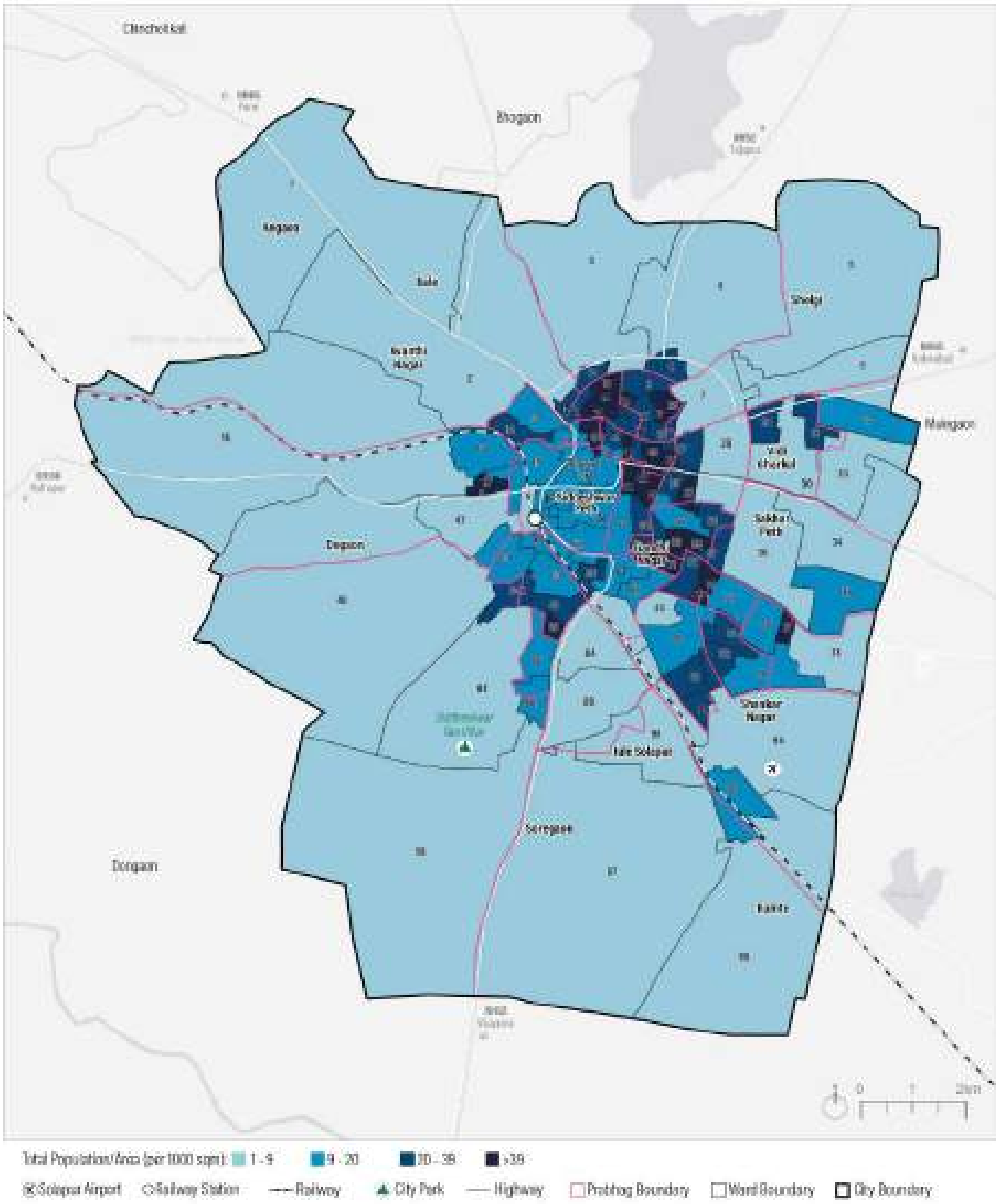
Annexure 1-30 Access to Emergency Fire Services – Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with >33°C LST overlaid to gridded population density with limited access to fire stations (unserviced population)	Landsat 8, Solapur Municipal Corporation 2021, World Settlement Footprint 2019, Census 2011

**Urban heat risk is assumed for areas with LST >32°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021*

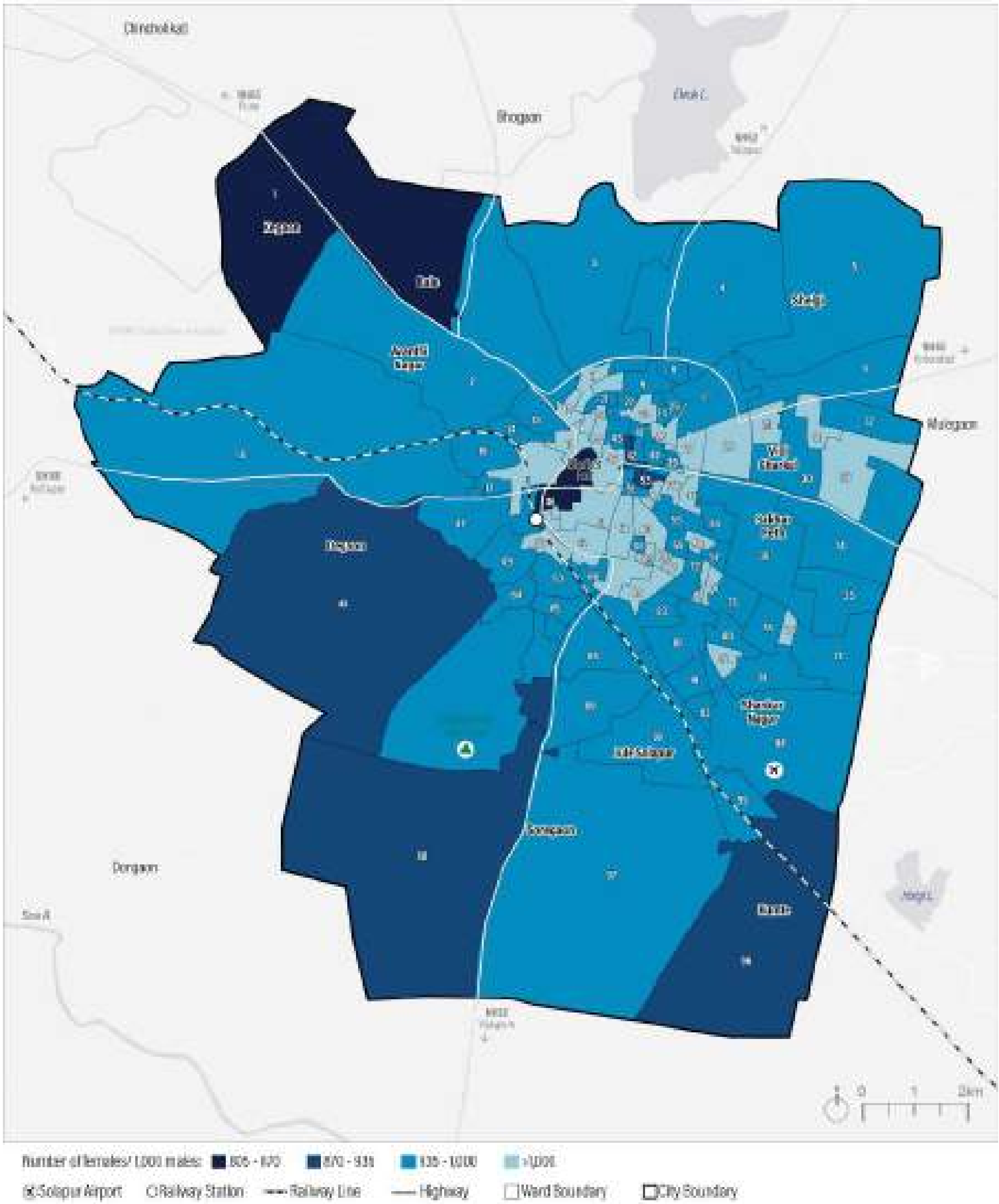
ANNEXURE 2: MAPS & FIGURES

Annexure 2-1: Population density (persons per 1000 sqm)



