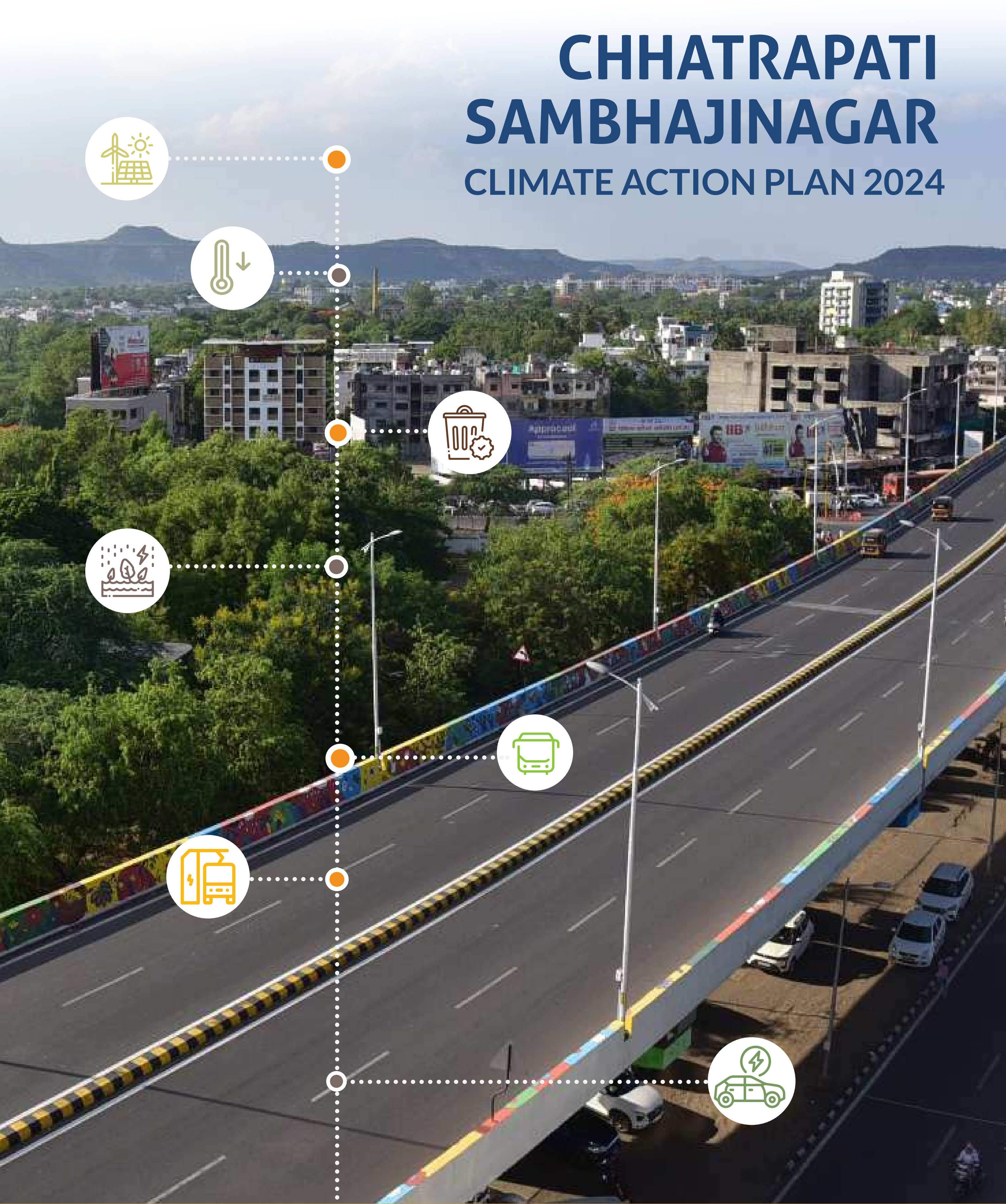
Government of Maharashtra
Environment and Climate Change Department

CHHATRAPATI SAMBHAJINAGAR

CLIMATE ACTION PLAN 2024



Prepared and compiled by WRI India

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ABBREVIATIONS

2W	Two-wheeler Vehicle
4W	Four-wheeler Vehicle
CSMC	Assistant Municipal Commissioner
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ASCDCL	Aurangabad Smart City Development Corporation
BAU	Business as Usual
C&D	Construction and Demolition
CAAQMS	Continuous Ambient Air Quality Monitoring System
CAP	Climate Action Plan
CBO	Community Based Organisation
CDP	City Development Plan
CEAI	Central Electricity Authority of India
CIDCO	City and Industrial Development Corporation
CGWB	Central Ground Water Board
CIRIS	City Inventory Reporting and Information System
CMP	Comprehensive Mobility Plan
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CPCB	Central Pollution Control Board
CREDAI	Confederation of Real Estate Developers' Associations of India
CSIR	Council of Scientific & Industrial Research
CSMC	Chhatrapati Sambhajinagar Municipal Corporation
CSCAF	Climate Smart Cities Assessment Framework
CSO	Civil Society Organization
CSR	Corporate Social Responsibility
CTTP	Comprehensive Traffic and Transportation Plan
CURB	Climate Action for Urban Sustainability
DCR	Development Control Regulations
DISCOM	Distribution Companies
DMC	Deputy Municipal Commissioner
DMIC	Delhi-Mumbai Industrial Corridor
DP	Development Plan
E&P	Existing and Planned
ECBC	Energy Conservation Building Code
EREs	Extreme Rainfall Events
ESR	Environmental Status Report
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GOI	Government of India
GPC	Global Protocol for Communities
GPS	Global Positioning System

GSDA	Groundwater Surveys and Development Agency
GSM	Global System for Mobile Communication
GW	Groundwater
GWRP	Groundwater Recharge Potential
ha	Hectare
HH	Households
HT	High Tension
IAS	Indian Administrative Services
ICLEI	International Council for Local Environmental Initiatives.
ICT	Information and Communications Technology
IEC	Information, Education and Communication
IGBC	Indian Green Building Council
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public Transport
ISWM	Integrated Solid Waste Management
km	Kilometre
kmph	Kilometre Per Hour
KPI	Key Performance Indicators
KW	Kilowatt
LBSAP	Local Biodiversity Strategy and Action Plan
LPG	Liquefied Petroleum Gas
LST	Land Surface Temperature
LT	Low Tension
MAHAGENCO	Maharashtra State Electricity Distribution Company Ltd.
MASSIA	Marathwada Association of Small Scale Industries & Agriculture
MC	Municipal Commissioner
MEDA	Maharashtra Energy Development Agency
MER	Monitoring, Evaluation, Reporting
MIDC	Maharashtra Industrial Development Corporation
MJP	Maharashtra Jivan Pradhikaran
MLD	Million Litres Per Day
MNGL	Maharashtra Natural Gas Limited
MODIS	Moderate Resolution Imaging Spectroradiometer
MoHUA	Ministry of Housing and Urban Affairs
MPCB	Maharashtra Pollution Control Board
MRF	Materials Recovery Facility
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSW	Municipal Solid Waste
MVA	Majhi Vasundhara Abhiyan
MW	Megawatt
MWh	Megawatt hour
NAAQ	National Ambient Air Quality
NAPCC	National Action Plan for Climate Change
NBS	Nature-based Solutions
NCAP	National Clean Air Programme
NCEI	National Centers for Environmental Information
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index

NGO	Non-governmental Organization
NMT	Non-motorized Transport
NOx	Nitrogen Oxides
NOAA	National Oceanic and Atmospheric Administration
PM	Particulate Matter
PNG	Piped Natural Gas
PPP	Public-Private Partnership
PV	Photovoltaic
RCP	Representative Concentration Pathways
RDF	Refuse-derived Fuel
RE	Renewable Energy
RSPM	Respirable Suspended Particulate Matter
RTO	Regional Transport Office
RWH	Rainwater Harvesting
SCADA	Supervisory Control and Data Acquisition System
SC/ST	Scheduled Castes/Scheduled Tribes
SDG	Sustainable Development Goals
SLCPs	Short-lived climate pollutants
SO_2	Sulphur Dioxide
SPM	Suspended Particulate Matter
STP	Sewage Treatment Plant
SWH	Solar Water Heaters
SWM	Solid Waste Management
TPD	Tonnes Per Day
UHI	Urban Heat Island
UNDP	United Nations Development Programme
URDPFI	Urban and Regional Development Plans Formulation and Implementation
UNICEF	United Nations Children's Fund
W2E	Waste to Energy
WAYU	Wind Augmentation and Purifying Units
WRI	World Resources Institute

Photo credit: ASCDCL

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 Chhatrapati Sambhajinagar is leading the way forward in tackling the climate crisis by adopting the Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar Municipal Corporation.

I personally congratulate the Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar city is actively contributing to the effort of tackling the climate crisis by adopting its own Chhatrapati Sambhajinagar 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.

Chhatrapati Sambhajinagar has a unique opportunity to shape its future urban development while considering the impact of climate change. The newly created Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar CAP mark 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 Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar 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 oururban communities and realize the dream of a 'Climate-Forward Maharashtra'.

PLEDGE

SHRI. G SREEKANTH (IAS)

Municipal Commissioner and Administrator, Chhatrapati Sambhajinagar Municipal Corporation

It is with great pride and gratitude that I introduce a remarkable achievement in our ongoing journey towards sustainability – the Chhatrapati Sambhajinagar Climate Action Plan (CAP), representing the dedicated efforts of the Chhatrapati Sambhajinagar Municipal Corporation (CSMC). This milestone is a testament to the unwavering support of the Government of Maharashtra's Department of Environment and Climate Change and the steadfast commitment of Chhatrapati Sambhajinagar's residents.

I sincerely congratulate the Deputy Municipal Commissioner (Solid Waste and Environment), the City Engineer, and all departments of CSMC and ASCDCL involved for their tireless contributions to shaping the Chhatrapati Sambhajinagar CAP. We would also like to thank our knowledge partners, the World Resources Institute (WRI) India, for preparing the CAP.

Chhatrapati Sambhajinagar has confronted severe climate risks, including urban heat, groundwater depletion and waterlogging in recent years. The Chhatrapati Sambhajinagar CAP provides tailor-made solutions meticulously designed to address the city's climate vulnerabilities, with a strong focus on adaptation and mitigation across six urban sectors.

It is crucial to emphasise that this plan has been formulated with extensive stakeholder consultations across CSMC's departments and other agencies. Our approach is grounded in rigorous scientific analysis, tuned to the specific challenges faced by the citizens of Chhatrapati Sambhajinagar.

The overarching goal of the Chhatrapati Sambhajinagar CAP is to guide our city towards a net-zero future, embracing an inclusive approach to urban development centred on low-carbon initiatives. The various departments of CSMC and other parastatal agencies play a crucial role in owning many of these proposed actions. Citizens, businesses, and other stakeholders are also critical in implementing the CAP.

I urge all residents, businesses, government agencies and civil societies of Chhatrapati Sambhajinagar to support CSMC in implementing the Chhatrapati Sambhajinagar CAP effectively in a timely manner.

MESSAGE

SHRI. MADHAV PAI

CEO, WRI India

Tier II cities are crucial to India's growth, and the Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar Municipal Corporation's team in shaping the city's first ever 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 Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar into becoming a more resilient city that fosters innovative thinking and sustainable practices.

KHAM RIVER RESTORATION SITE
Photo credit: ASCDCL

ACKNOWLEDGEMENTS

The Chhatrapati Sambhajinagar Climate Action Plan (CAP) was developed under the leadership and direction of Department of Environment and Climate Change, Government of Maharashtra, Chhatrapati Sambhajinagar Municipal Corporation (CSMC), and Aurangabad Smart City Development Corporation Ltd. (ASCDCL).

We extend our heartfelt gratitude to certain individuals for their invaluable support and remarkable contributions to the Chhatrapati Sambhajinagar CAP. Their names are listed here:

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All maps in this report are intended as visualisations to communicate citywide data analysis for information purposes only and are not to scale.

This report should be referred to as the ‘Chhatrapati Sambhajinagar Climate Action Plan, 2024.’

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SECTION - I
Climate Action Planning Process

Photo credit: WRI India

1. CLIMATE ACTION PLANNING- APPROACH AND METHODOLOGY

1.1 BACKGROUND

India accounts for nearly 6.5% of the global greenhouse gas (GHGs) emissions, 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 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, India has committed to addressing climate change impacts by implementing national-level policies at the local level. Through large urbanisation infrastructure investment programmes led by the Ministry of Housing and Urban Affairs (MoHUA), many sub-missions and programmes have been financed to make cities sustainable through low-carbon development strategies.

In India, metro cities or large cities have begun focussing on the causes and impacts of climate change using the lens of adaptation and mitigation strategies. However, Tier II Indian cities that have a million-plus population continue to not have capacity and capability to understand and focus on climate-related risks. Therefore, the Government of Maharashtra and Children's Investment Fund Foundation (CIFF) have shortlisted three Tier II cities (project cities) in Maharashtra, namely Solapur, Nashik, and Chhatrapati Sambhajinagar (formerly known as Aurangabad) to develop three Climate Action Plans (CAPs), one for each city.