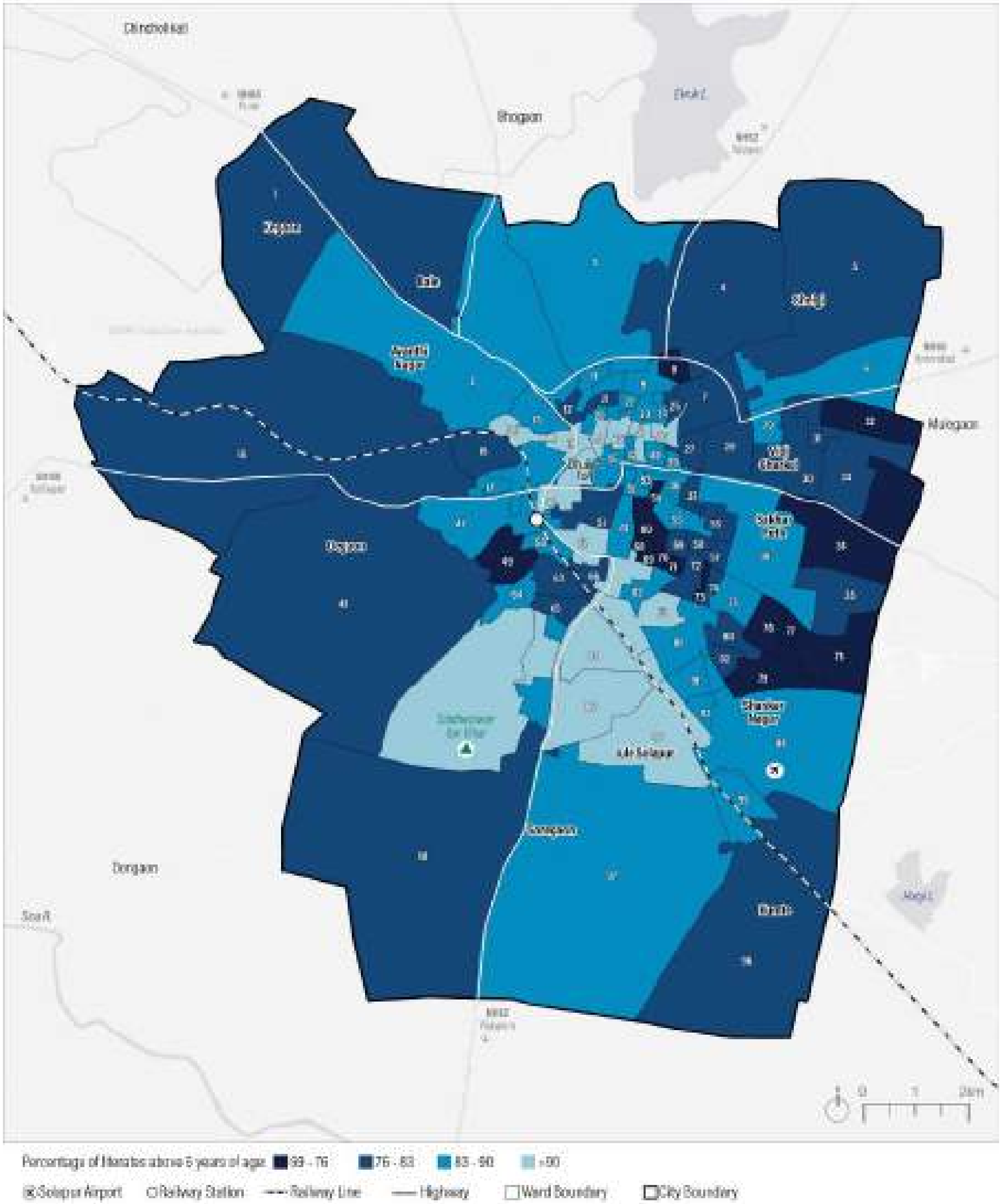
Source: WRI India using Census 2011

Annexure 2-2: Gender ProfileSource: WRI India using Census 2011



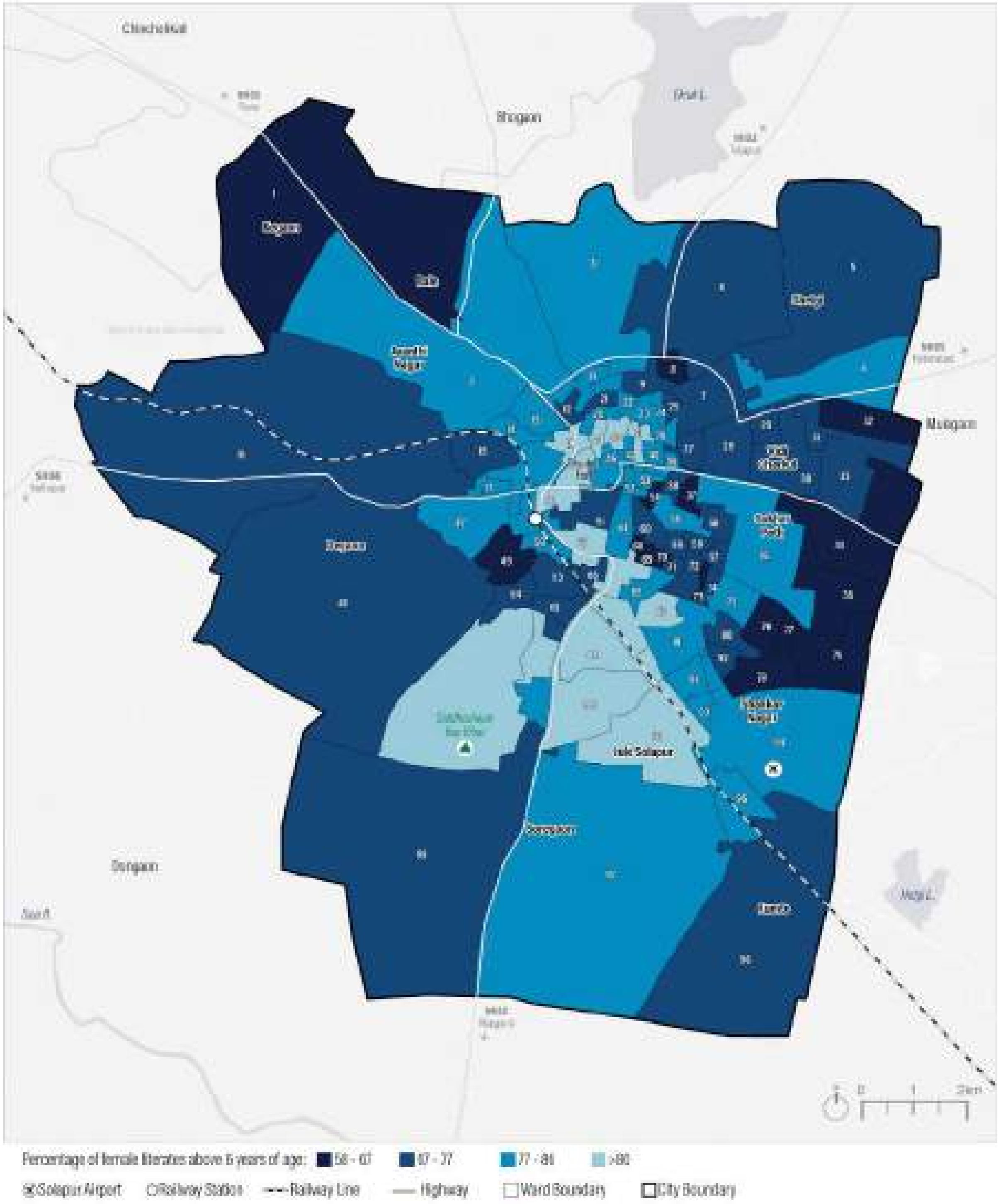
Source: WRI India using Census 2011

Annexure 2-3: Effective Literacy Rate



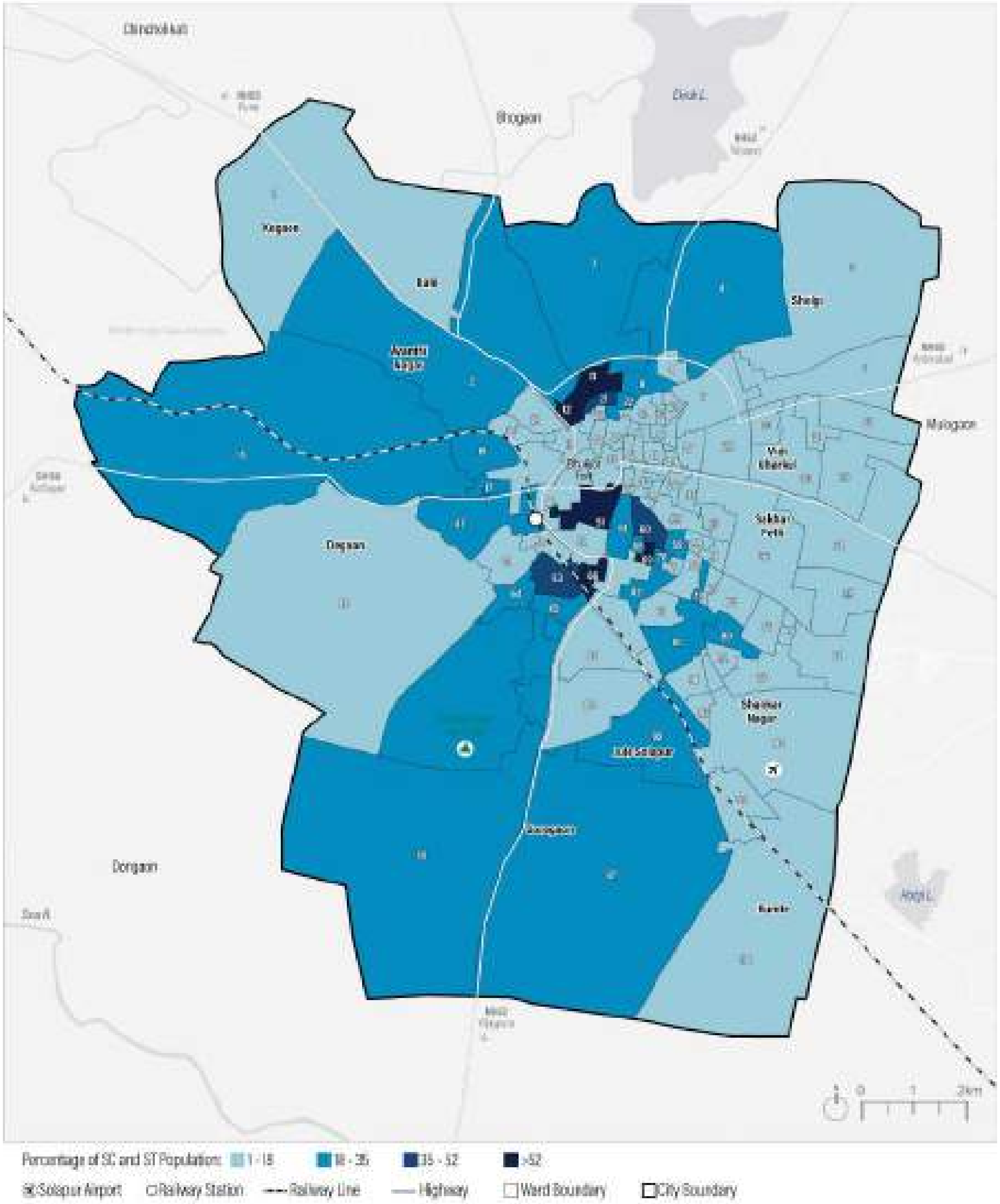
Source: WRI India using Census 2011

Annexure 2-4: Effective female literacy Rate



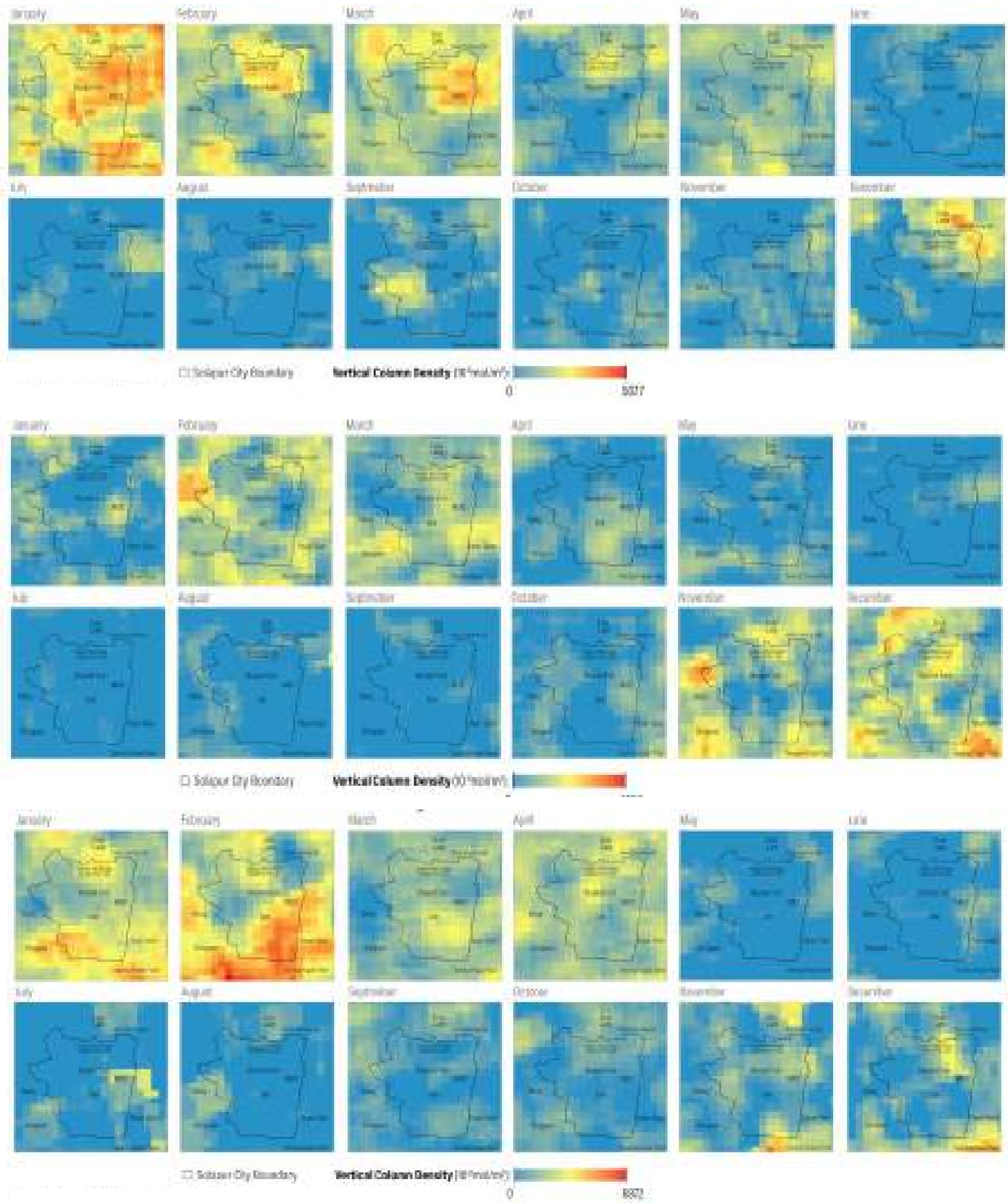
Source: WRI India using Census 2011

Annexure 2-5: Social Composition



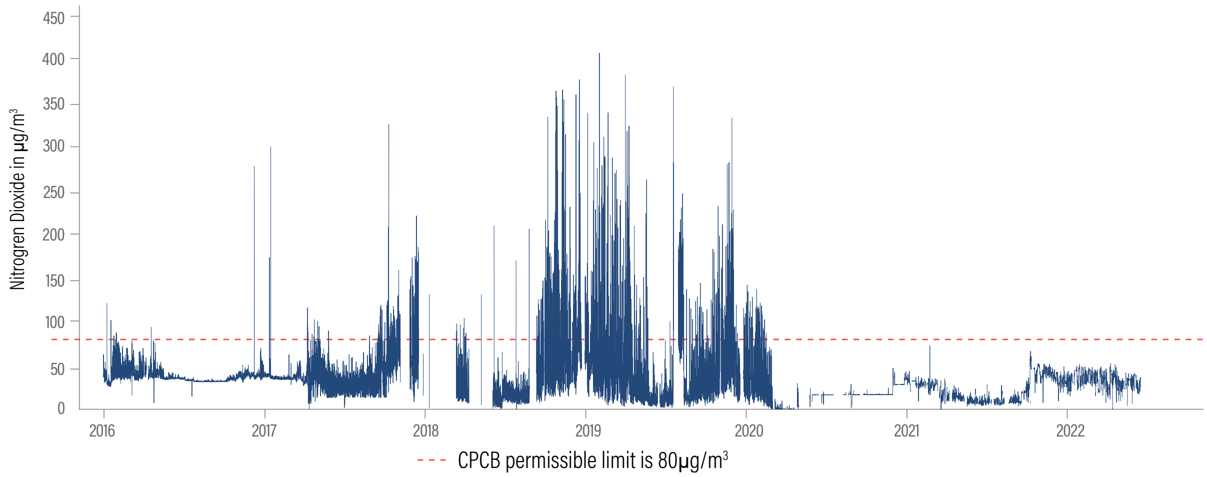
Source: WRI India using Census 2011

Annexure 2-6: Monthly average concentrations of Sulfur Dioxide (SO_2) in Solapur from 2019-2021



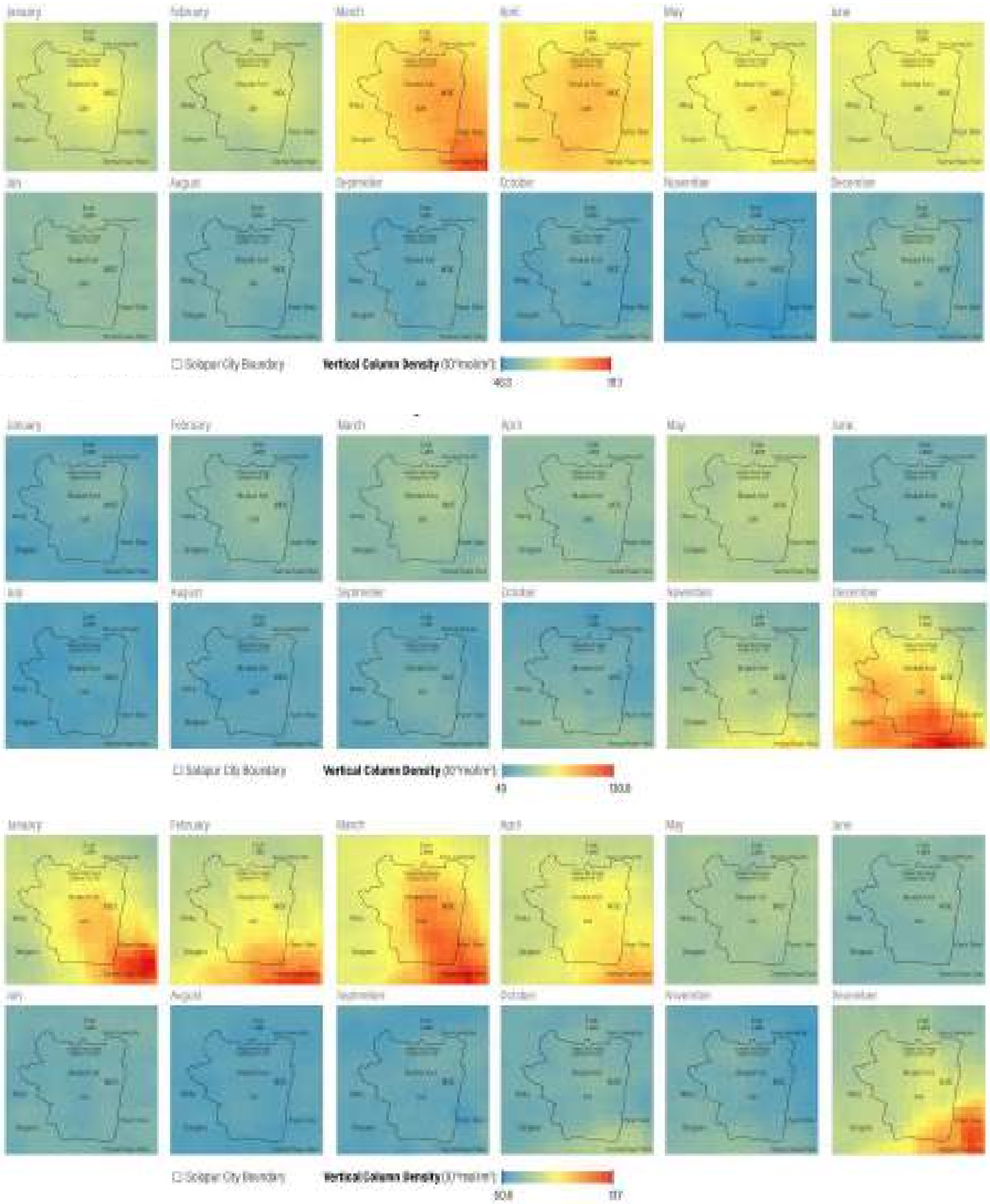
Source: WRI India using Sentinel data

Annexure 2-7: Hourly Nitrogen Dioxide (NO_2) concentrations at the SMC air quality monitoring station between January 2016 and July 2022



Source: CPCB

Annexure 2-8: Monthly average concentrations of Nitrogen Dioxide (NO2) in Solapur from 2019-2021

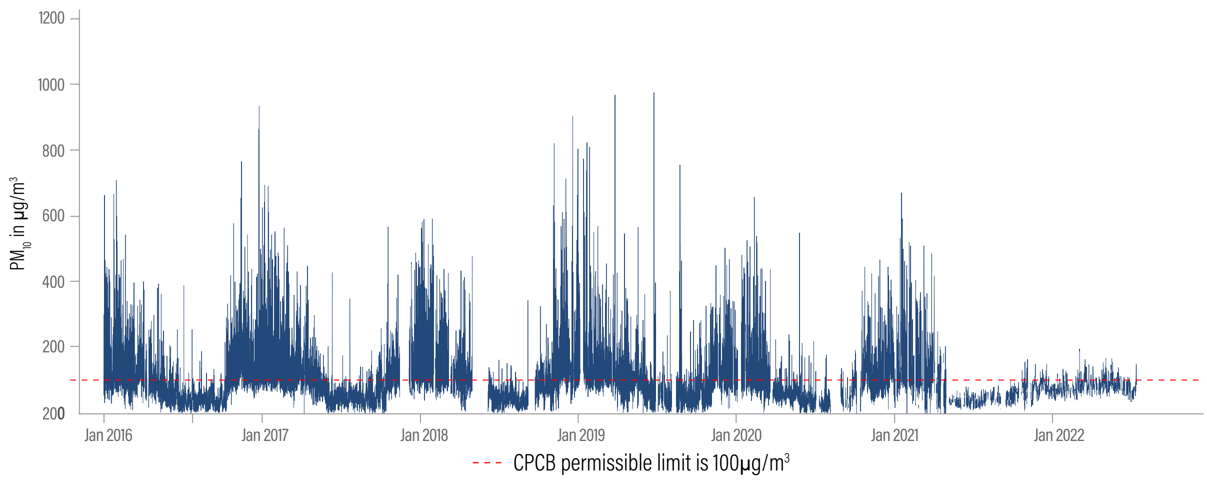


Source: WRI India using Sentinel data

Annexure 2-9: Monthly average concentrations of Carbon Monoxide (CO) in Solapur from 2019-2021