World Resources Institute (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 Chhatrapati Sambhajinagar 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 Green House Gas (GHG) emissions that face 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 a need for informed climate action planning that would integrate climate science with mitigation and adaptation strategies within development strategies.

The Climate Action Plan 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 aligns with the Climate Smart Cities Assessment Framework (CSCAF) through the six sectors that are common between in the two frameworks. While the CSCAF framework is a first step towards cities mainstreaming climate-centric measures, the CAP further strengthens it through a more comprehensive process of localising the measures.

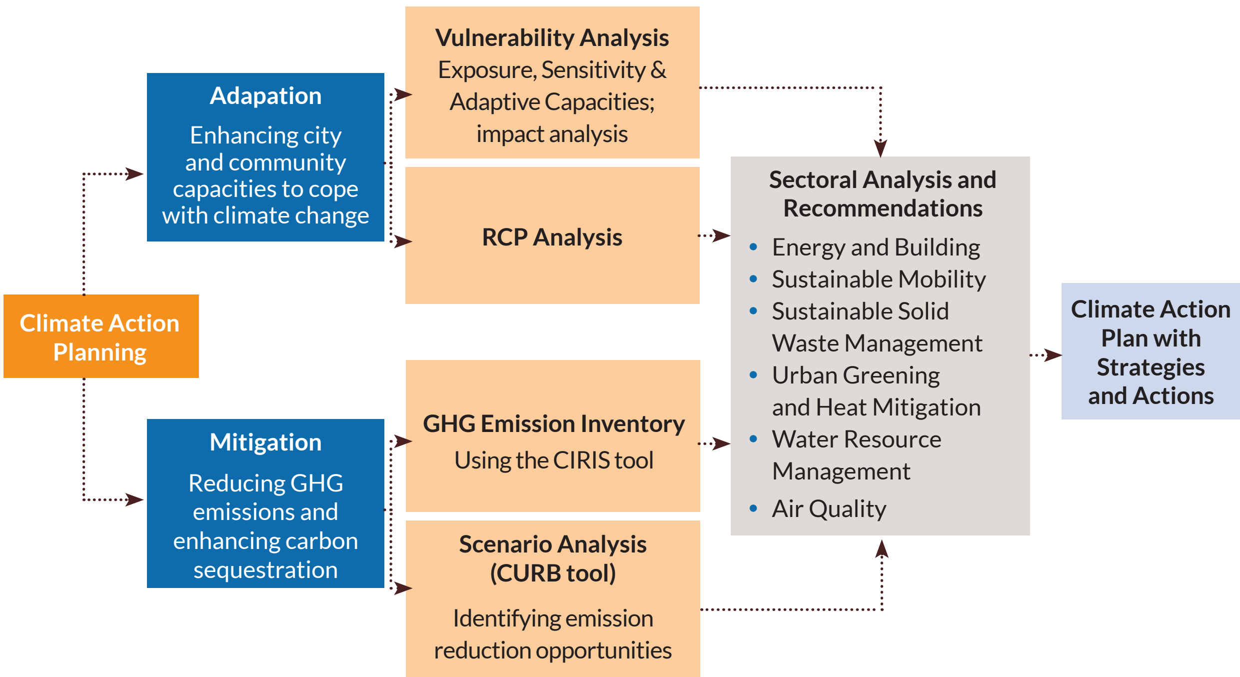
The CAP focuses on two key strategies:

Adaptation is the first strategy that focuses on the impacts of climate change and sectoral sub-strategies and actions to enhance the capacity of the city and community to cope with climate change, and

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

These climate action planning strategies are powerful tools for monitoring progress towards climate goal as these allows cities to formulate evidence-based adaptation and mitigation actions and goals. Refer to Figure 1-1.

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



Source: WRI India analysis

1.3 DEVELOPMENT OF CAP - APPROACH AND METHODOLOGY

1.3.1 CAP process in Chhatrapati Sambhajinagar

The preparation of the Chhatrapati Sambhajinagar Climate Action Plan commenced by signing the Letter of Intent (LoI) with the Chhatrapati Sambhajinagar Municipal Corporation (CSMC) on December 22, 2021. The LoI was signed by the Hon'ble Commissioner, CSMC. Following this, an inclusive and consultative five-step process was undertaken by WRI India to develop the CAP, as detailed in the 12 steps below:

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

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

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

4 Developing Climate Profile
Conducting Vulnerability Assessment (VA) and developing greenhouse gas (GHG) emissions inventory, identifying climate risks, identifying sectors

5 Stakeholder consultations
Conducting a capacity building workshop on VA and GHG emissions inventory

6 Scenario Analysis and RCP Analysis
Carrying out Future Scenario and Representative Concentration Pathways (RCP) analyses

7 Stakeholder Consultations
Validating various assumptions under the Scenario analysis

8 Sectoral analysis
Conducting a review of sectoral goals, strategies and actions by WRI India's sectoral experts

9 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 Chhatrapati Sambhajinagar Climate Action Plan

10 Stakeholder consultations
Receiving feedback on draft Chhatrapati Sambhajinagar CAP presentation

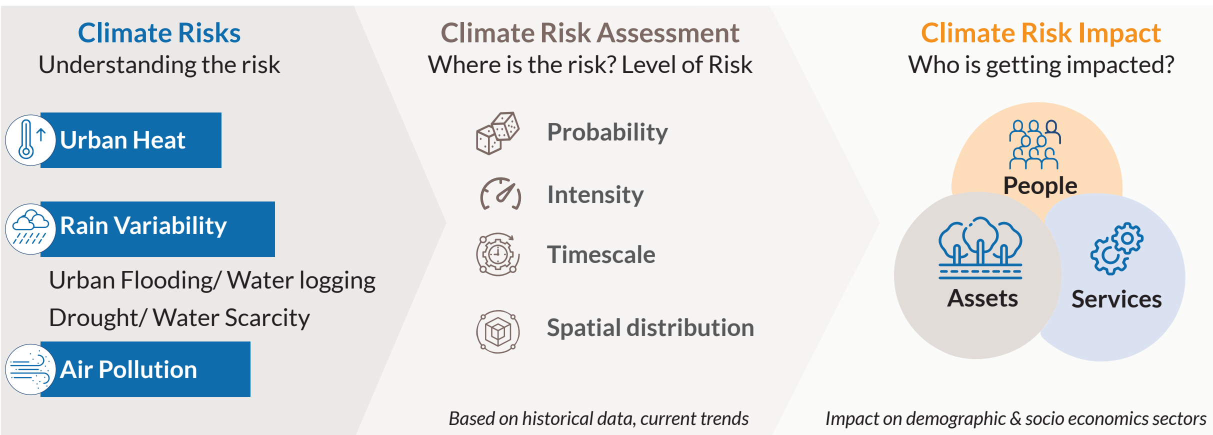
11 Finalisation of the CAP
Finalisation of CAP by addressing all comments

12 Launch of the CAP
Launch of the Chhatrapati Sambhajinagar CAP

1.3.2 Vulnerability Assessment framework

WRI India's Vulnerability Assessment framework is based on the IPCC's 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 from city authorities to highlight differential vulnerabilities and adaptation needs in the city Refer to Figure 1-2.

Figure 1-2: Vulnerability Assessment Framework

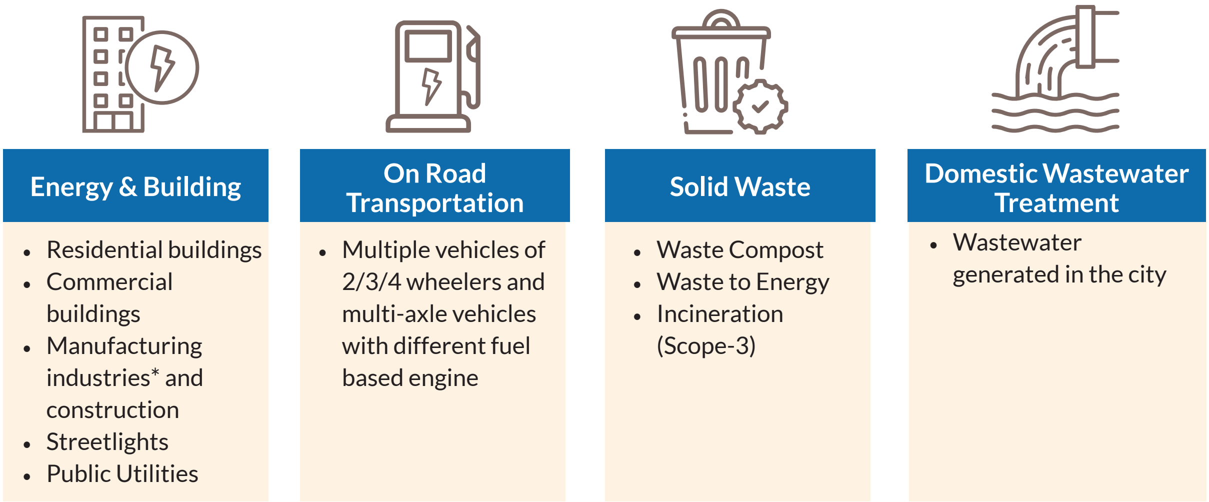


Source: WRI India analysis

1.3.3 GHG emissions inventory and scenario analysis - Framework

The GHG emissions inventory for Chhatrapati Sambhajinagar 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 (ICLEI). It includes an analysis of three sectors — stationary energy, transport, and waste (municipal solid waste and wastewater) as seen in Figure 1-3. The GHG inventory of Chhatrapati Sambhajinagar city helps identify opportunities for emissions reduction.

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



Source: CIRIS tool

The Scenario Analysis will be in line with low carbon action pathways, and three scenarios will be developed:

1. Business as Usual
2. Existing and planned scenario
3. Ambitious climate action scenario

The scenario analysis will be heavily guided by the data collection and consultation activities with sectoral experts.

1.3.4 Key stakeholders

CSMC 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 Chhatrapati Sambhajinagar city.

Table 1-1: Key agencies and their roles

S.N.	Name of agency	Role/ sector
1	Chhatrapati Sambhajinagar Municipal Corporation (CSMC)	City administration managing - water supply, sanitation, solid waste management, roads and bridges, development plan, streetlights, etc.
2	Aurangabad Smart City Development Corporation Ltd. (ASCDCL)	Smart city SPV managing projects related to area based development and pan city.
3	Regional Transport Office (RTO)	Vehicle Registration
4	Oil companies	Sale of petrol, diesel and CNG
5	MSEDCL	Electricity distribution and supply
6	MAHAGENCO	Electricity generation
7	GSDA	District ground water management
8	Traffic police	Traffic management
9	Indian Meteorological Department IMD	Rainfall and temperature data
10	MPCB	Control and regulation - Air, water, and land pollution
11	Forest Department	Social forestry programme and greening measures
12	Disaster Management Authority	Preparation and response during disasters

1.3.5 Aligning with global, national, and sub-national planning goals

The Chhatrapati Sambhajinagar CAP is aligned with the UN's Sustainable Development Goals and India's NDCs. To leverage policy and financial support, the CAP considers key elements from various national and subnational schemes and missions. Refer to 1-4.

- The six sectors of the Chhatrapati Sambhajinagar CAP line up with the five sectors of the Climate Smart Cities Assessment Framework 2.0, developed by Climate Centre for Cities and NIUA, supporting MoHUA's Smart Cities Mission.
- Chhatrapati Sambhajinagar CAP has established linkages with the Swachh Bharat Mission (Urban).
- Being a non-attainment city, the National Clean Air Program (NCAP) is implemented in Chhatrapati Sambhajinagar.
- Funding for air pollution and waste management is available under the Fifteenth Finance Commission, Government of India (GoI).
- At the sub-national level, the planning goals for the Chhatrapati Sambhajinagar CAP are aligned with the Government of Maharashtra's Majhi Vasundhara Abhiyan (MVA), which is a climate action policy approach where urban local bodies champion local climate actions on the five elements of nature or the *Panchamahabhutas*: Earth (Bhumi), Air (Vayu), Water (Jala), Energy (Agni), and Enhancement (Akash). CSMC has received the the Best Amrut City in Aurangabad Division award

under MVA 2.0 in 2022 and ranked 4th in the state of Maharashtra.

- 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. Chhatrapati Sambhajinagar city is a signatory in this campaign, and the Chhatrapati Sambhajinagar CAP provides a robust roadmap to achieve this goal within the targeted timeframe.
- At the city level, the Chhatrapati Sambhajinagar CAP is in alignment with Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and Smart City Mission, which focus on infrastructure development for urban revival projects.

Figure 1-4: National and Sub-national Schemes and Mission in India

National Level	स्वच्छ भारत एक कदम स्वच्छता की ओर	NCAP NATIONAL CLEAN AIR PROGRAMME	NIUA C3 Climate Centre for Cities	NAMAMI GANGE	XV FINANCE COMMISION FUNDING
Sub-national Level	माझी वसुंधरा				
City wide initiative	अमृत Atal Mission for Rejuvenation	Smart City	RACE TO ZERO	RACE TO RESILIENCE	
Common indicators across all the above initiatives	Energy and Green Buildings	Urban Planning, Green Cover & Biodiversity	Mobility and Air Quality	Water Resource Management	Waste Management

1.4 CONSULTATIONS AND WORKSHOPS

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

Table 1-2: List of meetings

Date	Purpose	Key agencies/stakeholder consulted
21 December 2021	Launch and signing of 'Letter of Intent' with CSMC	Commissioner, officials from CSMC and ASCDCL, WRI India
16 Feb 2022	2nd Kick off meeting	Commissioner, Additional Municipal Commissioner, Deputy Municipal Commissioner (DMC)- Environment and Solid Waste, PHE, City Engineer, Fuel agency, Gardens Department Health Department, Zonal representatives, Fire Department, Water supply Department, MSEDCL, DDMA, IMD, RTO, Officials from Smart Bus Division, ASCDCL, and Civil Society Organizations working with CSMC.

Date	Purpose	Key agencies/stakeholder consulted
30 May 2022	Consultative meeting with Government stakeholders apprising them of CAP process and heat hotspot and water logging hotspot mapping	DMC- Environment and Solid Waste, PHE, City Engineer, Fuel agency, Gardens Department Health Department, Zonal representatives, Fire Department, Water supply Department, MSEDCL, DDMA, IMD, RTO, Officials from Smart Bus Division, and Civil Society Organizations working with CSMC.
29 May -3 June 2022	Data Collection and Stakeholders meeting	DMC- Environment and Solid Waste, Mechanical Department, Town Planning Department, DP unit, Officials from Smart Bus Division, GIS teams of ASCDCL.
4th August 2022	Capacity Building Workshop on Vulnerability Assessment and GHG Emissions Inventory	Around 20+ officials from 11 key departments and parastatal agencies such as Town Planning, DP Unit, Gardens, Fire, and a few stakeholders representing independent agencies such as IOCL, IGBC were in attendance.
23 August 2023	Stakeholder Consultation and workshop on presentation of the draft Climate Action Plan of Chhatrapati Sambhajinagar city	Around 15+ participants from CSMC, ASCDCL, MSEDCL, IGBC, sectoral experts attended the meeting which discussed the draft CAP in detai l. The workshop was presided over by Hon'ble Commissioner CSMC.

Figure 1-5: Glimpses from the Capacity building workshop

Source: *WRI India*

Near Rangeen Gate

2. CHHATRAPATI SAMBHAJINAGAR CITY PROFILE

2.1 BACKGROUND

2.1.1 Regional setting

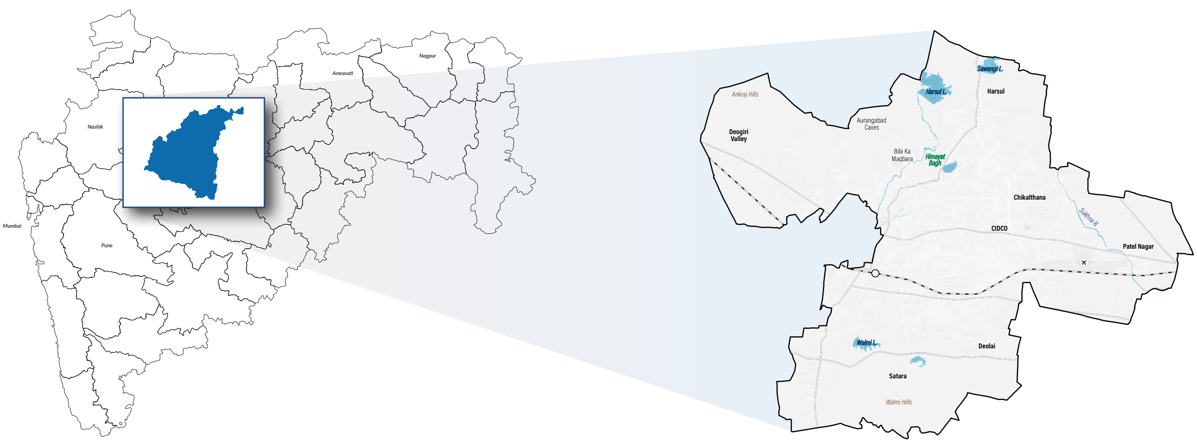
The city of Chhatrapati Sambhajinagar is a part of the Chhatrapati Sambhajinagar district in the Marathwada region of Maharashtra. The Marathwada region is made of eight districts, namely Jalna, Chhatrapati Sambhajinagar, Parbhani, Hingoli, Nanded, Latur, Osmanabad and Beed and covers a geographical area of 64434 km^2. It accounts for about 30% of the state's area. The urban population of Marathwada region was 5,072,074 in 2011, with Chhatrapati Sambhajinagar city comprising 23% with a population of 11,88,059[3].

2.1.2 History

The city of Chhatrapati Sambhajinagar was founded by Malik Ambar in 1610 and named Khadki. In 1653, it was conquered by Aurangzeb[4] and renamed as Aurangabad. Built as his military base, Aurangzeb built many fortifications and gates, with 52 gates present across the city. Hence, it is famously known as the City of Gates.

Chhatrapati Sambhajinagar has a booming tourism industry and is termed as the 'tourism capital of Maharashtra'. The city is renowned for the UNESCO World Heritage sites of Ajanta and Ellora caves. Its other historical attractions include Bibi ka Maqbara, which is the burial ground for Emperor Aurangzeb's wife, a 17th century water mill named the Panchakki, the Salim Ali Lake and bird sanctuary, and the intricate Daulatabad Fort that was named the 'Best Fort in India' by the British. The city is also home to the famous Himroo handlooms products.

Figure 2-1: Location map of Chhatrapati Sambhajinagar in a regional setting



Source: WRI India analysis; CSMC; https://en.wikipedia.org/wiki/File:Maharashtra_Divisions_Eng.svg

2.1.3 Location and connectivity

Chhatrapati Sambhajinagar city is well connected with all the major cities of India by road, rail, and air. The city is located on Hyderabad-Manmad and Pune-Aurangabad-Manmad rail routes, which are broad gauge lines. There are two direct trains daily, to and from Mumbai. There are 45 trains passing through the city, which include Express as well as Passenger trains (ESR, 2022). The nearest domestic airport is the Chhatrapati Sambhajinagar Airport at Chikhalthana, about 10 kms away from the city on Jalna road. The city is therefore, well connected with the state capital, the national capital, and all major towns (Draft DP, 2013).

2.1.4 Geography

The city of Chhatrapati Sambhajinagar is situated at 19°53'59" north latitude and 75°22'46" east longitude and an altitude of 581.4m above mean sea level. chhatrapati Sambhajinagar is the administrative headquarters of the Aurangabad Division.

2.1.5 City Economy

Chhatrapati Sambhajinagar is well-connected to several metros in India, including Delhi, Mumbai, Hyderabad and Pune, by air and railways. The development of the city can be attributed mainly to the industrial development by Maharashtra Industrial Development Corporation (MIDC). There are a total of 4 MIDC areas in and around Chhatrapati Sambhajinagar city. MIDC Chikhalthana and MIDC Railway station lie inside the CSMC limits, while MIDC Waluj and MIDC Shendra are 12 kms and 15 kms from the city, respectively. Key industries in the city include pharmaceuticals, breweries, seed companies, textiles, automotive, and auto component manufacturing. Waluj also hosts the recombinant insulin manufacturing plant of Wockhardt.

The city also hosts an auto cluster called the Marathwada Auto Cluster (MAC), a common infrastructure facility at Waluj Industrial Area, instituted by the Chamber of Marathwada Industries and Agriculture (CMIA), Chhatrapati Sambhajinagar. There is also a well-planned Aurangabad Industrial City (AURIC) here, which is a part of the Delhi-Mumbai Industrial Corridor (DMIC). It is developed over 10,000 acres of land in Shendra and is home to the manufacturing units of key companies such as Lupin, Ajanta Pharma, Johnson and Johnson and automobile companies namely Skoda and Bajaj Auto. Other major companies such as Siemens, Liebherr, Perkins, and Crompton Greaves are also located in the region (The Week, 2019).

According to Census of India 2011, the percentage of male and female workers to total workers is 79.75% and 20.25%, respectively. The labour participation ratio of the municipal corporation limit is 32.15% (Draft DP, 2013). The percentage of workers in cultivators, agriculture labours, household industries, manufacturing processing servicing and repairs & others total main workers are 1.38%, 1.66%, 2.32%, and 85.32%, respectively. The industrial growth of the city has a positive impact on the economy of Chhatrapati Sambhajinagar.

A new industrial corridor named Shendra Bidkin Industrial Area (SBIA) connects the existing MIDC at Shendra with Bidkin town. This project is undertaken by Aurangabad Industrial Township Ltd (AITL), an SPV DMIC and MIDC, and is spread across 84.17 sq km. It is located in Shendra that is 17 km from Chhatrapati Sambhajinagar and has created employment opportunities in Chhatrapati Sambhajinagar.

2.2 TOPOGRAPHY

Geographically, Chhatrapati Sambhajinagar is strategically located on the Deccan Plateau in the Dudhana valley, between the Lakenvara range to the North and the Satara range to the South, surrounded by the hills of the Vindhya ranges. The city is situated on the banks of the rivers Kham and Sukhna., Both rivers are tributaries of the Godavari river and were facing neglect before the city began taking active restoration efforts.

There are three major lakes in the city, namely Salim Ali lake, Harsul lake, and Sawangi lake. The famous 17th-century water mill known as Panchakki is situated at a distance of 1 km from the city. It is known for its underground water channel that traverses more than 8 km to its source away in the mountains and culminates in an artificial waterfall that powers the mill. The city also has 52 gates, adding a unique aspect to the city's topography.

1. Major water bodies

The city has two main sources of drinking water, the Jayakwadi dam (2909 million cubic meter capacity), built in 1976 and situated 50km from the city , and the Harsul tank (6.67 million cubic meter) which was inaugurated in 1956 and is situated 9km from the city. The Jayakwadi dam was built as a source of irrigation and respite for the drought prone region of Marathwada. The other water bodies whose water is used for domestic purposes include the famous Salim Ali Lake situated near Himayat Bagh and the Sawangi lake.

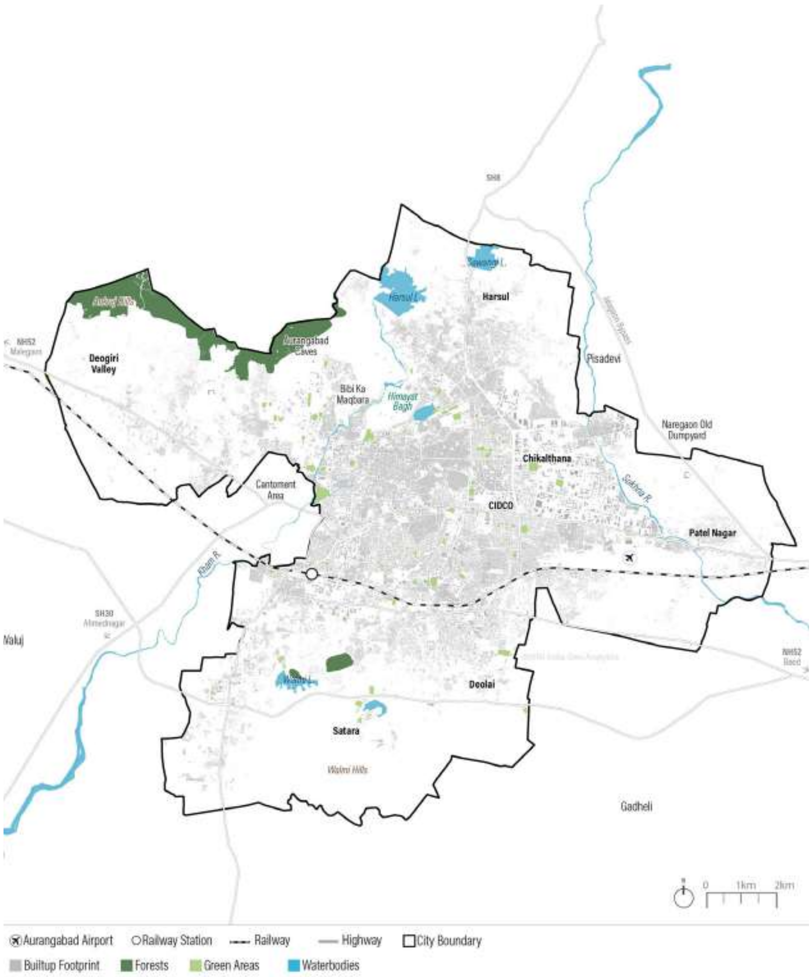
2. Neher system - Chhatrapati Sambhajinagar's 400 year-old aqueduct system

The *neher* water system was a series of subterranean aqueducts built by Malik Ambar that provided water to the people of Chhatrapati Sambhajinagar between 1612 and 1803. These transported water from higher level water sources, such as the hills, through the natural means of the gravitational pull. While there are 14 *neher*s, only three are functional (Neher-e-Ambari, Neher-e-Panchakki and Neher-e-Begumpura). With the advent of the pumping technology and rapid urbanisation, the *neher* system was neglected and can be revived as a sustainable method of water management for the drought prone city of Chhatrapati Sambhajinagar (Khadke & Iyer, 2019).