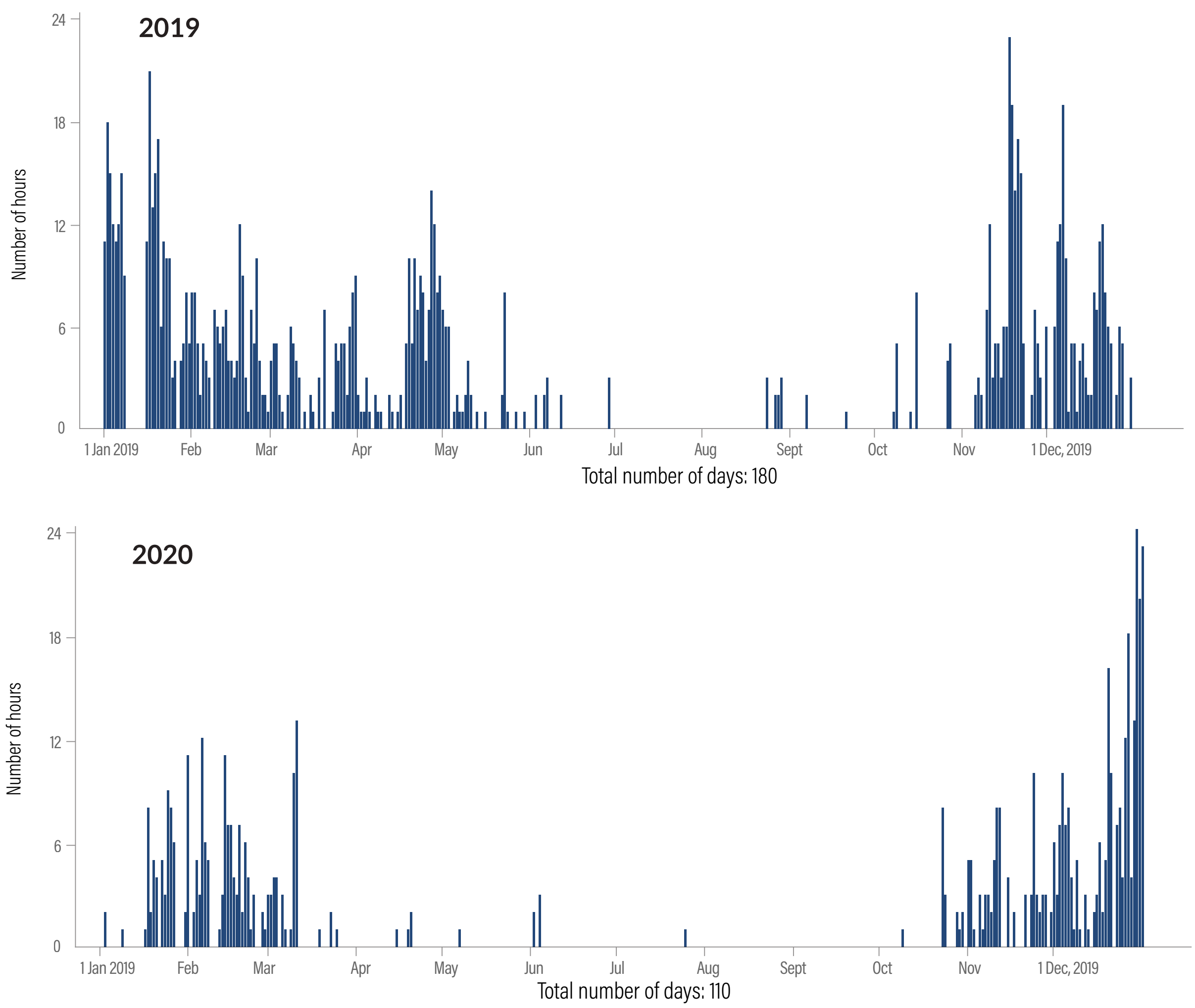
Source: *WRI India using Sentinel data*

Annexure 2-10: Time series of hourly concentrations of Respirable Suspended Particulate Matter (RSPM)



Source: CPCB

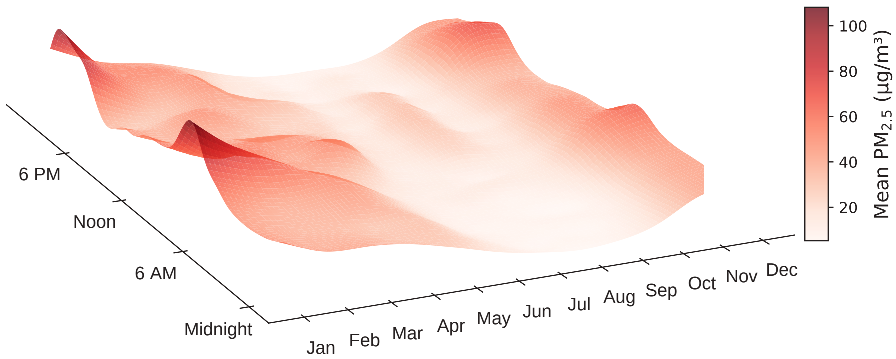
Annexure 2-11: CPCB threshold crossings of PM2.5 in Solapur in 2019 (top) and 2020 (bottom)



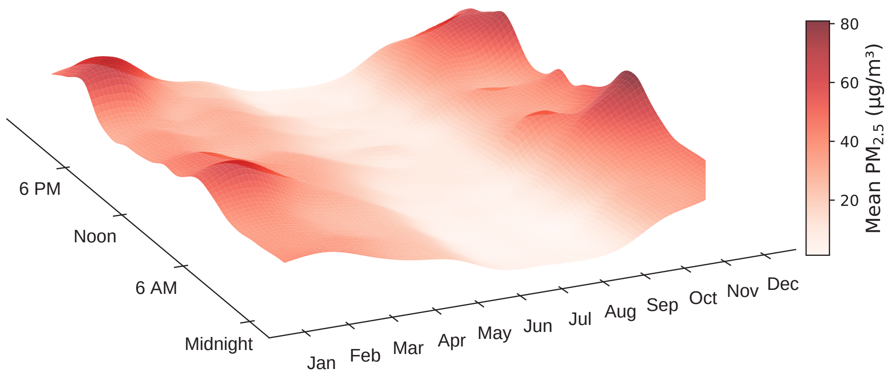
Source: WRI analysis using CPCB data

Annexure 2-12: 3D timeseries of monthly-hourly average concentration of $PM_{2.5}$ for 2019 and 2020

2019

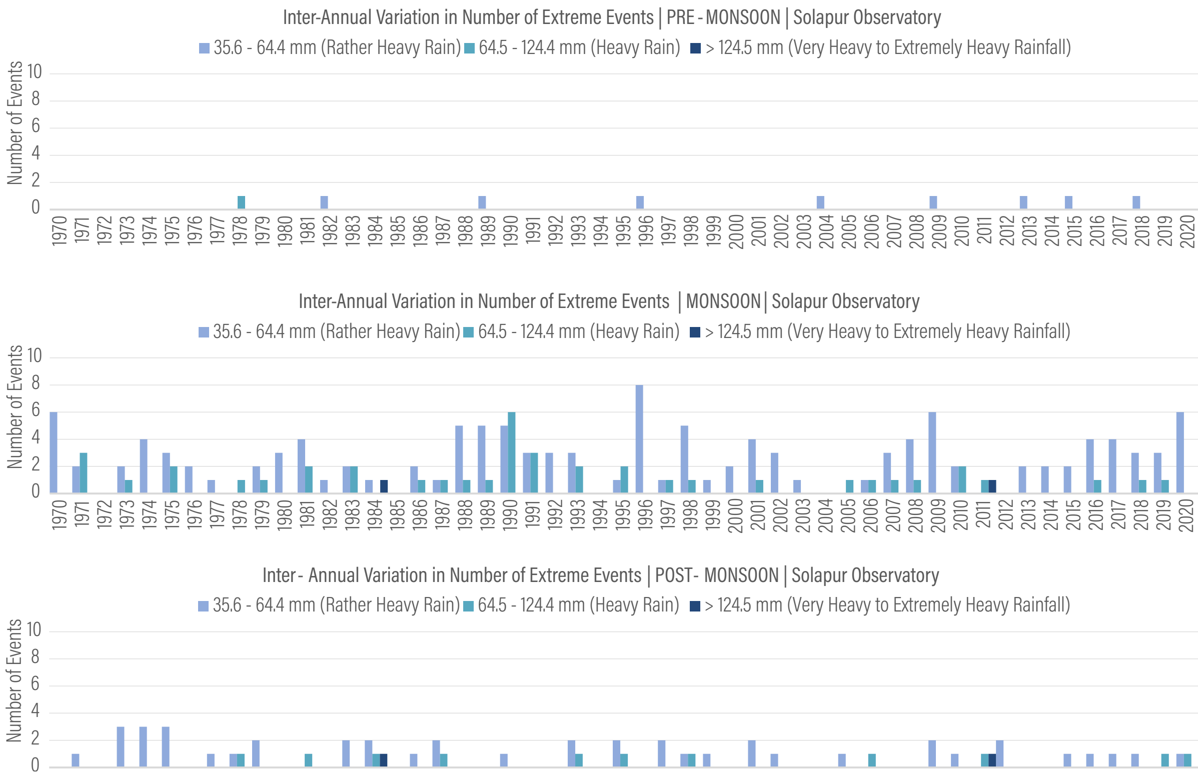


2020



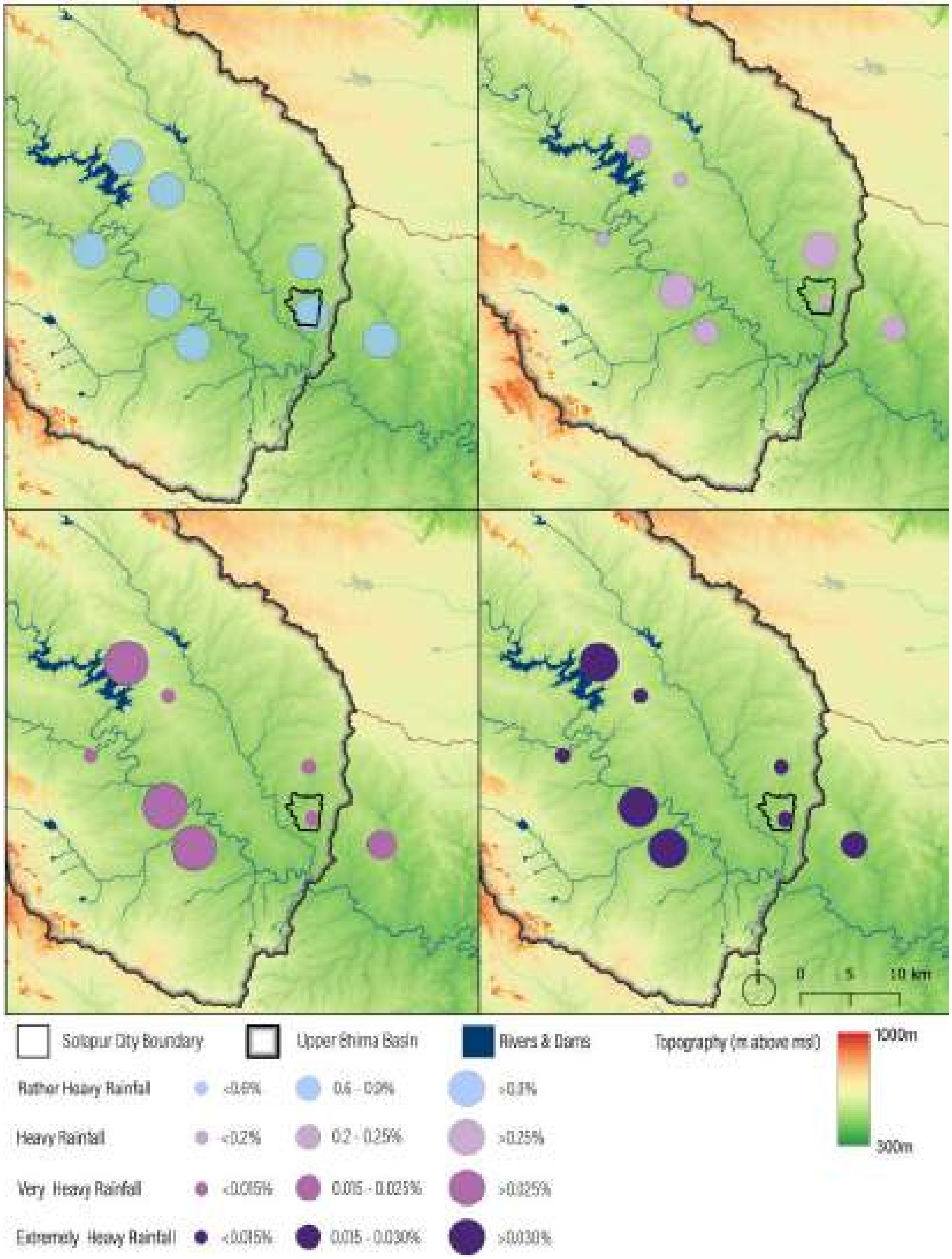
Source: WRI analysis using CPCB data, 2022

Annexure 2-13: Annual Seasonal Rainfall contribution by different rainfall intensities between 1970 and 2020, Solapur Observatory



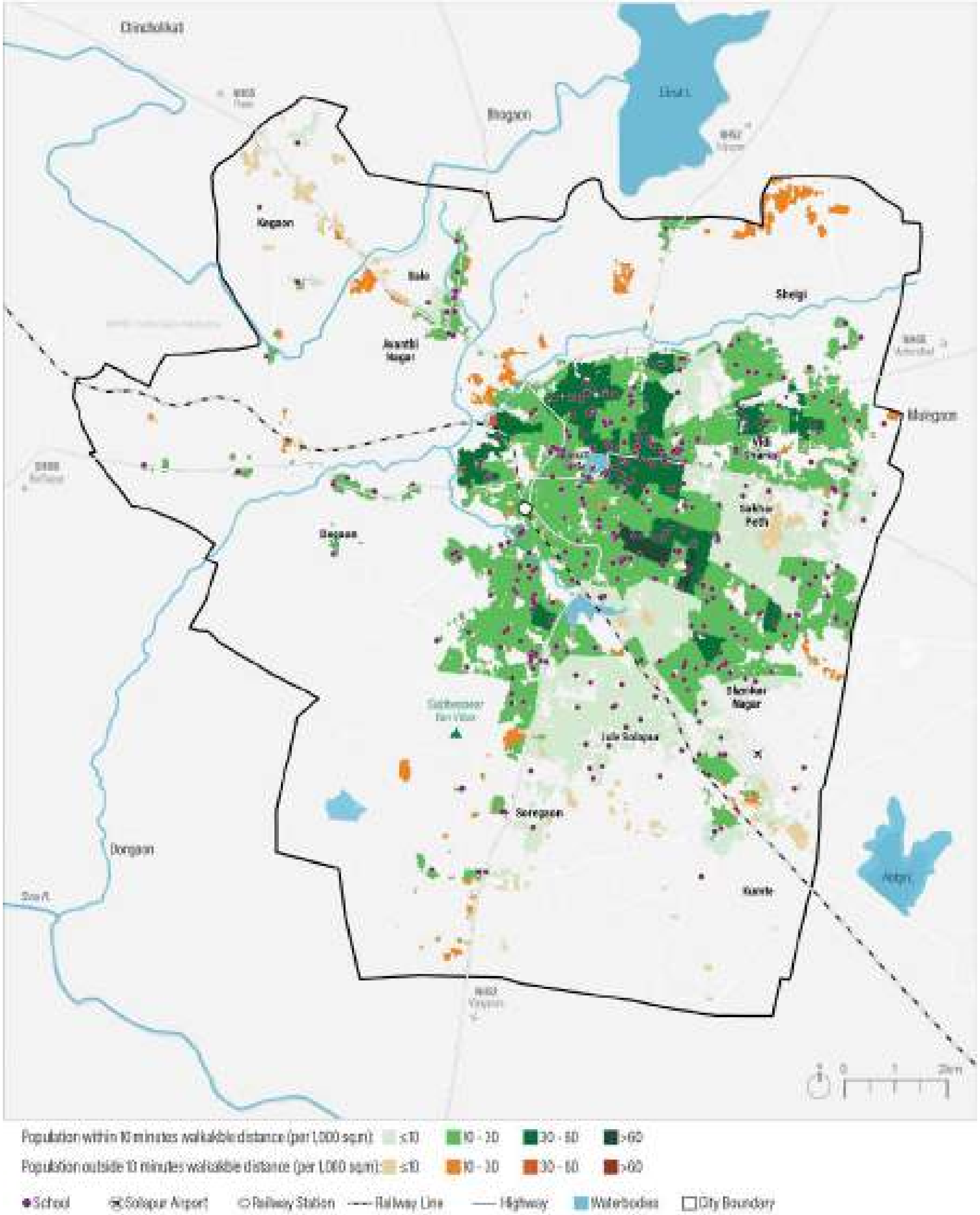
Source: WRI India using meteorological data from IMD