Figure 2-2: Photos of the Kham restoration

Source: *WRI India*

Figure 2-3: Ecological features of Chhatrapati Sambhajinagar city

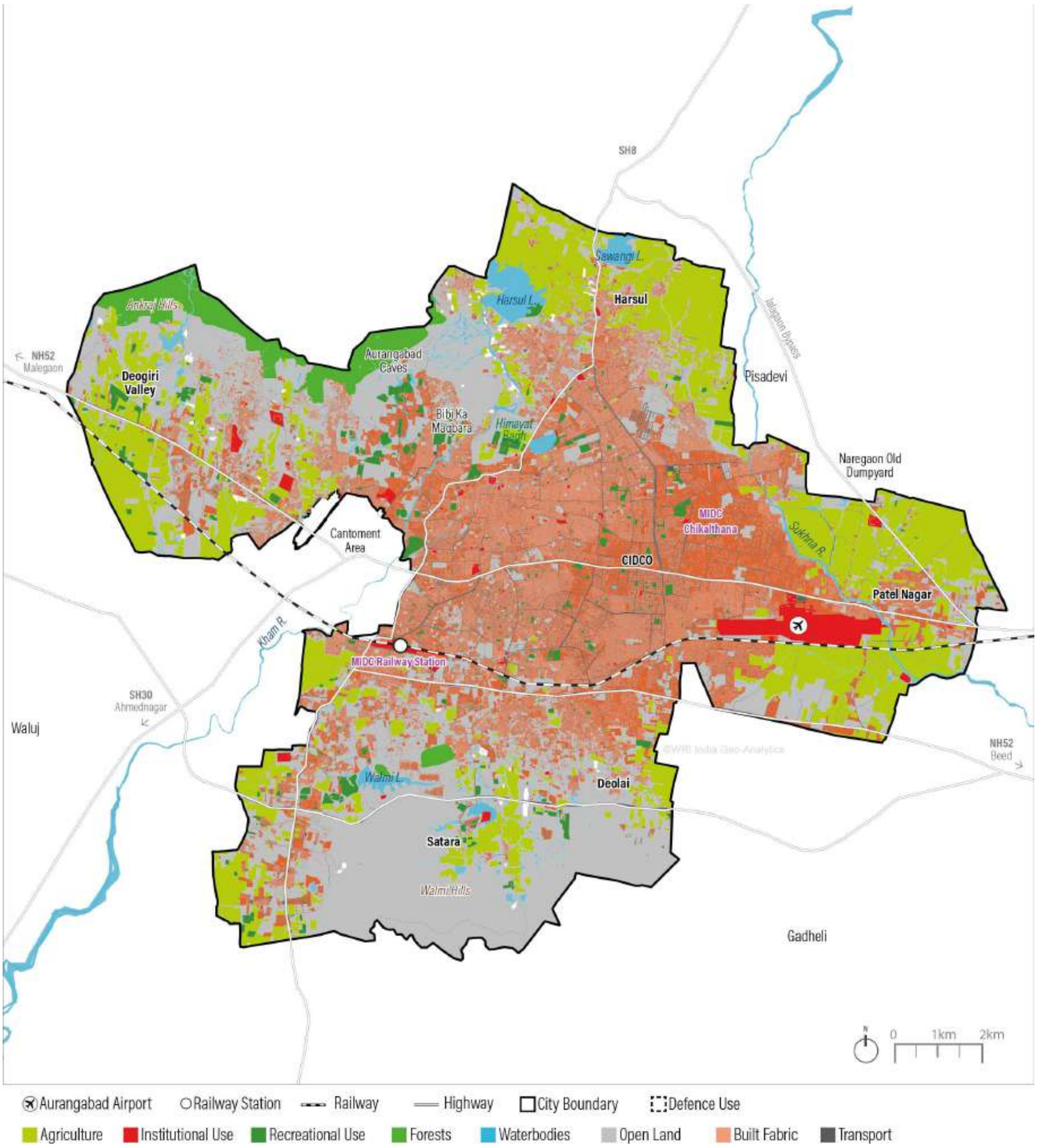


Source: *WRI India analysis, CSMC*

2.3 LAND USE AND DEVELOPMENT

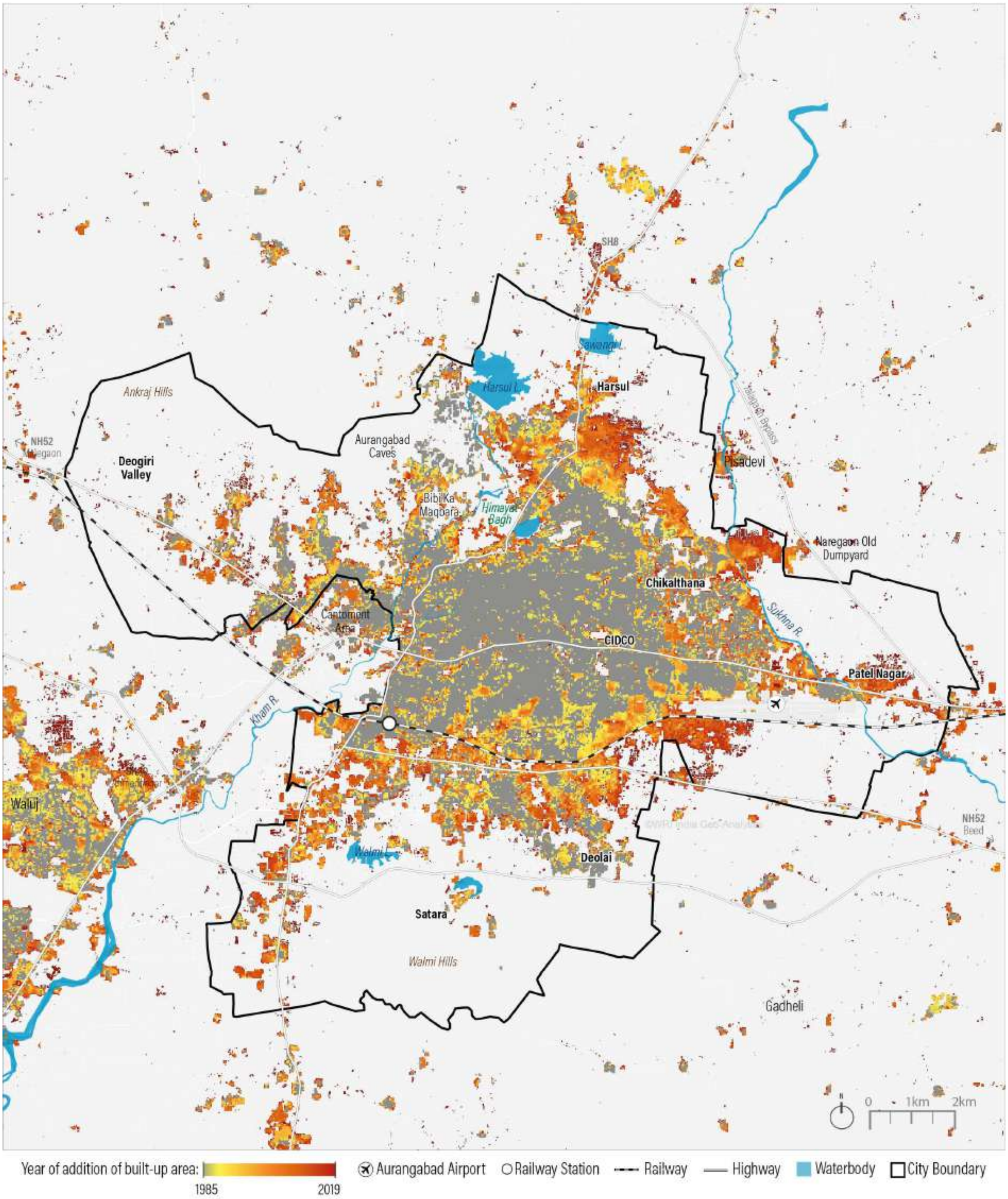
The Aurangabad Municipal Council was formed in 1936. It was categorised as an 'A' class municipal council[5] when the geographical area of the town was 54.40 sq. km. In 1982, the Council was converted into a Municipal Corporation and 18 villages in the vicinity were included. At present, the area of the Municipal Corporation is 138.5 sq. km. Since September 2006, the area planned by CIDCO has been included in the Municipal Limits (ESR, 2022).

Figure 2-4: **Study area: Chhatrapati Sambhajinagar Municipal Corporation Limits, 2022**



Source: WRI India analysis, CSMC 2022

Figure 2-5: Urban growth and expansion of Chhatrapati Sambhajinagar city



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

2.4 DEMOGRAPHY

2.4.1 Demographic growth in Chhatrapati Sambhajinagar city

As per Census of India 2011, the population of Chhatrapati Sambhajinagar, including the population in the outgrowth regions of Satara Tanda and Devlai, is 11,88,059 persons, which means the population density of the city is 6,620 persons/sq.km. Currently, the area of the CSMC is 179.46 sq.km. The city is divided into 9 zones, 99 Census wards (2011), and 115 administration wards, as presented in Figure 2-7.

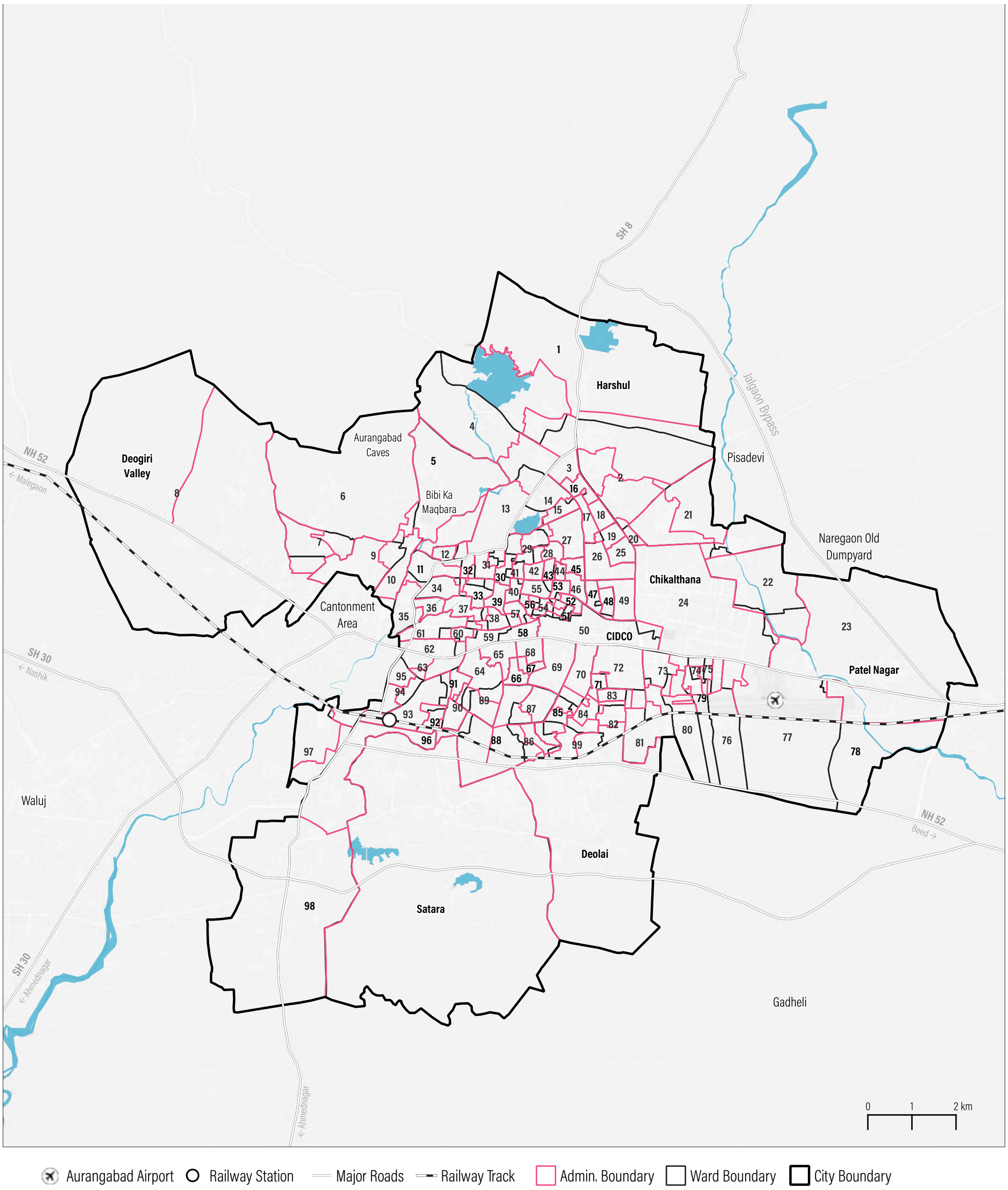
Due to rapid industrialisation and urbanisation, the city emerged has as an educational hub, a commercial centre, and a tourist attraction. Chhatrapati Sambhajinagar is home to diverse economic activities, ranging from industries and services to tourism and education (MPCB, 2020). The growth rate was the highest in 1981, at 8%. This could be due to the industrial development at Waluj, which attracted a significant populace for employment (ESR, 2022).