Annexure 2-14: Inter-annual Spatial Variation in Frequency of Different Rainfall Events between 1970 and 2020



Source: WRI India using meteorological data from IMD

Annexure 2-15: Access to All Schools

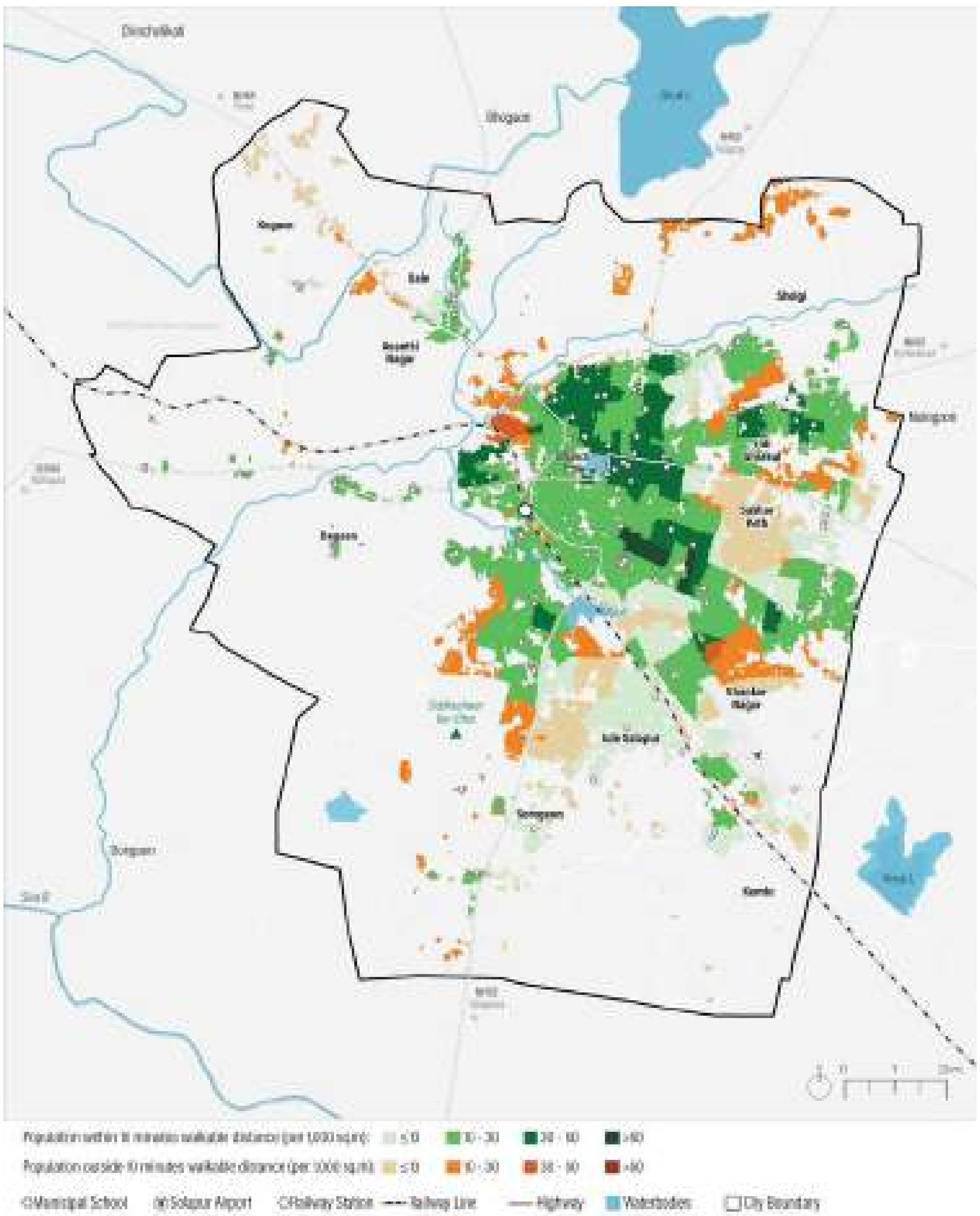


Source: WRI India using Census 2011, World Settlement Footprint 2019, National Informatics Centre 2018, Education Department SMC 2019

Caveat: Accessibility analysis is limited to physical provision and proximity evaluation. Enrolment, teacher-student ratio, drop-out etc. are not included. Schools having primary, secondary education facility (having 10th standard) are considered here. Junior Colleges (with only 11th and 12th standards) are excluded.

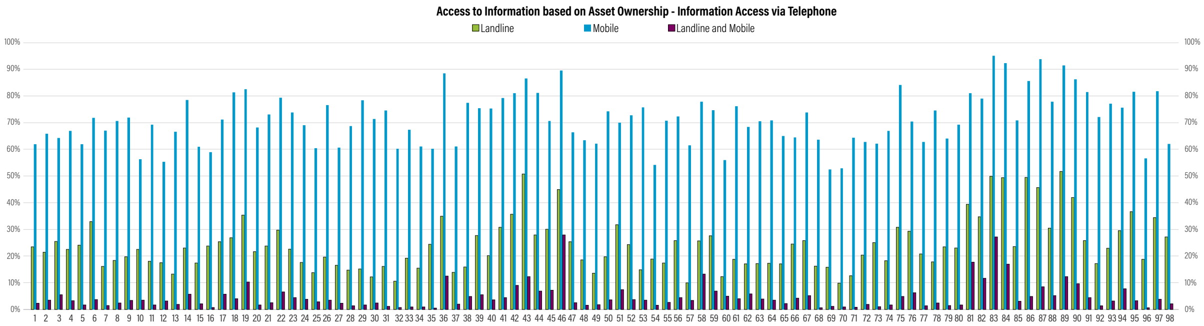
Assumption: Access to schools is mapped using service area polygons that are created for the schools for analyzing access within 1 km. It has been considered based on pedestrian accessibility standards within 10 minutes walkable distance (Bernard van Leer Foundation, 2018).

Annexure 2-16: Access to Municipal Schools



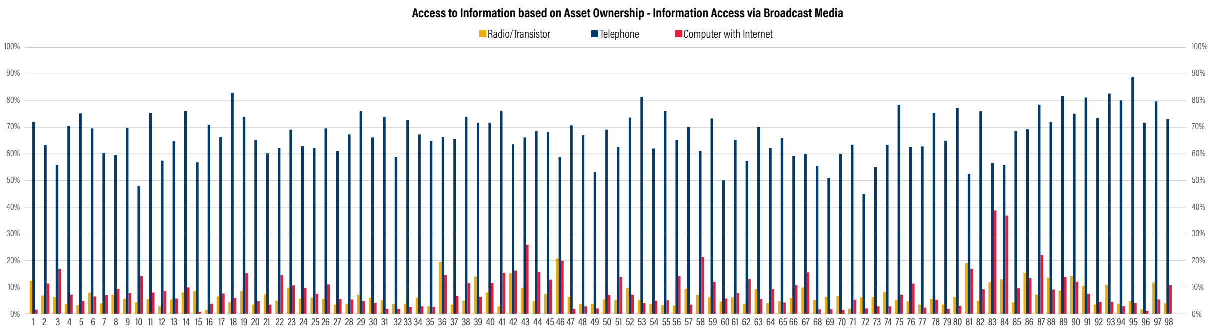
Source: WRI India using Census 2011, World Settlement Footprint 2019, National Informatics Centre 2018, Education Department SMC 2019

Annexure 2-17: Access to Information based on asset ownership- information Access via Telephone



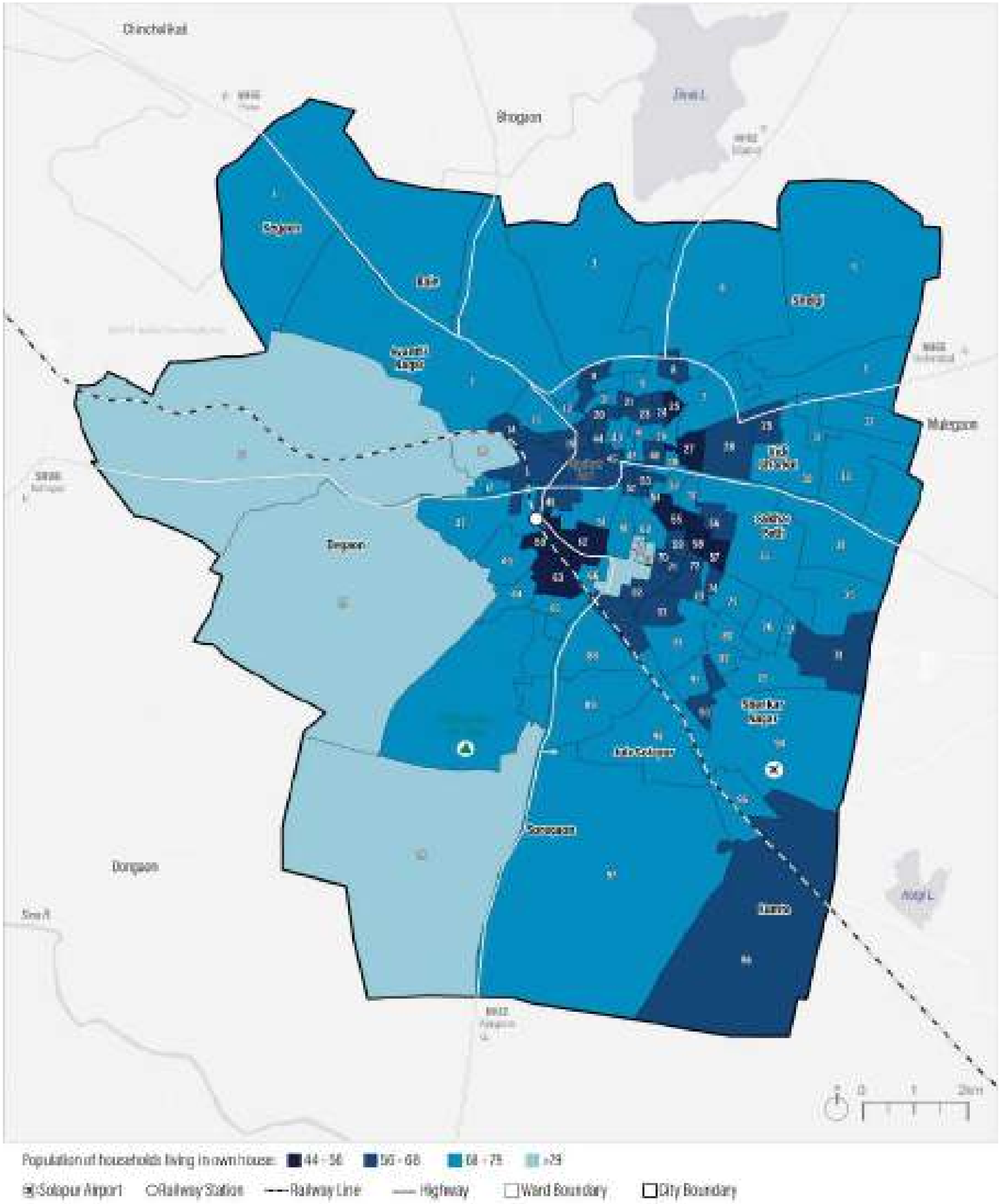
Source: WRI India using Census 2011

Annexure 2-18: Access to Information based on asset Ownership- information access via Broadcast Media