Table 2-1: Population growth in Chhatrapati Sambhajinagar

Year	Total population	Population growth (%)
1981	2,84,807	--
1991	5,73,272	101
2001	8,80,740	53.63
2011	11,75,116	33.42
2011*	11,88,059*	34.89

*Source: ESR 2022, WRI India Analysis using Census 2011; *Population including the outgrowth region of Satara Tanda and Devlai*

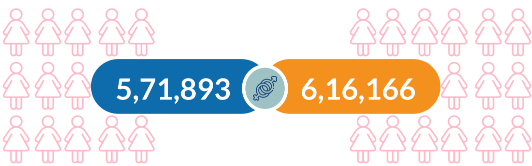
Figure 2-6: Ward boundaries based on Census 2011 and current administrative boundaries of Chhatrapati Sambhajinagar city



Source: WRI India using Census 2011, CSMC 2022

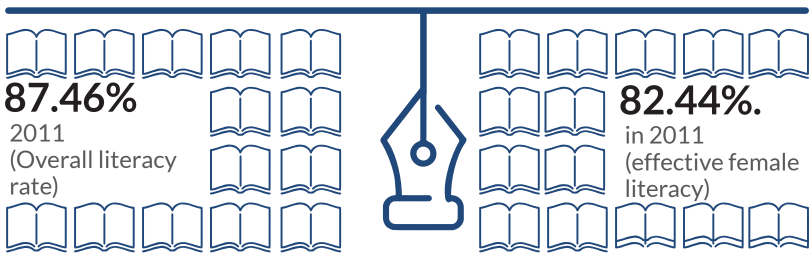
Chhatrapati Sambhajinagar city is also known as the tourism capital of Maharashtra. It attracts tourists all year round. The city has a daily floating population of 5%, which is 70,308 persons daily (SWM DPR, 2019)

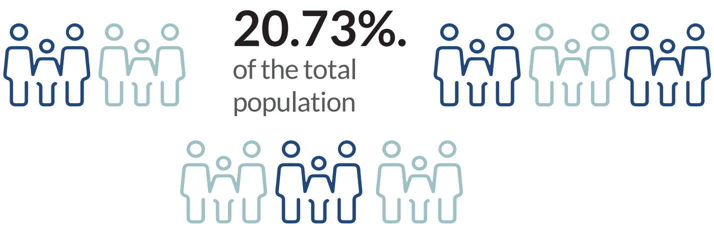
No. of HH and HH Size: As per Census of India 2011, the total number of households is 2,39,233.



Gender Profile: As per Census of India 2011, the population of Chhatrapati Sambhajinagar, including the outgrowth regions of Satara Tanda and Devlai, is 11,88,059. The male population is 6,16,166, and the female population is 5,71,893. The sex ratio, thus, works out to 928 females per 1,000 males

Effective Literacy: Of the total population of 11,88,059 persons, 8,98,430 persons are classed as literates as per Census of India 2011. This means that 87.46% of the total population from the development plan area is literate.





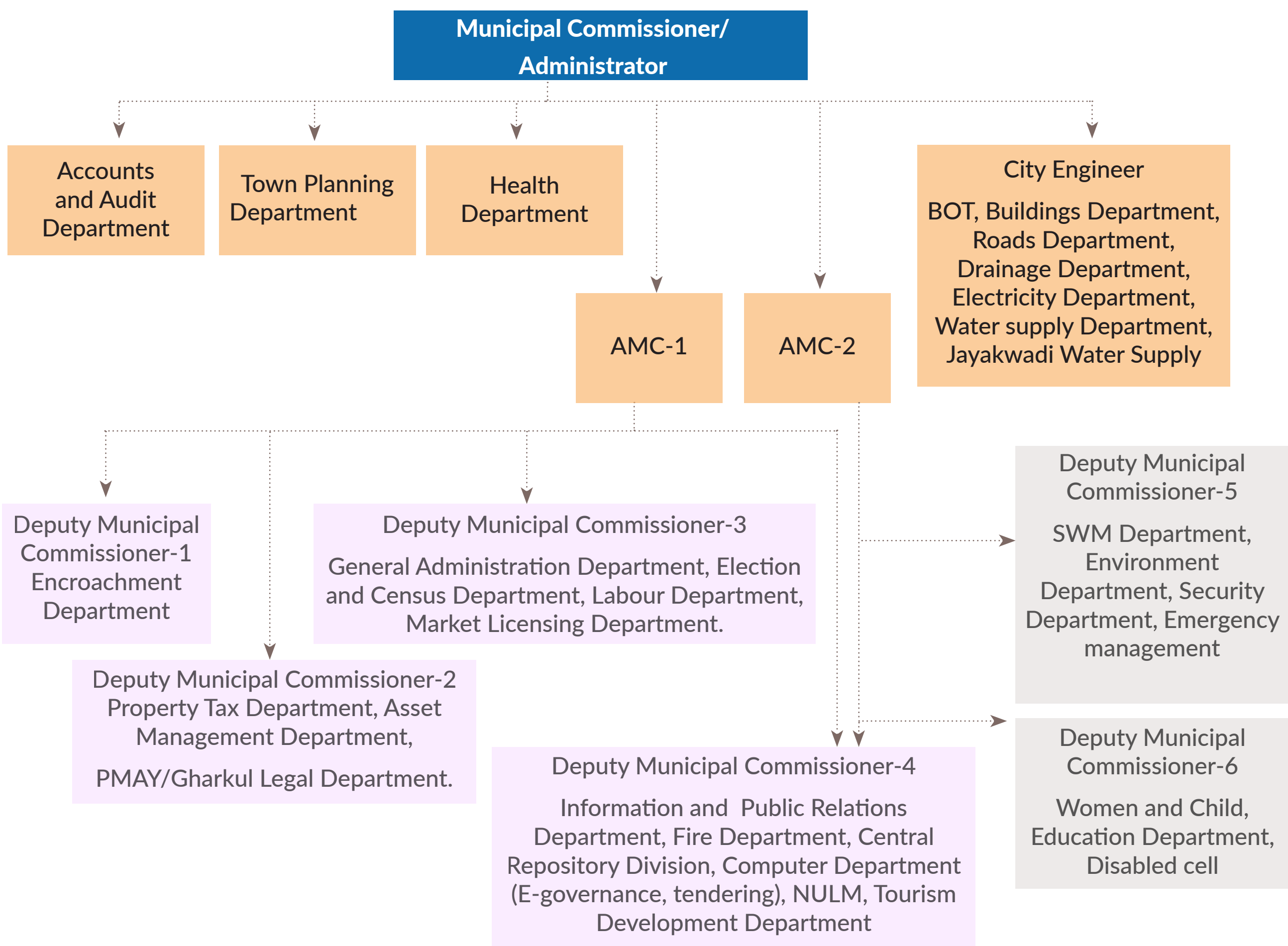
Social Composition Map: The total Scheduled Caste (SC) population is 2,30,660, and the total Scheduled Tribe (ST) population is 15,644. The percentage of social composition is 20.73%. Wards no. 7, 20,75, and 92 are home to more than 56% of SC and ST population.

2.5 CITY MUNICIPAL CORPORATION AND THE AUTHORITIES

CSMC was established in 1936 and became a Municipal Corporation in 1982. Chhatrapati Sambhajinagar city is currently divided into 115 administrative wards (also known as *Prabhags*) and 9 zones for which elections are held every 5 years. According to Census of India 2011, CSMC has comprises 2,39,233 houses to which it provides basic amenities, such as water and sewage. It spans an area of 179.46 sq.km. CSMC is also authorised to build roads within the Municipal Corporation limits and impose taxes on properties coming under its jurisdiction. The administration is headed by the Hon'ble Municipal Commissioner, as represented in Figure 2-8, and has several departments, such as Solid Waste, Water Supply, Town Planning, Gardens, Lights, and Sanitation. These departments plan and provide basic infrastructure and services for the city.

Other PSUs, SPVs and state-level agencies, such as MSEDCL, MPCB, Groundwater Surveys and Development Agency (GSDA), and Aurangabad Municipal Smart City Development Corporation Limited (ASCDCL), provide city-appropriate services.

Figure 2-7: Administrative structure of Chhatrapati Sambhajinagar Municipal Corporation



Source: WRI India analysis, CSMC 2022

3. CLIMATE CONTEXT

3.1 CLIMATE OVERVIEW

3.1.1 Temperature and humidity

Based on an analysis of NCEI data, since 2011, the hourly air temperature in summers (from March to May), has on an average ranged from 22°C to 41°C. It has also recorded hourly temperatures as high as 52.2°C in August 1984. Winters in Chhatrapati Sambhajinagar start in November and end in February, with the air temperature occasionally dropping as low as 7.5°C and rising to 36°C, based on the NCEI data analysed from 1975 to 2021. Moreover, according to the IMD data (1970-2021), on average, July, and August are the months with the maximum relative humidity (78-81%) while March and April have the lowest relative humidity (33-35%).

3.1.2 Rainfall analysis

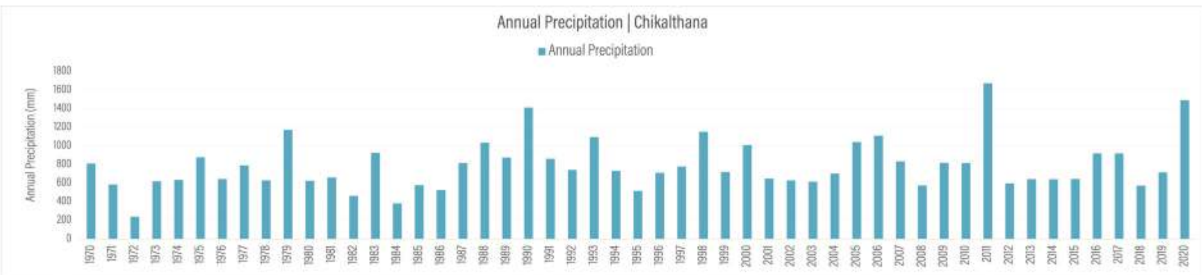
On average, Chhatrapati Sambhajinagar receives around 790 mm rainfall annually. The rainy season lasts for around one-and-a half months (52–72 days in a year). In 2011, the city received a maximum rainfall of 1673 mm, and the driest year with rainfall of 240 mm was 1972.

Rainfall in the months from June to September amounts to about 80% of the annual rainfall, with July being the wettest month for the city, while the remaining 20% of the showers are received during the pre- and post-monsoon months of February-May and October-January.

Chhatrapati Sambhajinagar city depends on Jayakwadi dam for its urban water needs. Chhatrapati Sambhajinagar has a declining ground water level trend of more than 0.2 m/year (CGWB, 2019), increasing water demands, and erratic rainfall.

The annual accumulated rainfall for the city between 1970 and 2020 is presented in Figure 3-1.

Figure 3-1: Annual precipitation at Chikalthana, Chhatrapati Sambhajinagar between 1970 & 2020



Source: WRI India using meteorological data from IMD, 2022

3.1.3 Wind speed and direction

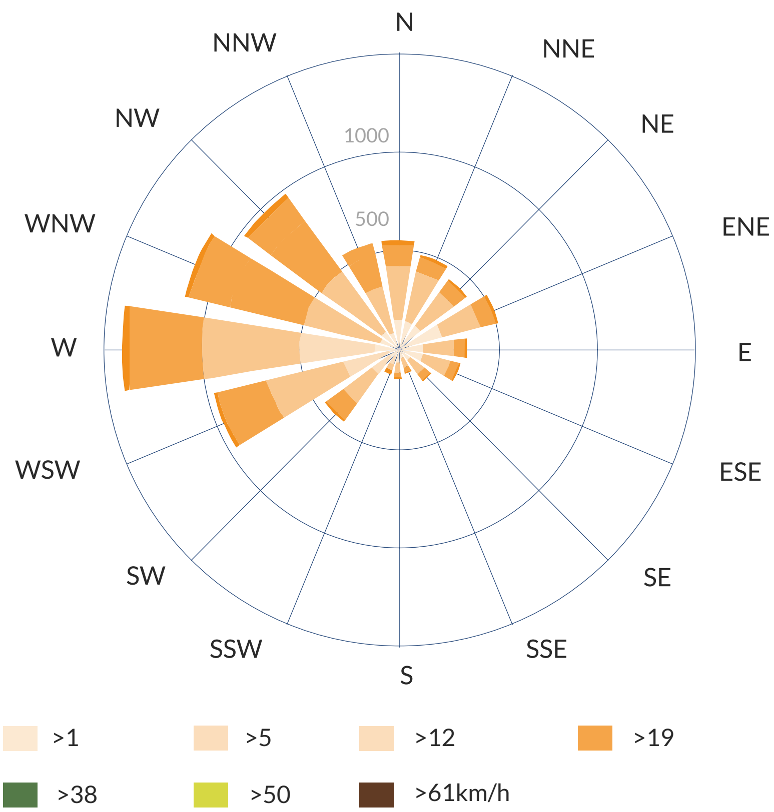
Winds are generally light to moderate, with an increase in speed during the latter half of the summers and in the monsoons. During summers, the winds blow predominantly from direction between west and north and during the monsoon they blow mostly from direction between south-west. During the rest of the year, the winds blow mostly from the direction between north-east and south-east. Table 3-1 shows the direction of wind (Draft DP, 2013).