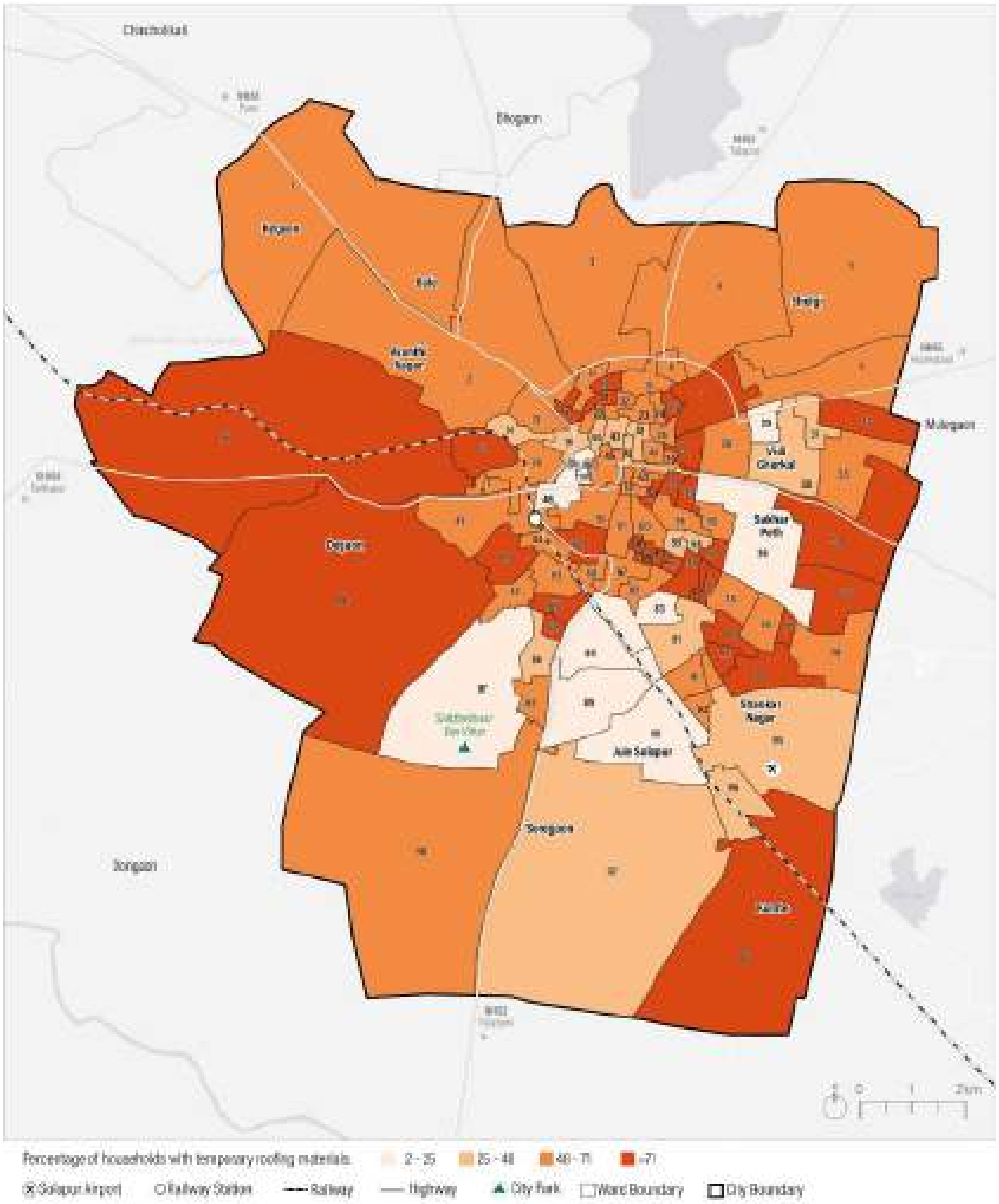
Source: WRI India using Census 2011

Annexure 2-19: House Ownership

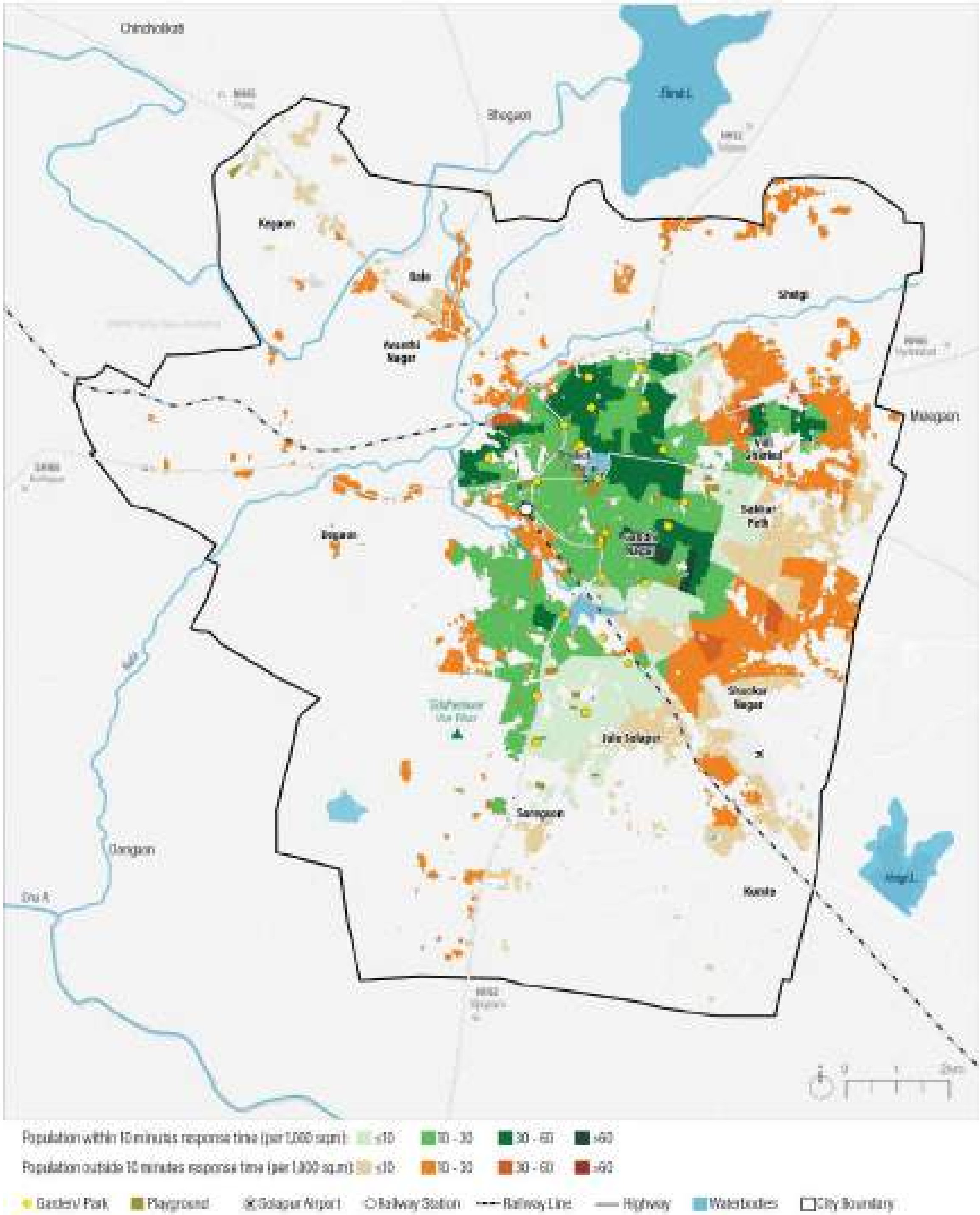


Source: WRI India using Census 2011

Annexure 2-20: House Condition

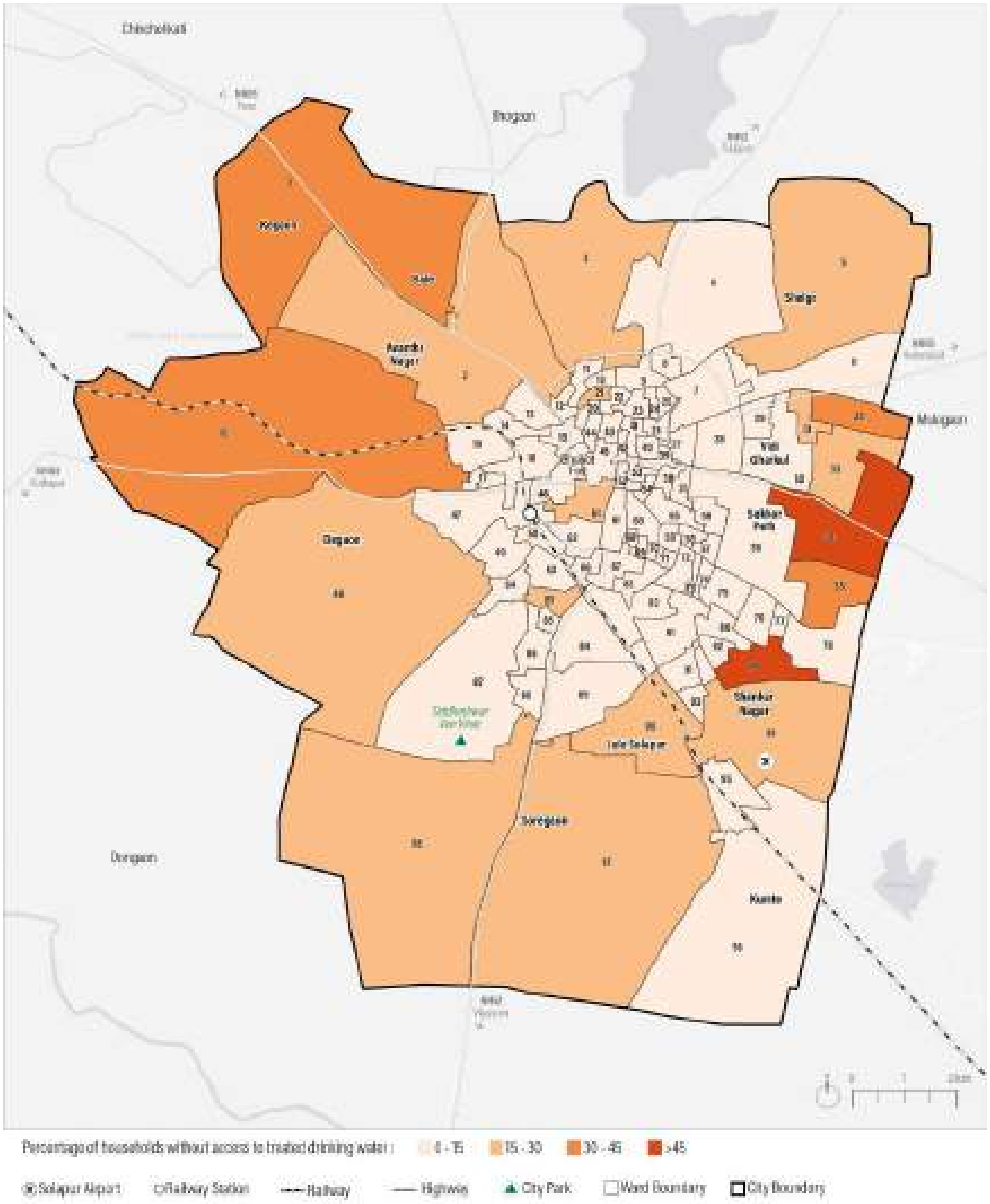


Annexure 2-21: Access to Public Recreational Spaces



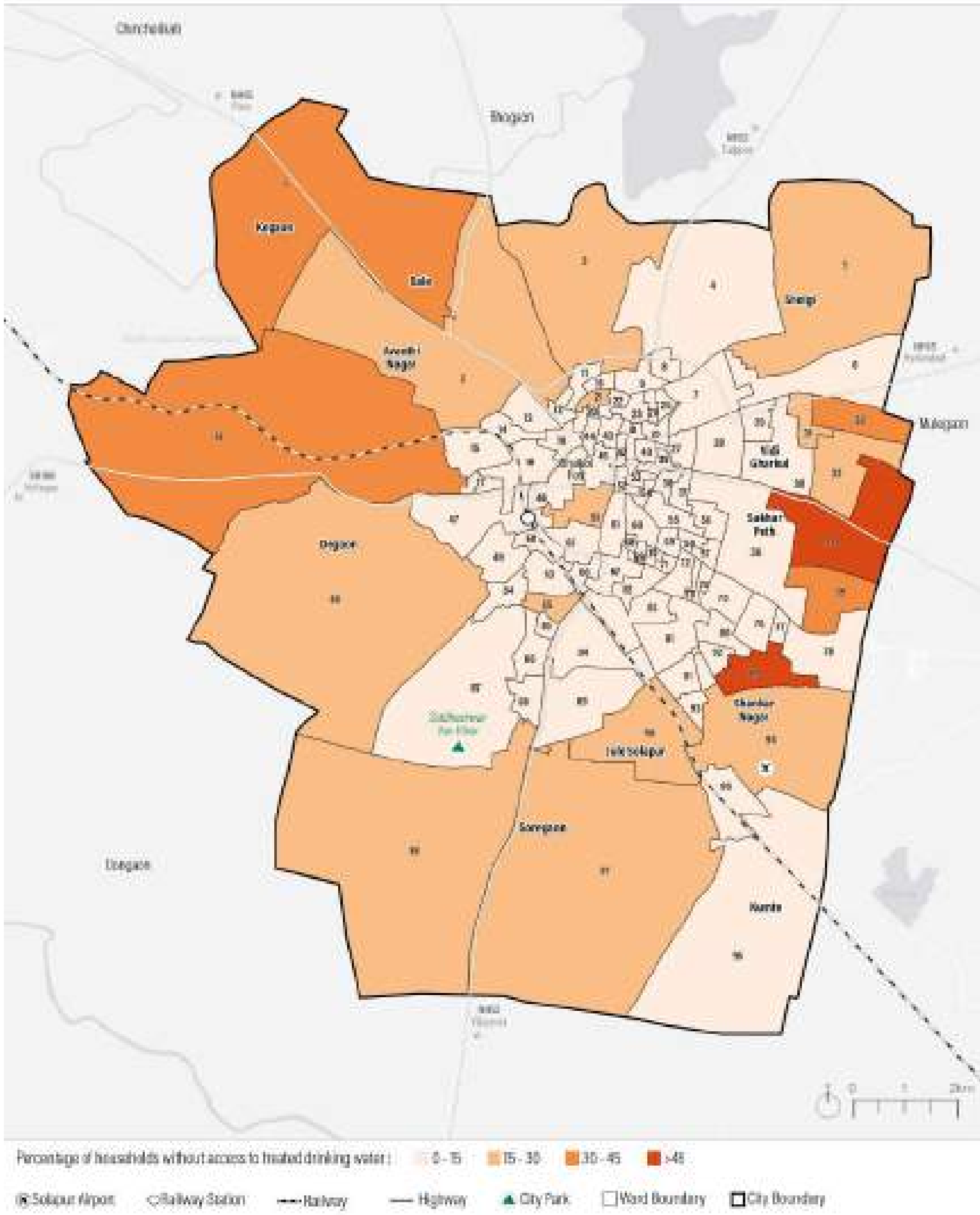
Source: WRI India using Census 2011, World Settlement Footprint 2019, Existing Land Use SMC (2018)

Annexure 2-22: Limited ease of access to drinking water (outside premises)