Table 3-1: Wind speed

Month	Morning	Evening	Wind Speed (KM/hr)
January	E/calm	W/SW	7.4
May	W/NW	W/NW	15.93
August	W/SW	W/NW	16.25
November	E/SE	NE/W	7.4

Source: Draft Development Plan, 2013, CSMC

Figure 3-2: Annual wind rose diagram for Chhatrapati Sambhajinagar City



Source: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/aurangabad_india_1278149

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 different geographical locations of Chhatrapati Sambhajinagar city using monitored weather data from sources, such as the Indian Meteorological Department (IMD), air quality stations, and various departments, and remote sensing techniques.

3.2.2 Key climate risks

The Climate Risk Index 2021[6] ranked India amongst the top 10 countries most affected in 2019, and the absolute losses incurred by India in 2019 from extreme weather events amounted to nearly $69 billion. Nearly 60% of India's land area is prone to earthquakes of moderate to very high intensity; 12% of land is prone to flood and river erosion; 5,700 kilometres of coastline is prone to cyclones and tsunamis; 68% percent of the cultivable land is vulnerable to drought; the hilly areas are at risk of landslides and avalanches; and 15% of the landmass is susceptible to landslides[7].

The IPCC Fifth Assessment Report analyses climatic drivers and estimates the 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, which will result in 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.

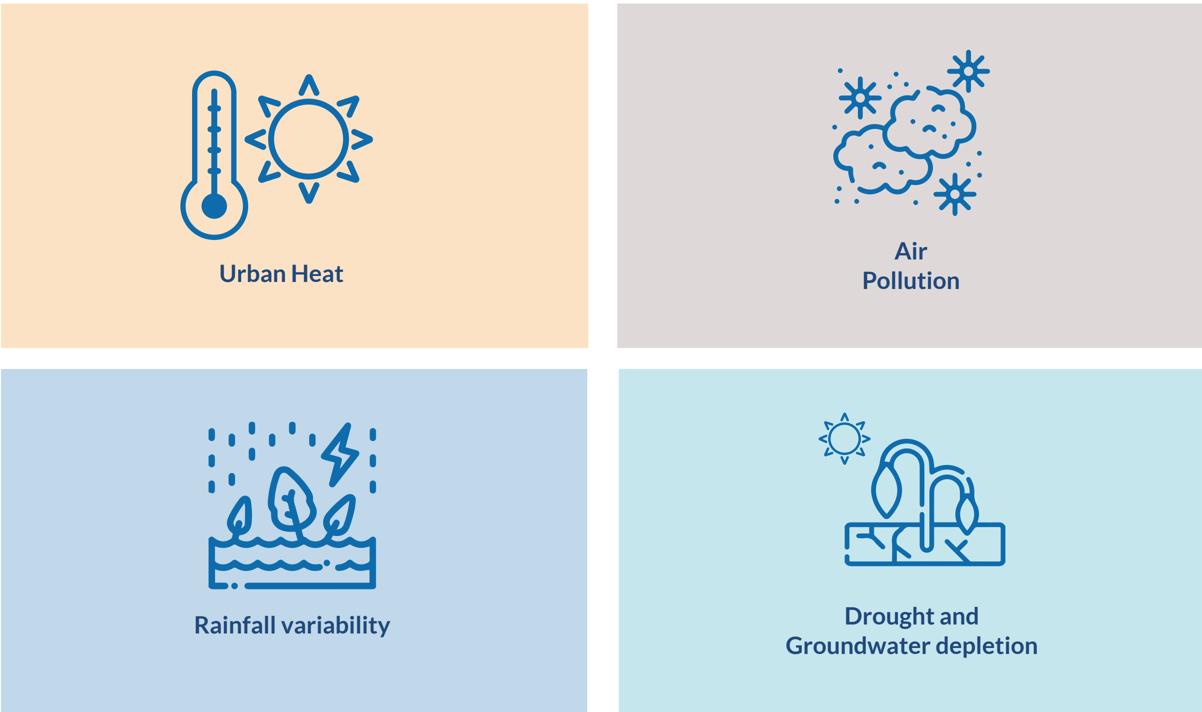
Increased riverine, coastal, and urban flooding is projected, with very low to medium risk in the near term and medium to very high risk in the long term, leading to widespread damage to livelihoods, infrastructure, and increased flood-related deaths and injuries. Asia is also projected to face more frequent and intense heat waves and intensified heat island effects, resulting in very high risk of heat related mortalities in the long term, especially among vulnerable groups such as outdoor workers and informal settlement residents. Consequently, Asia will witness exacerbated poverty, inequalities, and new vulnerabilities with medium to very high risk.

3.2.3 Key climate risks in Chhatrapati Sambhajinagar

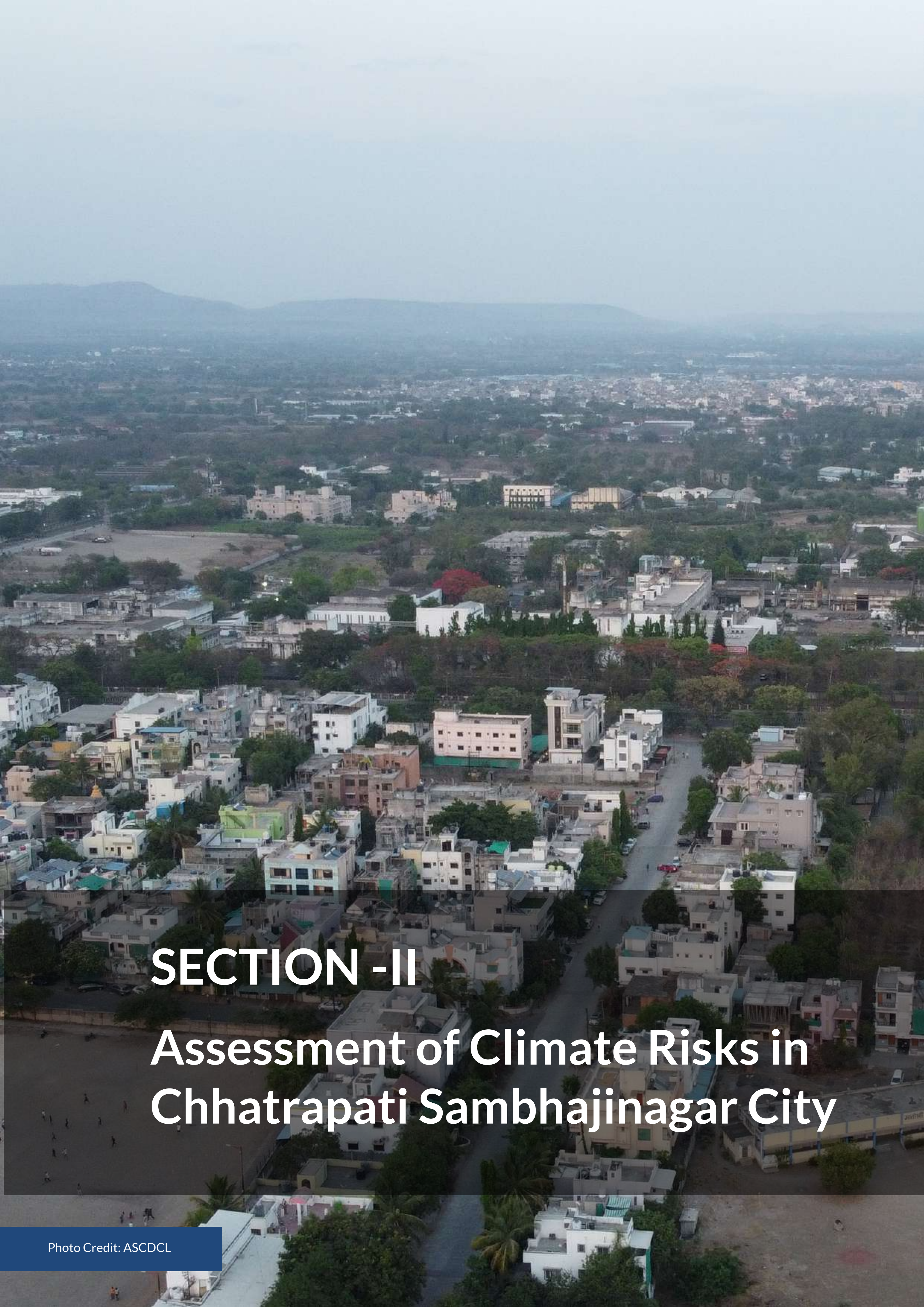
Chhatrapati Sambhajinagar city faces four major climate challenges – groundwater depletion, heat risk, rainfall variability and water stress, and air pollution risk. The increase in waterlogging incidences in the areas around the Kham river are being reported frequently, especially in the monsoons[8]. On the other hand, as 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 the state, the district, and the sub-division rather than city. The district management report defines the following as disasters: floods, droughts, lightening, hailstorms, earthquake, road accidents, rail accidents, fire accidents, crowd disasters, communal violence, and industrial accidents. However, in the context of climate-induced risks that Chhatrapati Sambhajinagar city faces, the current report focuses on drought, heat, air pollution and flooding. Although air pollution is an anthropogenic activity induced hazard, monitoring and reducing critical air pollutants can significantly contribute to minimising short-lived climate pollutants (SLCPs), such as methane, tropospheric ozone, hydrofluorocarbon (HFCs), and black carbon, which cause global warming. These GHG emissions are alive for a short span of time in the atmosphere but are more potent than carbon dioxide and, therefore, can deliver multiple benefits for development and human well-being.

Figure 3-3 : Key Climate Risks in Chhatrapati Sambhajinagar



Source: WRI India Analysis



SECTION -II

Assessment of Climate Risks in Chhatrapati Sambhajinagar City

Photo Credit: ASCDCL

4. URBAN HEAT RISK

4.1 ASSESSMENT

The assessment of urban heat risk analysis has been performed by analysing non-spatial and spatial parameters (Refer to Annexure 1-1) for air temperature and Land Surface Temperature (LST).

- Non-spatial parameters include air temperature using National Centers for Environmental Information (NCEI) data between 1975 and 2021, and night-time LST from Moderate Resolution Imaging Spectroradiometer (MODIS). Annual, seasonal, and monthly trends of these parameters were analysed to demonstrate an overall trend of increasing temperatures.

- The spatial analysis of heat risk uses LST data from Landsat (USGS) that helps identify local areas more exposed to heat stress, also known as Urban Heat Island (UHI) effect. Although air temperature and LST are inter-related, the spatial and temporal differences between them can have varying effects on each other, thereby limiting the current assessment to the analysis of air temperature and LST as two individual aspects of urban heat risk.

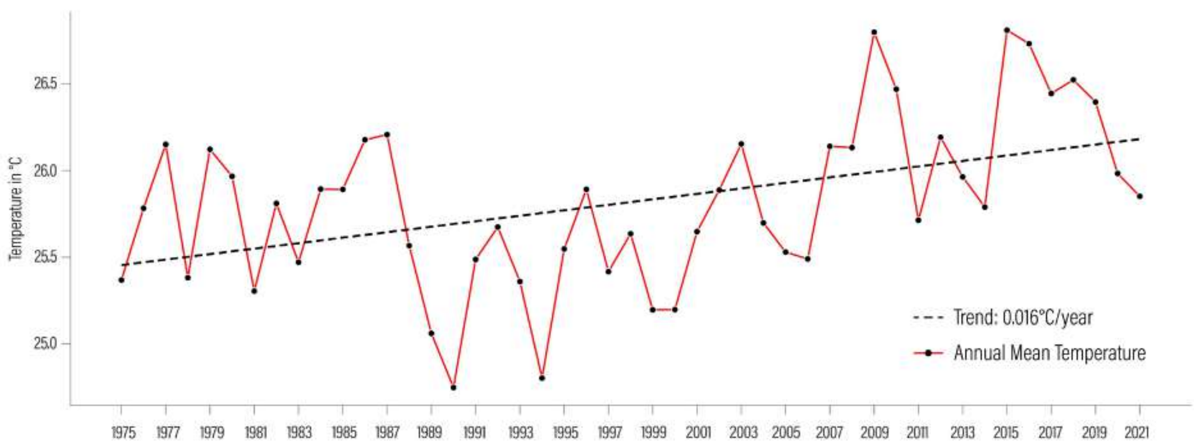
4.2 KEY FINDINGS

4.2.1 Temperature trend analysis

1. Annual Air Temperature Trend

The annual mean temperatures were calculated for Chhatrapati Sambhajinagar from the years 1975 to 2021. The data for this temporal analysis was sourced from NCEI. The trend analysis shows that between 1975 and 2021, annual mean air temperatures have risen by 0.1°C per decade as seen in Figure 4-1.

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

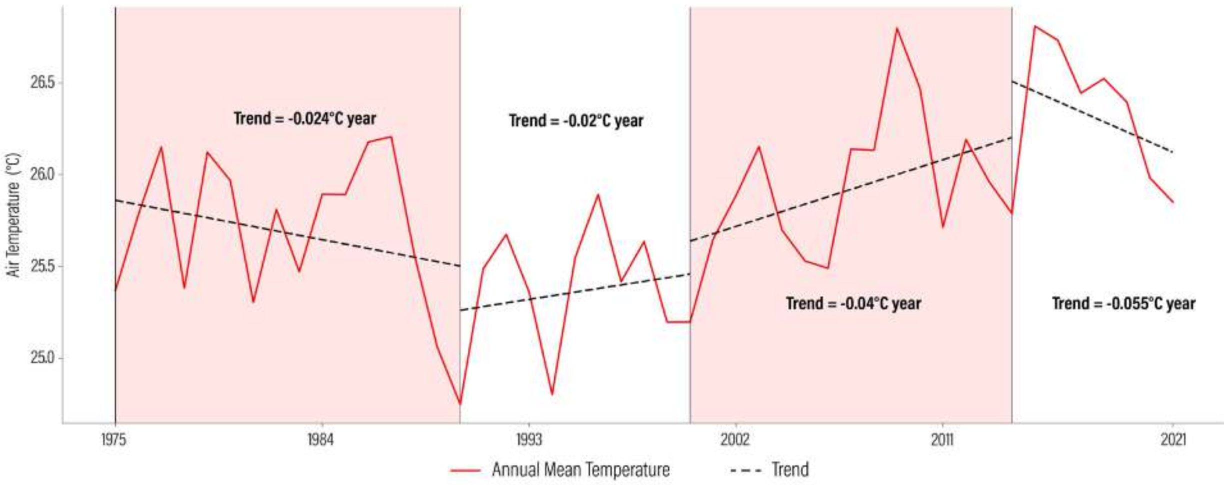


Source: WRI India analysis 2022, NCEI 1975-2021

2. Change Point Detection

In addition to interpreting the annual average trend entirely, it is also 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 such breakpoints that were identified using an established mathematical method. These divide the entire period into four sections, each with a different slope, as shown in Figure 4-2.

Figure 4-2: Change Point Detection

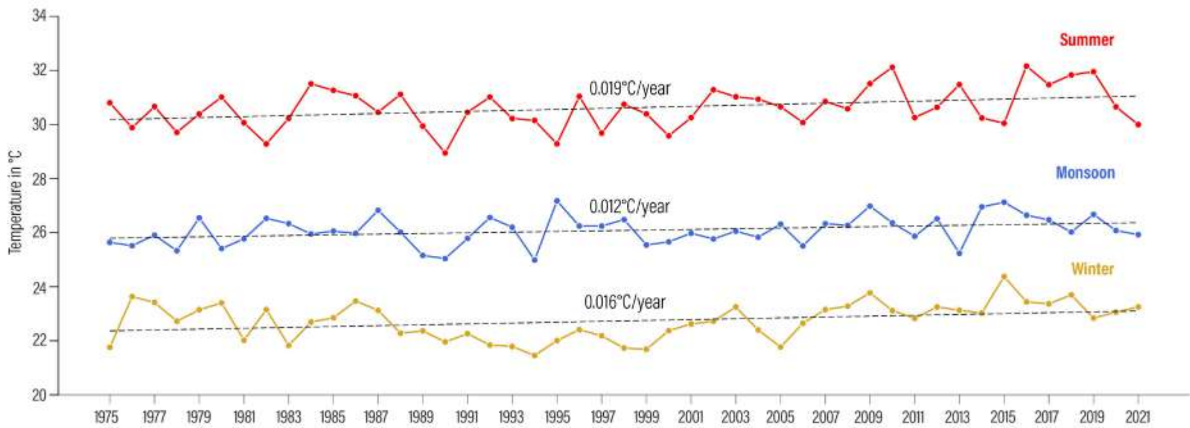


Source: WRI India analysis 2022, NCEI 1975-2021

3. Seasonal Air Temperature Trend

The annual average temperatures can be broken up as per the three seasons to understand seasonal trends. Figure 4-3 below shows these trends in Chhatrapati Sambhajinagar, with the largest increase in the summer season followed by winter and then monsoon.

Figure 4-3: Seasonal Air Temperature Trends



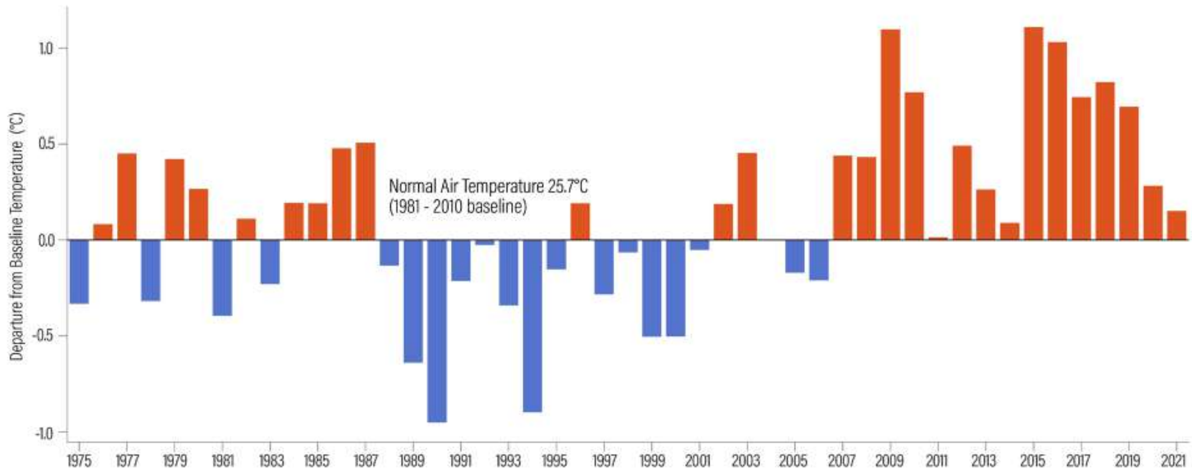
Source: WRI India analysis 2022, NCEI 1975-2021

4. Annual Air Temperature Deviations

Figure 4-4 shows the annual air temperature deviations in Chhatrapati Sambhajinagar from 1975 to 2021. The baseline temperature for the city, 25.7°C, was calculated following IMD guidelines (IMD, 2021). It is the average temperature of the period 1981-2010. The anomalies were calculated by subtracting the baseline temperature from each year's annual average temperature.

In all, 27 years are observed to have been warmer than the baseline average in this period. Since 2007, all the years show markedly high deviations, which indicate a warming pattern in the city.

Figure 4-4: Deviations of annual air temperature from the baseline



Source: WRI India analysis 2022, NCEI 1975-2021

4.2.2 Extreme Heat Events

A heat wave is a period of high air temperature, which becomes fatal to the human body based on duration of exposure. Heat wave and extreme heat wave incidents in Chhatrapati Sambhajinagar were analysed between 1975 and 2022.

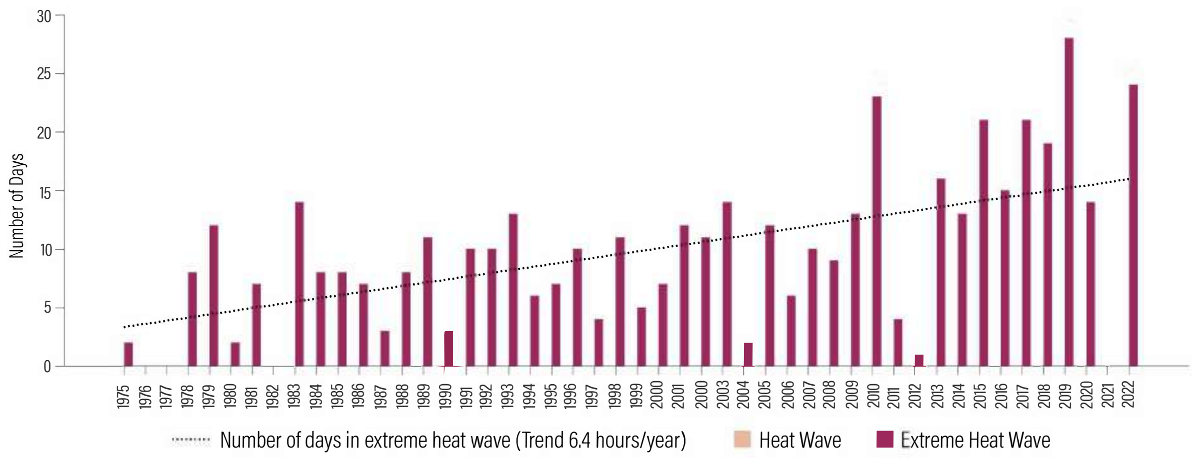
1. Heat Waves

First, data for only those days was considered where the maximum temperature was above 40°C as IMD requires areas within plains to obey this threshold (a threshold of 30°C should be applied to areas in hilly regions). In each year, as per IMD's guidelines, the days that had a deviation from the daily long-term average air temperature between 4.5°C and 6.4°C were classified as 'heat wave' and where the deviation was more than 6.4°C were classified as 'extreme heat wave'.

The years 2010, 2019, and 2022 were three of the hottest in this period, with 23, 28 and 24 days, respectively, classified under extreme heat wave. Lastly, an absence of heat wave days indicates that if the maximum temperature of the day crosses 40°C, the day is much more likely to experience an extreme heat wave than a heat wave.

Figure 4-5 shows an increasing trend, with 6.4 hours every year getting added to the time that the city spends in extreme heat waves. Note that in each year, all these days are exclusively in the summer season.

Figure 4-5: Number of days spent in Extreme Heat wave



Source: WRI India analysis 2022, NCEI 1975-2022 (July)*

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 NOAA, as shown in Table 4-1, which also shows the health hazards associated with the different heat index categories.

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

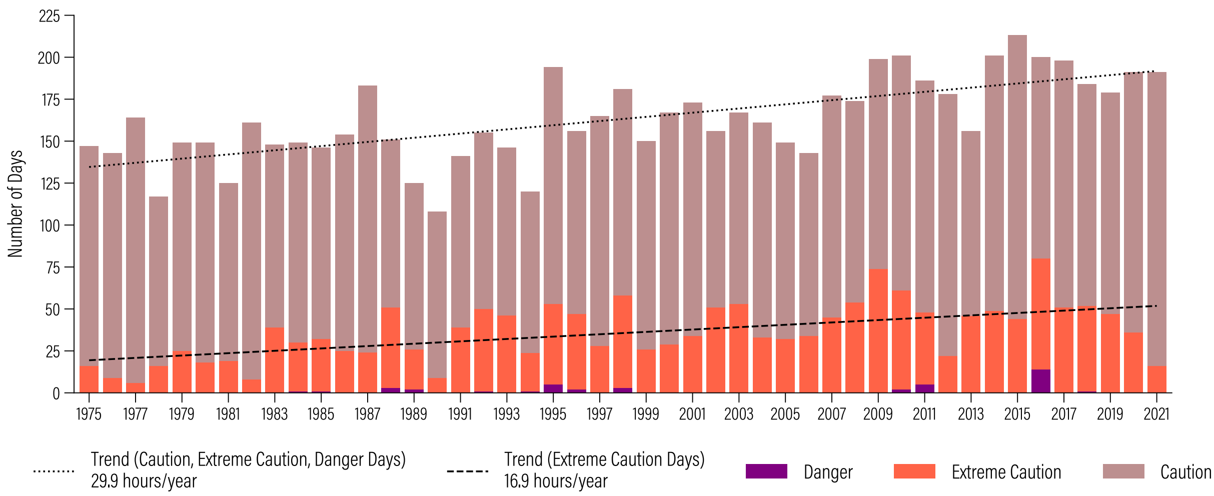
Table 4-1: Heat Index Classification

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: National Oceanic and Atmospheric Administration

As seen in Figure 4-6, every two years than a day is getting added to the number of extreme caution days while the combined number of 'Caution', 'Extreme Caution', and 'Danger' days is increasing at the rate of more than a day per year. The year 2016 had the maximum number of days (14) in the 'Danger' category owing to the severe heat wave that swept across Maharashtra.

Figure 4-6: Heat index Classification between 1975 & 2021



Source: WRI India analysis 2022, NCEI 1975-2021

4.2.3 Land Surface Temperature (LST) Analysis

Satellite-derived LST is highly effective in studying the UHI phenomenon where the temperatures in the urban areas are considerably higher than the sub-urban and ex-urban areas. Elevated night-time surface temperatures as compared with day-time surface temperatures over the urban areas characterise the UHI effect, because of which the effect is most prominent at night

(William et al., 2005). LST, being the radiative skin temperature of the land, measures the emission of thermal radiance from the land surface where the incoming solar energy interacts with and heats the ground or the surface of the canopy in vegetated areas along with the other surfaces it interacts with (Ansar et al., 2021).