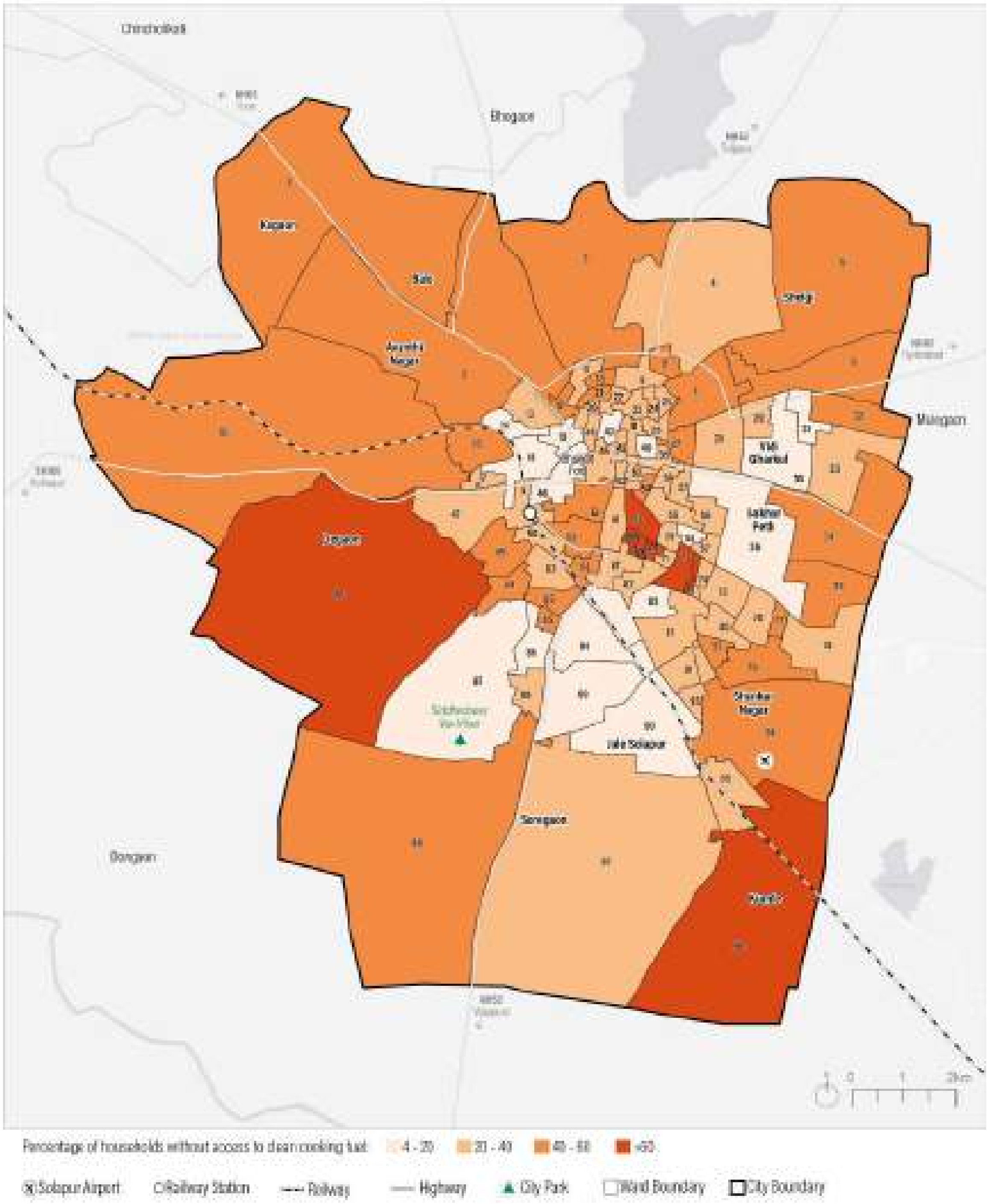
Source: WRI India using Census 2011

Annexure 2-23: Lack of access to treated drinking water



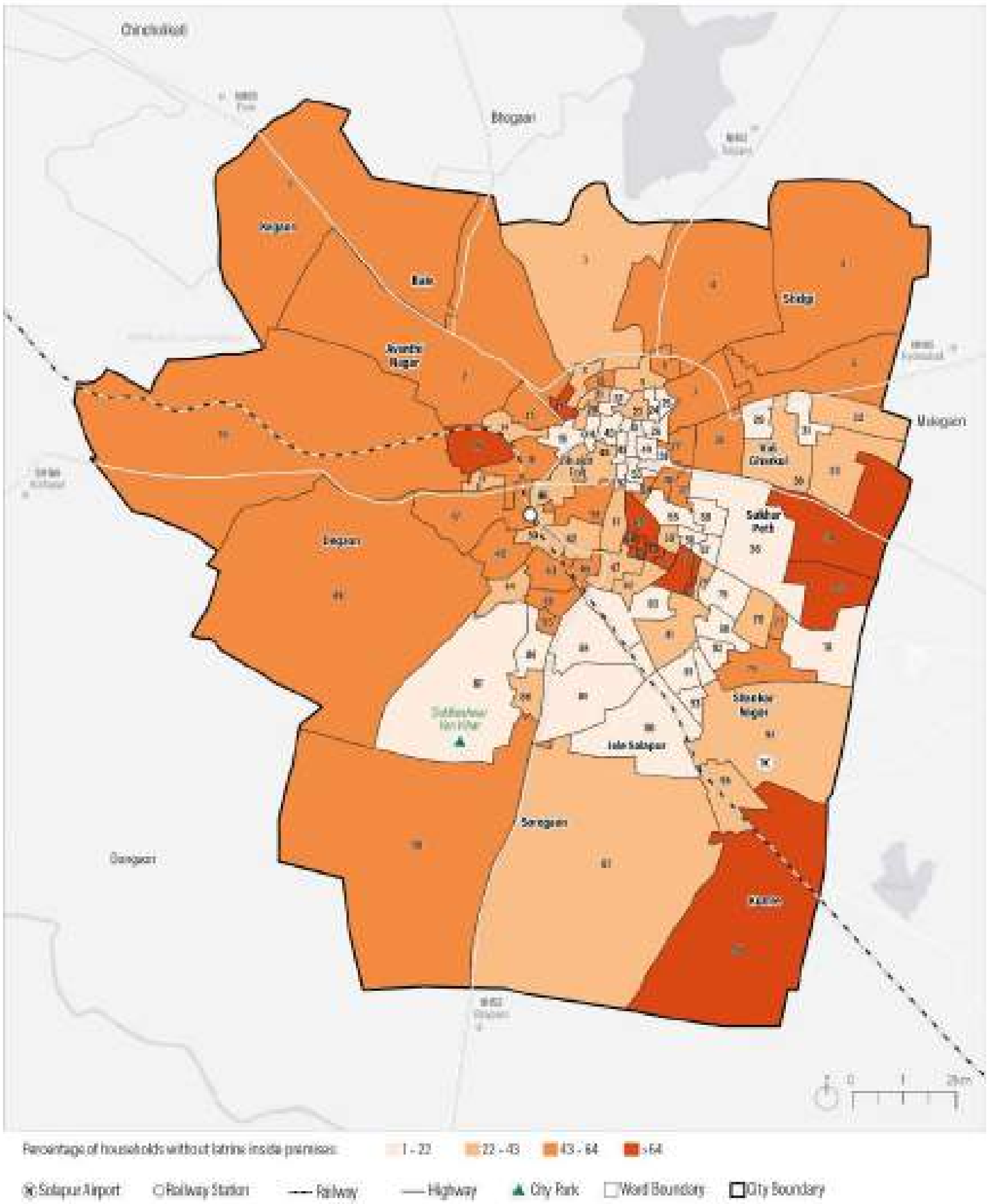
Source: *WRI India using Census 2011*

Annexure 2-24: Lack of Access of Clean Cooking Fuel



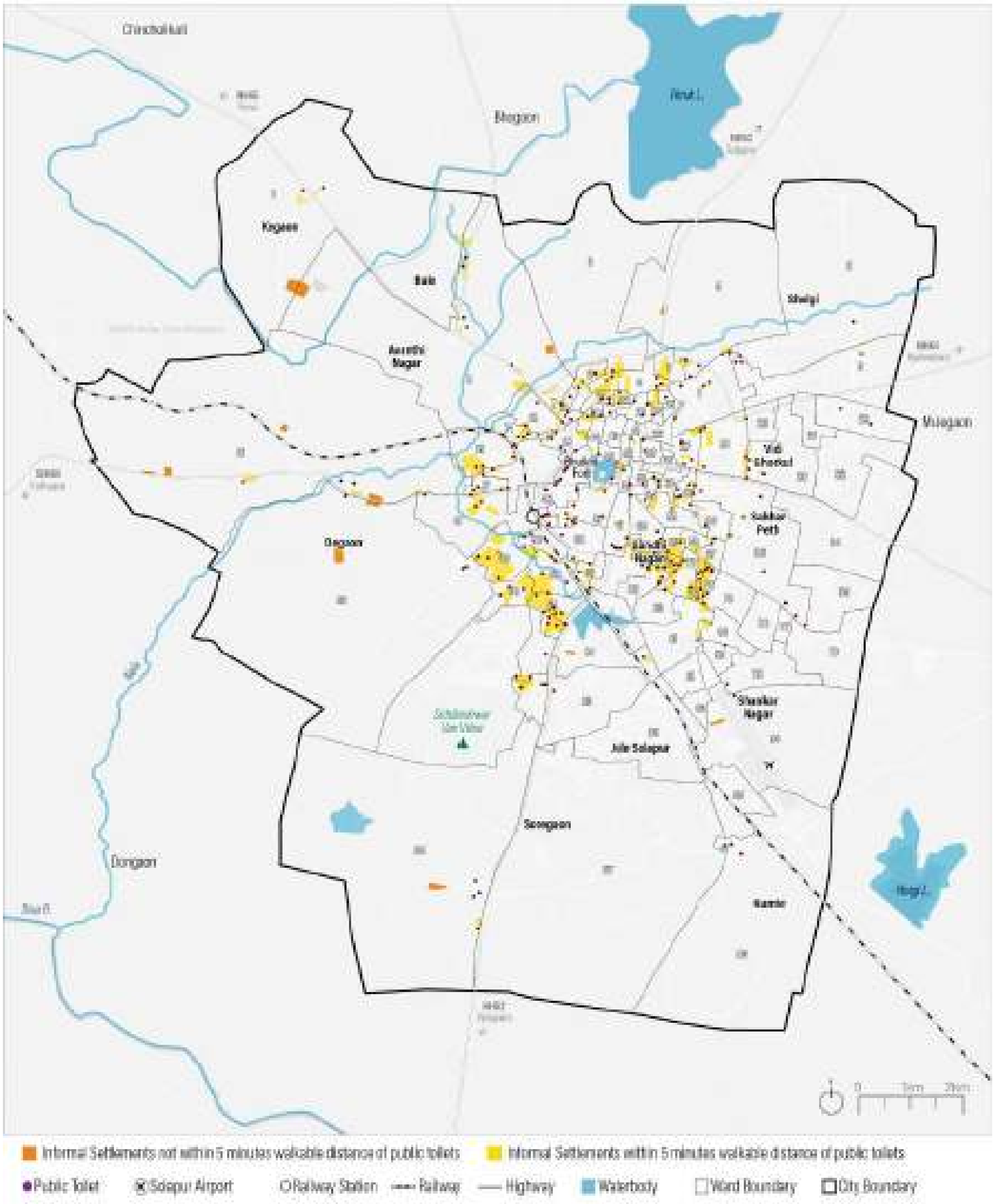
Source: WRI India using Census 2011

Annexure 2-25: Limited ease of access to latrine (outside premises)



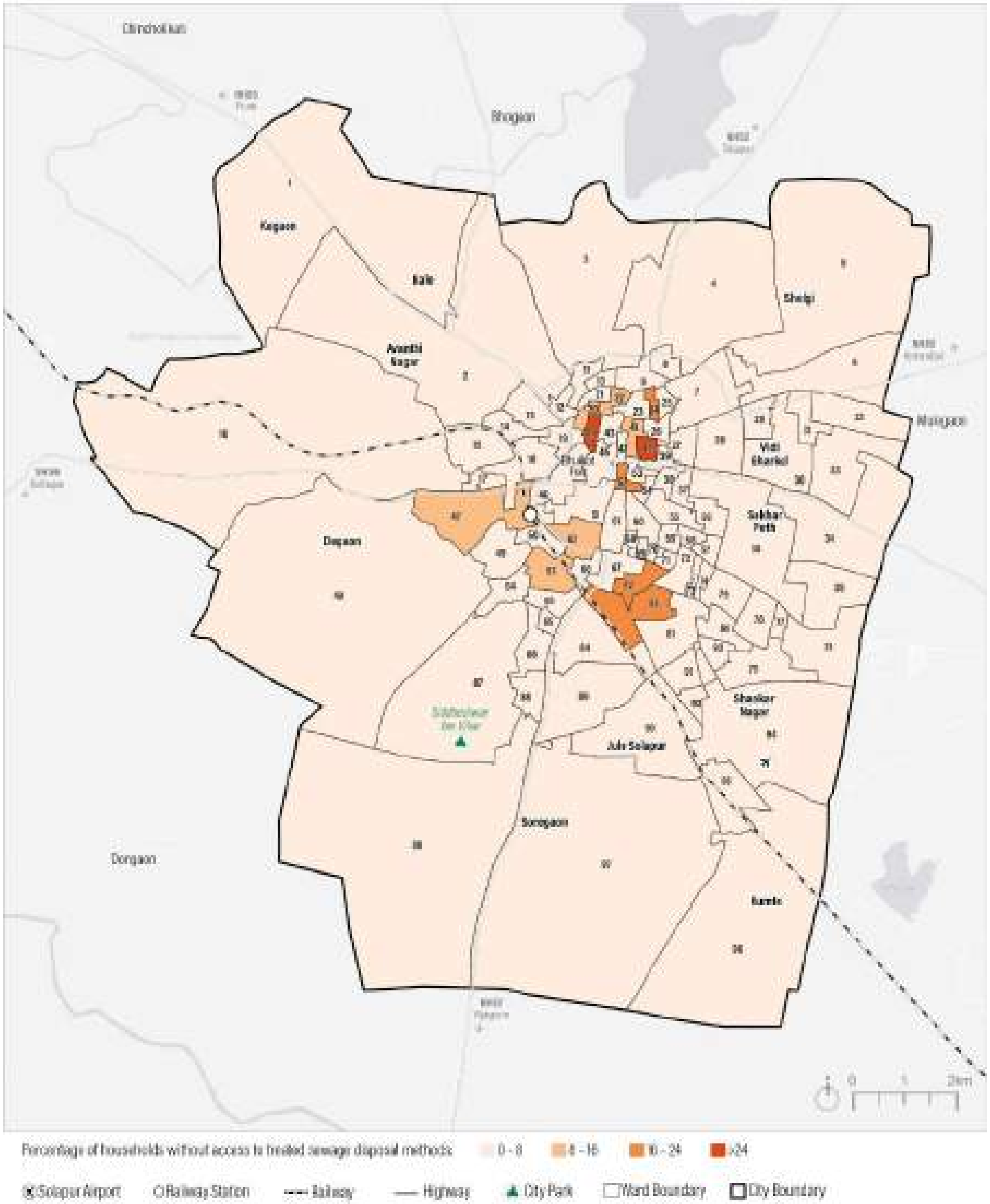
Source: WRI India using Census 2011

Annexure 2-26: Access to Public toilets (in respect to slums)



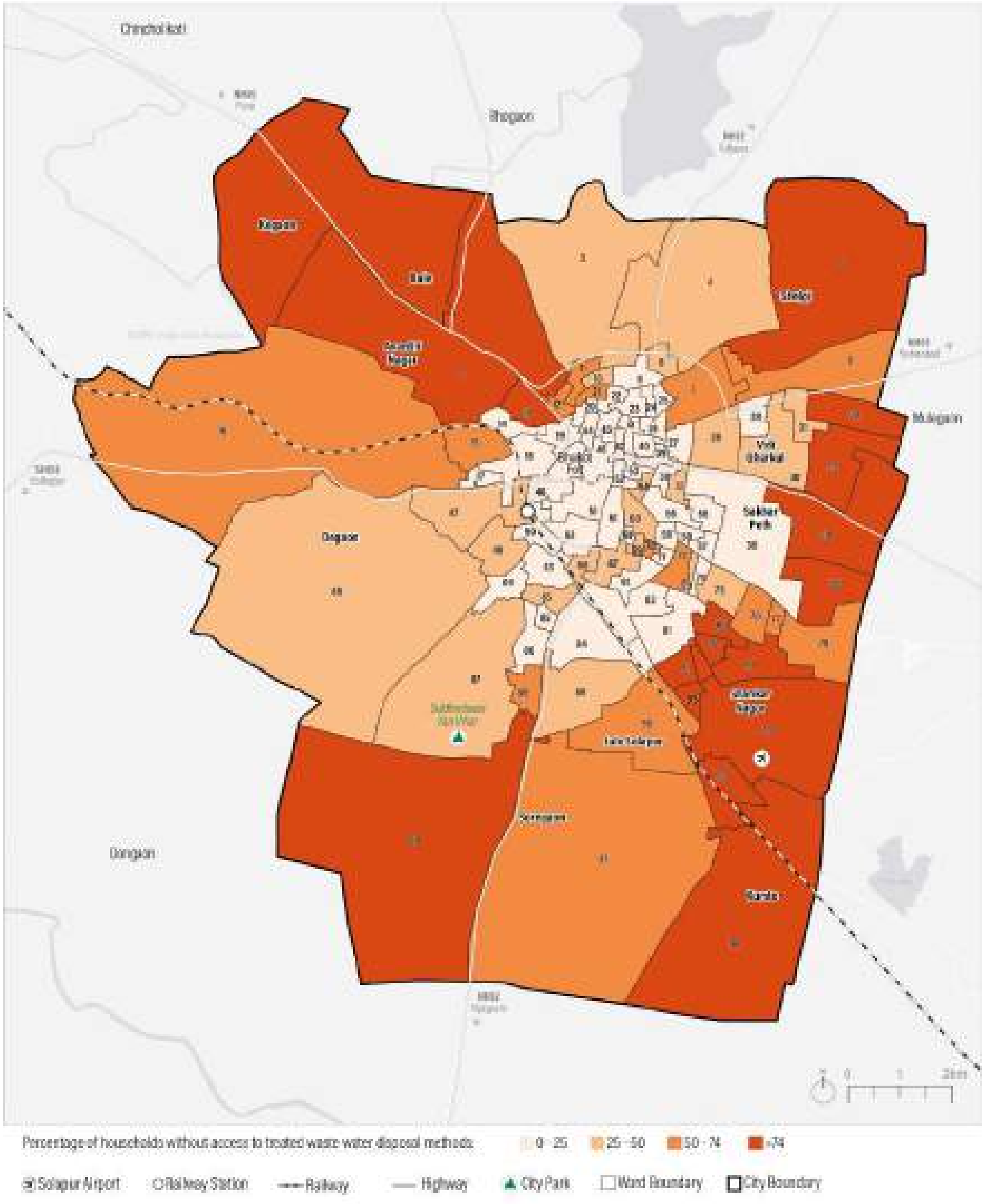
Source: WRI India using Solapur Municipal Corporation 2022

Annexure 2-27: Lack of access to treated sewage disposal methods



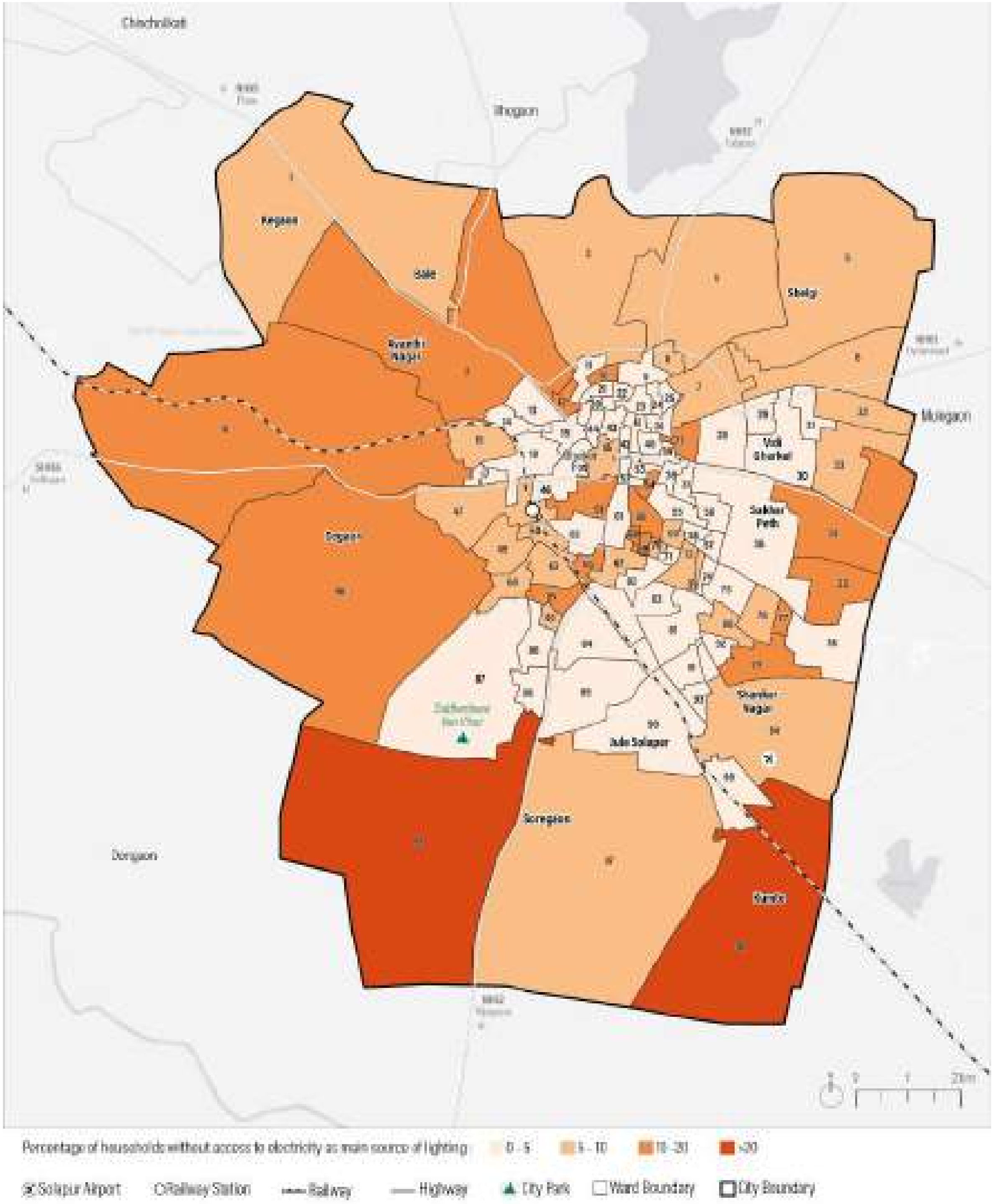
Source: WRI India using Census 2011

Annexure 2-28: Lack of treated wastewater disposal methods



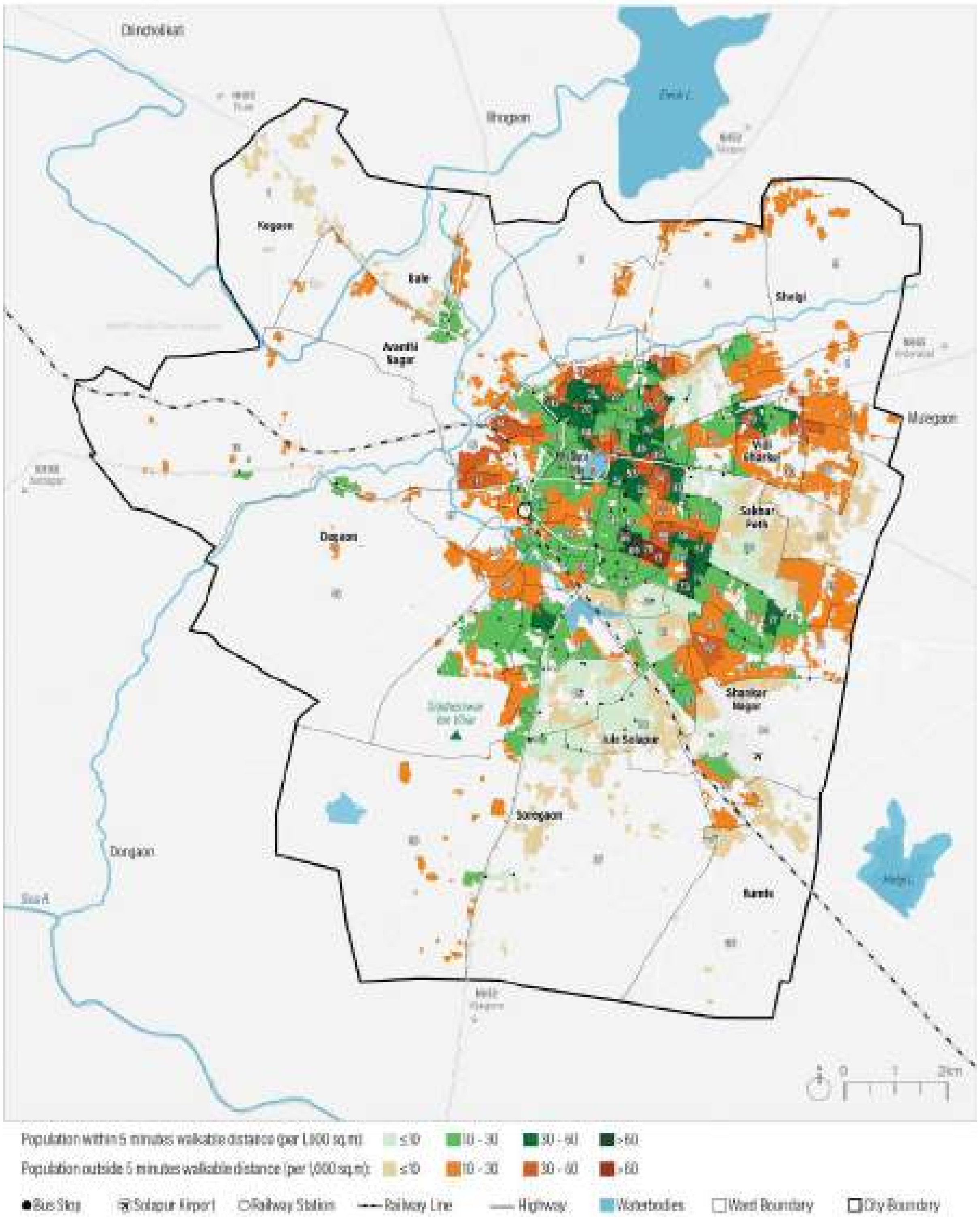
Source: WRI India using Census 2011

Annexure 2-29: Lack of Access to Electricity Grid



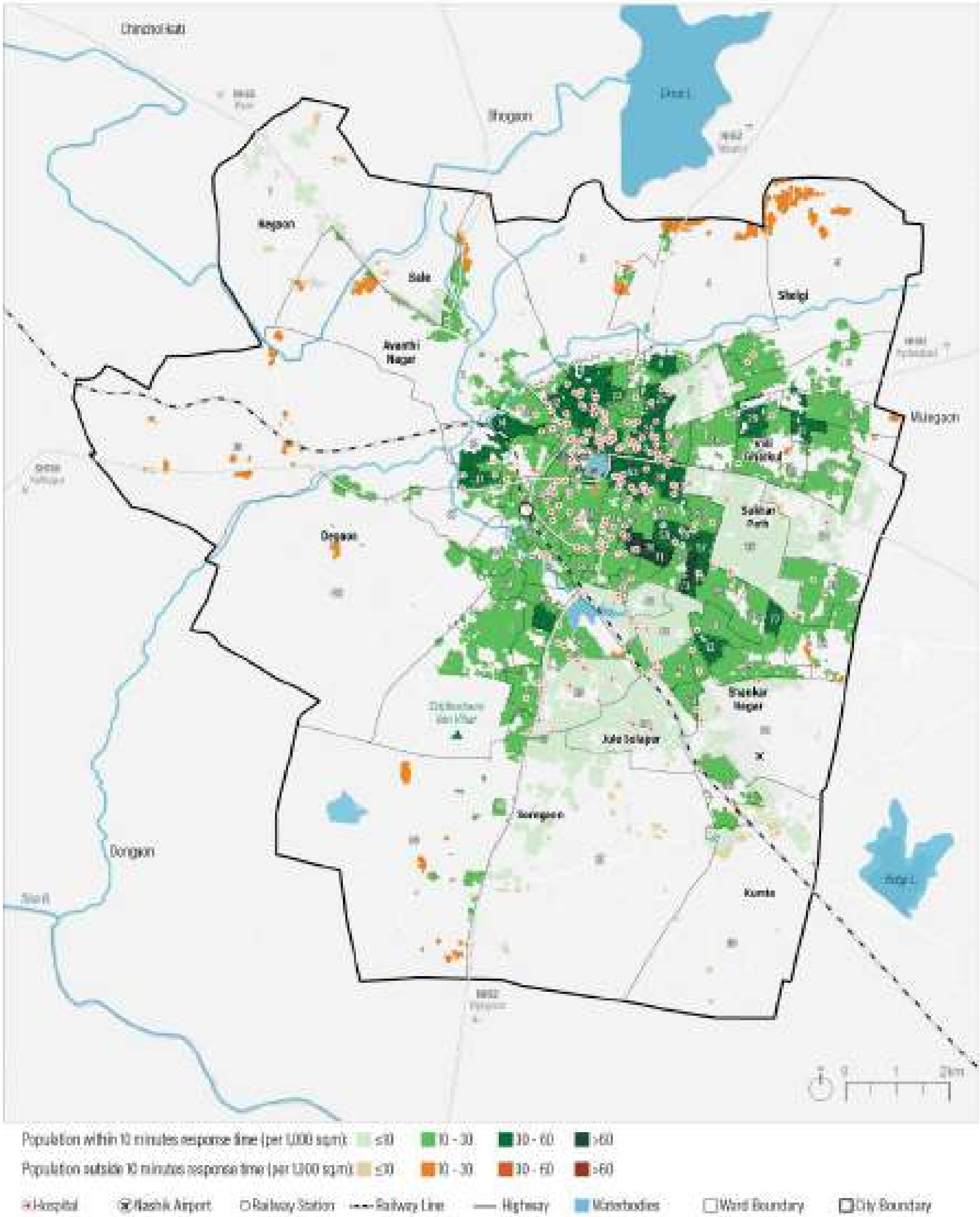
Source: WRI India using Census 2011

Annexure 2-30: Access to Bus Stops



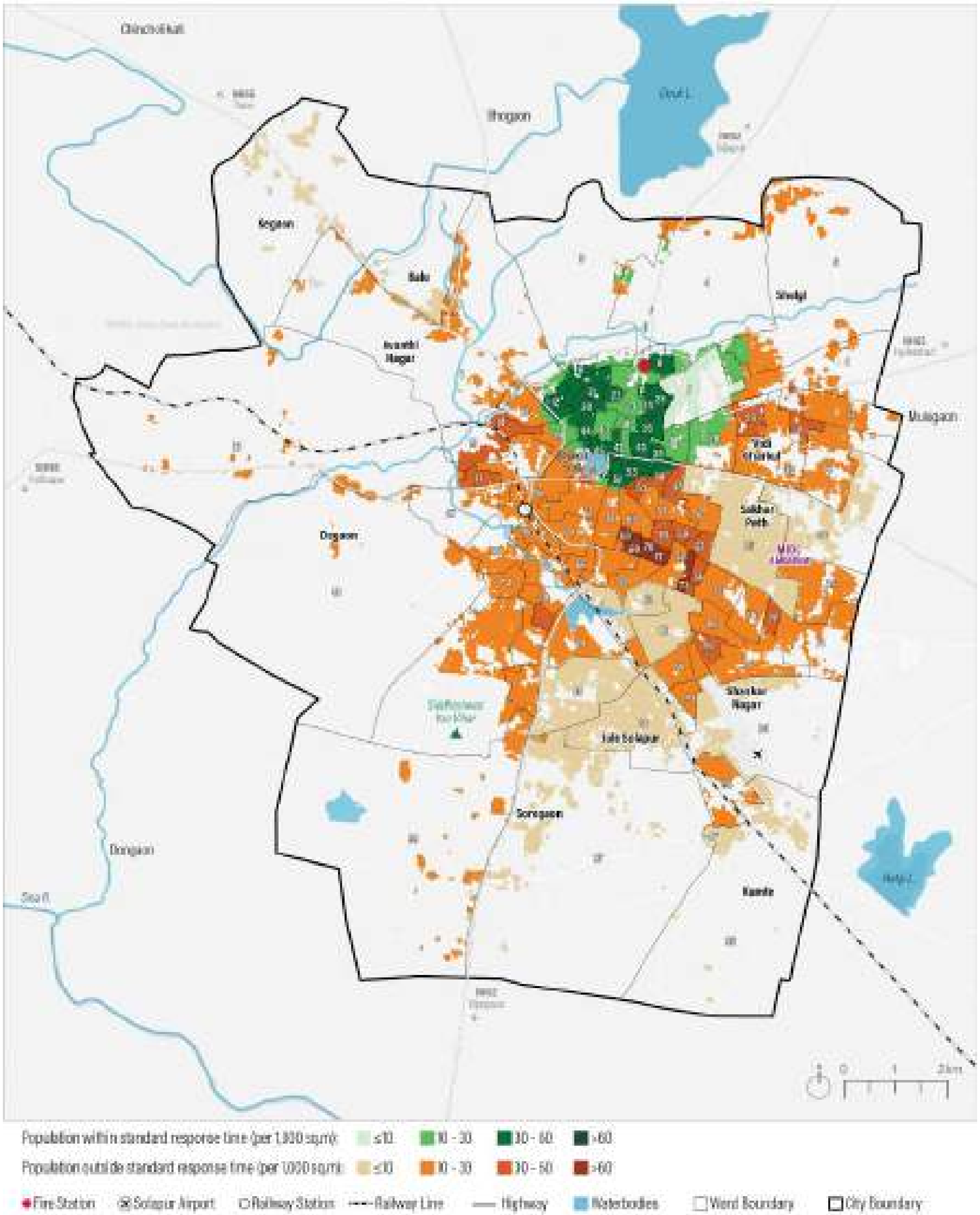
Source: WRI India using Census 2011, World Settlement Footprint 2019, Solapur Municipal Corporation 2020

Annexure 2-31: Access to Hospitals



Source: WRI India using Census 2011, World Settlement Footprint 2019, Solapur Municipal Corporation 2020

Annexure 2-32: Access to fire stations



Source: WRI India using Census 2011, World Settlement Footprint 2019, Solapur Municipal Corporation 2021

ANNEXURE 3: VULNERABILITY ASSESSMENT (VA) PROCESS- DATA REQUIREMENT

Annexure 3-1: Type of data required

What is city exposed to?	Who's sensitive to the risk?		Who needs to adjust to the potential risk?	
CLIMATE HAZARD **RISK** **Urban heat** **Air Pollution** **Rainfall & Lightning** **Droughts** Satellite Imagery IMD Disaster Management Dept. Fire Dept. MPCB & CPCB Town Planning Dept	DEMOGRAPHY AND SOCIO-ECONOMY City/wards/Prabhag boundary slum locations and area existing landuse **Demographic Context** • Literacy • Gender imbalance • Social composition **Socio-economic Aspects** **Physical Environment Aspects** • House condition map • Access to daily urban recreation spaces **Infrastructure and service Aspects** • Access to drinking water • Access to Sanitation • Access to cooking fuel • Access to electricity • Access to public transit (bus) • Access to health care • Access to fire service	**Census dept.** **Town planning Dept.** **Electrical Dept.** **Water supply Dept.** **Sewage /Drainage Dept.** **Tax/GIS Mapping Dept.** **Public Health Dept.** **Education Dept.**	IMPACT ASSESSMENT **Impact on lives** • Population at risk due to flood • Population at risk due to heat • Social composition **Impact on livelihood** • Potential impactr on employment hubs • Migrant workforce due to flood and heat **Impact on Services** • Infrastructure exposed to hazard risks • Public transport stations with limited access • Infrastructure and property losses	**Town planning Dept.** **Water supply Dept.** **Sewage /Drainage Dept.** **Tax/GIS Mapping Dept.** **Disaster Dept.** **Waste Dept.**

Annexure 3-2: Source of data required

What is city exposed to?

CLIMATE HAZARD
RISK

Urban heat
- Landsat
- NCEI
- IMD

Air Pollution
- MPCB/CPCB
- Source Apportionment study
- Fire Dept
- NSSO?

Rainfall & Lightning
- IMD
- District Disaster Management
- Waterlogging Hotspots

Droughts
- District Disaster Management
- GSDA
- Public and Private Borewells

Who's sensitive to the risk?

DEMOGRAPHY AND SOCIO-ECONOMY

City administrative Limits
- Census Ward boundaries(98)
- Prabhag boundaries(26)

Slum/ Vulnerable Communities
- PMAY Slum Dept

LandUse/ Builtuse and Built-up
- TP Dept
- Satellite
- GIS Dept

Demographic Context
- Polpulation density

Socio-economic Aspects

• Literacy
- **Location of schools**
- **Effective literacy**

• Gender Imbalance
- **Sex Ratio**

• Social Composition
- **SC/ST Population**

Physical Environment Aspects
- Household Condition Map
- Access to urban recreational spaces

Infrastructure and service Aspects

• Access to drinking water
- Tap water connections

• Access to sanitation
- HH toilet access
- Public toilets

• Access to cooking fuel
- HH fuel
- Quantity of wood/ Kerosene

• Access to electricity
- Meter connections

• Access to public transit(bus)
- Bus routes/ frequency
- Locations bus stops

• Access to health care
- Other data?
- Public health dept

• Access to fire services
- Fire dept

Who needs to adjust to the potential risk?

Impact on lives

• Population at risk due to flood
- Waterlogging hotspots

• Population at risk due to heat
- Satelite
- Built-up GS dept

Impact on livelihood

• Potential impactr on employment hubs
- Economic Census
- ELU

• Migrant workforce due to flood and heat

Impact on Services

• Infrastructure exposed to hazard risks

• Public transport stations with limited access

• Infrastructure and property losses
- Water supply Dept
- Sewage/ Drainage Dept
- Waste Dept
- Transport Dept

Legend:
- City Municipal Data
- Census 2011
- Primary / Secondary
- Satellite imagery
- Trendlines Agencies

ANNEXURE 4: GHG EMISSIONS INVENTORY – DATA REQUIREMENT

Annexure 4-1: GHG Inventory – sectors to be analysed

Stationary Energy	Transportation	Waste
• Residential buildings • Commercial buildings and institutional buildings • Manufacturing industries and construction • Utility and streetlights	• Road Transport: 4W, 3W, 2W Buses	• Municipal Solid Waste Management • Waastewater treatment

Annexure 4-2: Stationary Energy Sector Emissions – Type of data required

Data required	Stakeholders involved	Data format (FY 2010-2021)
LPG consumption and electricity consumption (HT and LT) with solar generation for • Residential Buildings • Commercial and institutional buildings • Public utilities: Streetlights, STPs, WTPs • Manufacturing and construction industries • Other sources	• State Electricity utility company (MAHAGENCO and MSEDCL) • Fuel agencies • Electric Department Municipal Corporation	• LPG sales in MT • HT and LT consumption (kWh) • HT and LT consumers • RE generation (kWh) Category wise

Annexure 4-3: Transport Sector Emissions – Type of data required

Data required	Stakeholders involved	Data format (FY 2010-2021)
• City-level fuel sales (petrol, diesel, Auto LPG, CNG)	• Fuel agencies BPCL, HPCL, IOCL, Go gas, Essar, Reliance	• Fuel sales (petrol, diesel in KL, Auto LPG in tonnes)

Annexure 4-4: Waste and Wastewater Sector Emissions – Type of data required

Data required	Stakeholders involved	Data format (FY 2010-2021)
• Annual waste generated • Annual waste composted/digested • Waste composition • Annual waste recycled • % of waste water treated and % that is directly discharged • Landfill in city	• Solid waste department • Sanitation department • Consultant managing waste water STPs	• Waste quantities in tonnes per day • Waste Composition as percentage • Amount of methane collected in tonnes/year from STP

ANNEXURE 5: GHG EMISSIONS – SCENARIO ANALYSIS

APPROACH AND METHODOLOGY

The following steps provide the details of the planning of climate action in 5 steps using the CURB tool:

1. City Information and setup: In this step, the user must input basic information about the city, including the climate, area, base year and target years, and population. This is followed by sectoral information, which comprises the bulk of data requirements for the tool. The complete data requirements template can be found on the World Bank website.

2. GHG Inventory: This step involves entering a GHG inventory for the city in alignment with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) framework. The GHG inventory is pivotal and informs the Business-as-Usual scenario for the city, estimating the emissions increase if no climate action is taken.

3. Context: This tab helps the user understand the main drivers for emissions and energy across each sector. It also allows users to benchmark the city's emissions performance with other cities compared by region, development index or climate.

4. Actions: This module is the crux of the tool and allows users to enter targets for different sectors and subsectors and develop scenarios by customizing and bundling multiple interventions into a comprehensive plan. The targets should be based on the city's authority to intervene in the sector and should ideally be verified with stakeholders. Along with emission and energy reductions, this module also provides the associated investment and payback period for each action. It also provides a general understanding of co-benefits associated with each action category.

5. Results: Finally, this module provides the combined impact of selected interventions as well as ectoral targets achieved. It also allows users to compare the impacts of different scenarios.

ANNEXURE 6: STAKEHOLDER CONSULTATIONS

Date	Objective	Other details
25th Jan 2022	Launch Event & Signing of the LOI	The Letter of Intent (LOI) for the Solapur Climate Action Plan was signed by the then Municipal Commissioner of Solapur, P. Sivsankar (IAS)
08th Feb 2022	Kickoff meeting Solapur Climate Action Plan	With this Solapur became among one of the five cities in the state that will to create a CAP to ensure sustainable development. A meeting was held with all Heads of Departments to discuss data requirements from various departments within the SMC and external stakeholders under the leadership of the Commissioner of Solapur. The WRI India team presented the goals, aims, and objectives of the Plan, and the steps that would be taken to created data templates which was then shared with various departments.
July 27, 2022	Presentation and Workshop: Vulnerability Analysis and Greenhouse Gas Inventory	The goal of the workshop is to help city stakeholders understand the process in terms of tools used and data requirements for conducting VA and GHG emission inventory. Within VA, 3 risks were highlighted them being: air pollution, heat risk and rainfall variability. The implications were drawn, and preliminary findings were presented to the cities. The GHG emission inventory session focused on 3 sectors: Stationary Energy and Buildings, Transport, Waste and Waste water. The consultative discussion dove into issues key issues around data unavailability and data gaps in terms of carrying trend analysis. The workshop provided an opportunity for stakeholders to learn about the tools and processes and The workshop was inaugurated by Hon. Commissioner Shri P. Shiv Shankar and in the presence of the newly appointed Deputy Commissioner Shri Macchindra Gholap. The workshop saw participants from: various departments in SMC (PHE, Waste Management, Water Supply, Transport), agencies like IMD, NHAI, MPCB, GSDA, RTO and private players such as fuel companies representatives and academicians.
06 July, 2023	Presentation and Discussion: Solapur CAP Draft	The goal of the workshop was to invite stakeholders to reflect and comment on the sectoral strategies and actions reflected under the CAP. During the process of CAP, there were six sectors that were identified, Transport, Energy and Buildings, Municipal Solid Waste Management, Air Pollution, Water and Flooding, Greening, and Urban Heat. This was a large-scale consultation that took place in Solapur City since the inception of the Climate Action Plan project in January 2022. Active participation of city stakeholders was seen across all such interactions and also other interactions with city officials over the course of the project thus far. The workshop saw participants from across the sectors that were identified with a mix of stakeholder groups within the municipal corporation and associated bodies. The workshop was presided over by Additional Commissioner Shri. Sandip Karanje and the Deputy Commissioner Shri Macchindra Gholap. The workshop saw participants from: various departments in SMC (PHE, Waste Management, Water Supply, Transport), agencies like NHAI, RTO and private players such as fuel companies representatives and academicians.

CAPACITY BUILDING WORKSHOPS AT SMC

ANNEXURE 7: NOTES ON CLIMATE PROJECTIONS USING RCP SCENARIOS

1. Background: The historical data (precipitation, minimum air temperature, maximum air temperature) has been obtained from the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis (ERA5) of the global climate at the spatial resolution of 0.25 degrees. The climatic projections are obtained through the process of running the GCMs under the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor, Stouffer, & Meehl, 2012) at a daily temporal scale for daily average maximum air temperature, daily average minimum air temperature and daily average precipitation. These modelled results are available for the four RCPs at a resolution of 0.125° x 0.125° to 5° x 5° varying based on the model simulations.

For RCP 4.5, the pre-downscaled projections dataset from NASA NASA Earth Exchange (NEX) - Global

Daily Downscaled Projections (GDDP) - at a spatial resolution of 0.25 degrees x 0.25 degrees, have been utilized to decipher granular spatial variations. This dataset has been processed directly in Google Earth Engine at various study area domains for a comprehensive understanding of the climatic behaviour in terms of precipitation and air temperature for the future until the year 2100 for the defined epochs and entire study timeline.

For RCP 6, CMIP5 direct outputs have been obtained from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) established at the Lawrence Livermore National Laboratory (LLNL), California. The data comprises of 13 model simulation outputs at varying resolutions up to 5° x 5°. The spatial analysis for RCP 6 has not been included due to the coarse resolution and unavailability of the downscaled product viable to understand the study area/ domain-wise spatial variations in the climate variables as considered for analysing RCP 4.5.

Caveat: The analysis is limited to consistently available data available from ERA5 and CMIP5 products for RCP scenarios 4.5 and 6. While the learnings from IPCC AR6 have been thoroughly nested in the Climate Change Resilience and Vulnerability Assessment of the city, the climate projections have not been revised with the Shared Socio-economic Pathways as updated in AR6, anchored extensively by the latest CMIP6 simulations, due to limited spatial products (all 21 GCM) available for the city at the desired (down) scale (PCMDI, 2022).

GCMs run using relatively coarse resolution grids (for Example, a few degrees or 10 KM2), which limits their ability to capture the spatial details in climate patterns that are often required or desired at regional or local analyses. Second, even the most advanced GCMs may produce projections that are globally accurate but locally biased in their statistical characteristics (i.e., mean, intensities, variance, etc.) when compared with real-time observations.

2. List of 21 models considered in the assessment (ESGF-LLNL, 2021): ACCESS1-0, CSIRO-MK3-60, MIROC-ESM, BCC-CSM1-1, GFDL-CM3, MIROC-ESM-CHEM, BNU-ESM, GFDL-ESM2G, MIROC5, CanESM2, GFDL-ESM2M, MPI-ESM-LR, CCSM4, INMCM4, MPI-ESM-MR, CESM1-BGC, IPSL-CM5ALR, MRI-CGCM3, CNRM-CM5, IPSL-CM5A-MR, NorESM1-M.

3. List of 13 models considered in the assessment: CCSM4, CSIRO-Mk3, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM, MIROC-ESM-CHEM, MIROC5, MRICGCM3, NorESM1-M, bcc-csm1-1.

4. Background: For precipitation - Each day of the annual or desired epoch is temporally aggregated using the daily average precipitation values for each pixel (the smallest spatial unit). For comparisons between the study area/ domain, the temporal aggregates of the annual or the desired epoch are represented as spatial summation of each pixel within the defined study area/ domain.

For Temperature - Each day of the annual or desired epoch is temporally aggregated using the daily maximum and minimum average temperature values for each pixel (the smallest spatial unit). For comparisons between the study area/ domain, the temporal aggregates of the annual or the desired epoch are represented as spatial mean across all the pixels within the defined study area/ domain.

5. List of 4 models used for spatial illustration in Precipitation change: GFDL-ESM2M, IPSL-CM5A-LR, MIROC-ESM-CHEM, NorESM1-M. These have been used within the analysis to keep consistency with the WRI Aqueduct floods methodology (WRI, 2015).

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23 Urban heat risk is assumed for areas with LST >33°C. This has been calculated by taking mode pf average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021

24 Using Google distance API for 05.11.2022 considering the best guess scenario results on vehicular speeds have been derived.

25 (Difference between maximum and minimum area coverage / Maximum area coverage) *100

26 (Number of slums with heat risk and beyond access to fire station / Total number of slums) *100

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31 List of 13 models considered in the assessment: CCSM4, CSIRO-Mk3, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM, MIROC-ESM-CHEM, MIROC5, MRI-CGCM3, NorESM1-M, bcc-csm1-1

32 List of 21 models considered in the assessment (ESGF-LLNL, 2021): ACCESS1-0, CSIRO-MK3-6-0, MIROC-ESM, BCC-CSM1-1, GFDL-CM3, MIROC-ESM-CHEM, BNU-ESM, GFDL-ESM2G, MIROC5, CanESM2, GFDL-ESM2M, MPI-ESM-LR, CCSM4, INMCM4, MPI-ESM-MR, CESM1-BGC, IPSL-CM5A-LR, MRI-CGCM3, CNRM-CM5, IPSL-CM5A-MR, NorESM1-M

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36 List of 4 models used for spatial illustration: GFDL-ESM2M, IPSL-CM5A-LR, MIROC-ESM-CHEM, NorESM1-M. These have been used within the analysis to keep consistency with the WRI Aqueduct floods methodology (WRI, 2015)

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