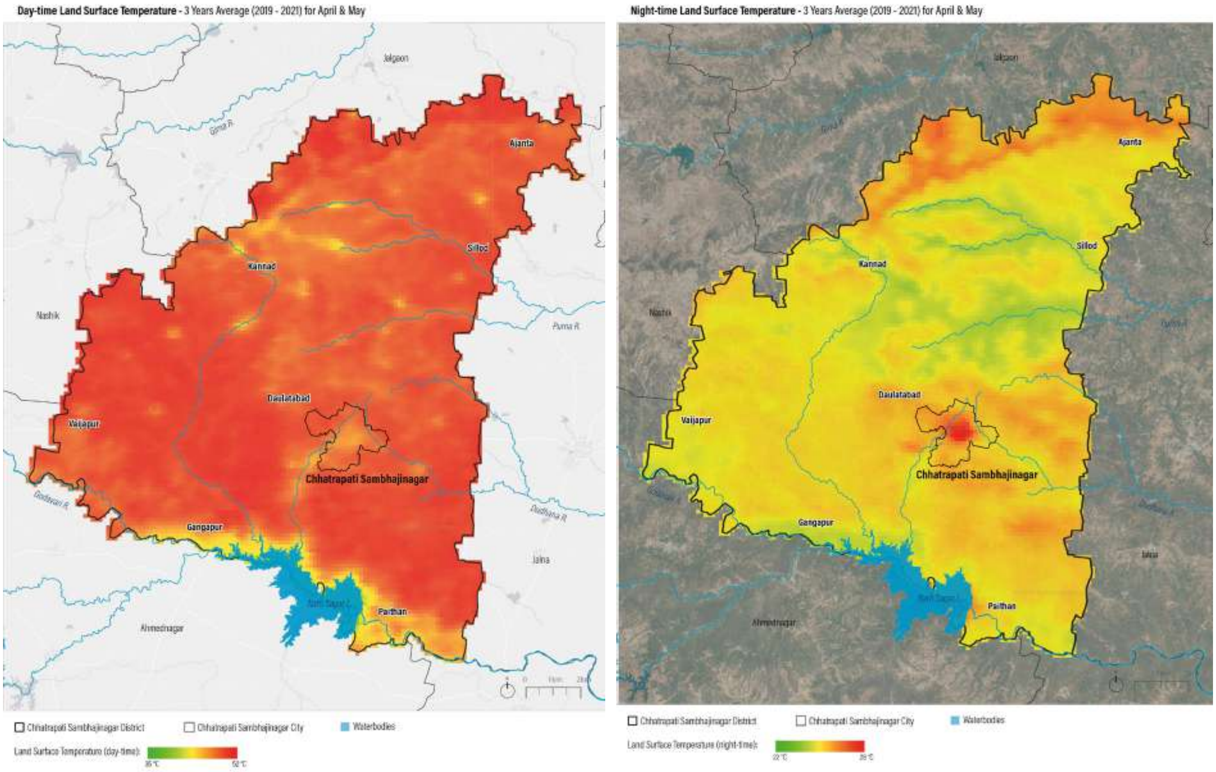
1. Urban Heat Island

The night-time LST has proven to be effective in studying the UHI effect in many studies, especially in the Indian context. The differences in day and night-time LST is a function of specific heat capacities of various land-covers. For example, waterbodies have a cooling effect during the day and a warming effect at night because of high specific heat capacity (Bala et al., 2020). Moreover, bare surfaces rapidly get warmed up because of the lower specific heat capacity when compared with waterbodies (Adeyeri et al., 2017).

The district map for LST (Figure 4-7) shows the difference in day and night-time LST where the UHI effect is seen to be prominent at night. One could observe visible UHI hotspots at Chhatrapati Sambhajinagar city core, Waluj, Daulatabad, Gangapur and Paithan. Figure 4-8 shows the long-term annual difference in day and night-time LST over city-core (urban), and rural (15 km buffer around municipal limits). Rural areas are observed to have greater surface temperature than the city core during the day due to factors such as agricultural patterns and soil moisture content, while the city core is consistently hotter than the non-built-up and rural areas marking more prominence of UHI at night. A study by Gosh and Deshmukh, 2020 shows UHI hotspots over the dense urban areas of Naregaon, Chikalthana airport area, Satara-Deolai Parisar, and Waluj industrial area, which supports the current analysis.

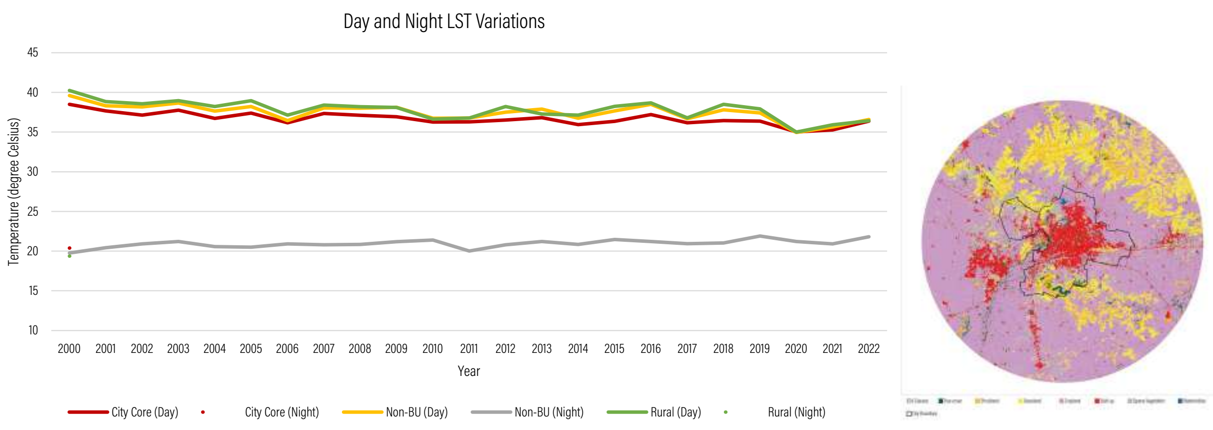
There is an observed difference of approximately 1.3 °C between the city core and rural areas, with a few monthly night-time LST averages recording differences of more than 2 °C. The city core is consistently hotter than the non-built-up and rural areas, marking prominence of UHI at night.

Figure 4-7: Day and Night LST over Chhatrapati Sambhajinagar district



Source: *WRI India analysis 2022, MODIS*

Figure 4-8: Day and Night-time LST differences among various areas in and around Chhatrapati Sambhajinagar



Source: *WRI India analysis 2022, MODIS, ESA WorldCover V100, CSMC)*

2. Long-term monthly and seasonal variations in night-time LST

The long-term 22-year trend in night-time LST over the built-up areas in Chhatrapati Sambhajinagar shows a gradual increase.

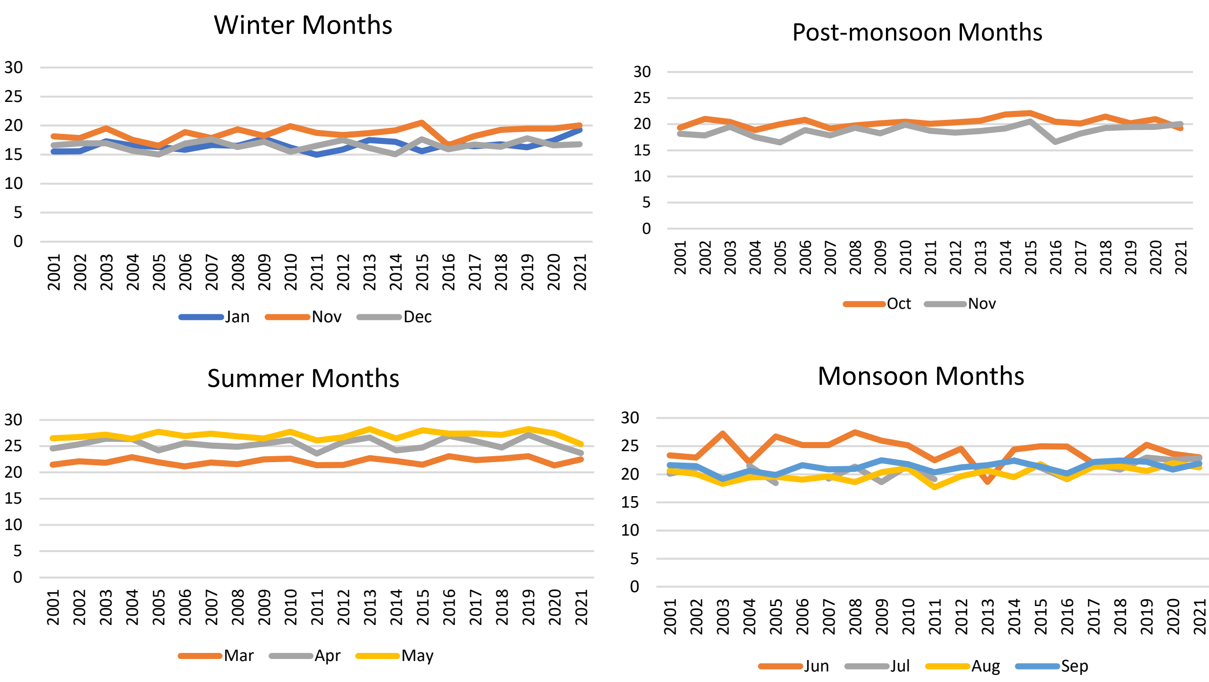
The breakdown of the above monthly trend into seasonal analysis (Figure 4-9) shows no significant trend for summer, monsoon, and post-monsoon seasons (Reference). The lack of a few pixels data in the monsoon months, especially June, could be accounted for the erratic patterns in the overall seasonal average. The winter season though seems to present an increasing trend from the year 2016.

3. LST Hotspots

The hotspot analysis has been done using 30m high-resolution pixel of Landsat 8 imagery. Due to the lack of such imagery available during the night, the LST has been derived for the summer months of April and May, and the post-monsoon months of November and December from the year 2019-2021 (Figure 4-10). The selection of the Landsat images was based on the cloud cover over the city, limiting the availability of clear images for long-term and seasonal analyses using Landsat 8. The analysis shows the presence of consistent hotspots in areas including Shahgunj, Chikalthana, and Savitri Nagar in both the studied seasons.

A rise of 0.5 °C per decade in night-time LST can be observed from the monthly trend over the built-up areas in Chhatrapati Sambhajinagar (Figure 4-9) .

Figure 4-9: Seasonal variations in night-time LST over Chhatrapati Sambhajinagar city-core

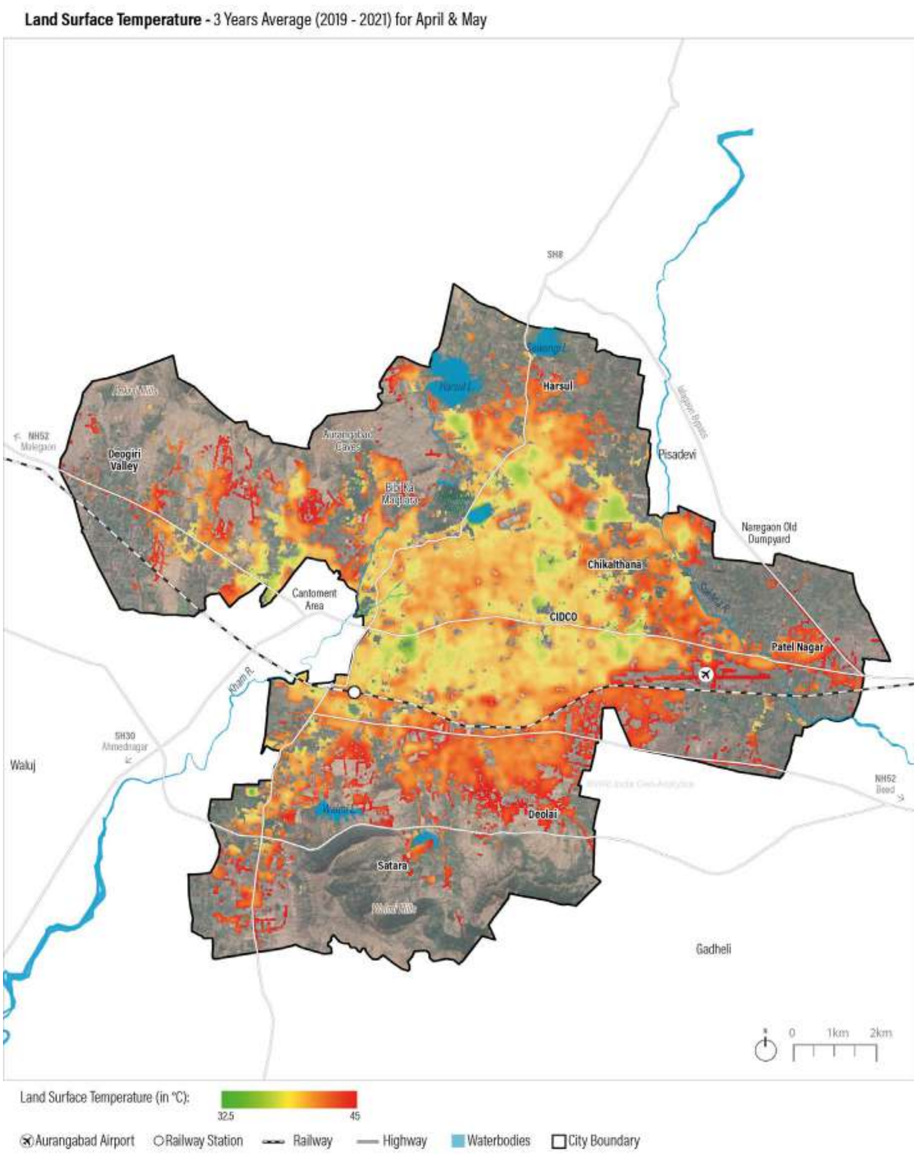


Source: WRI India analysis 2022, MODIS, CSMC

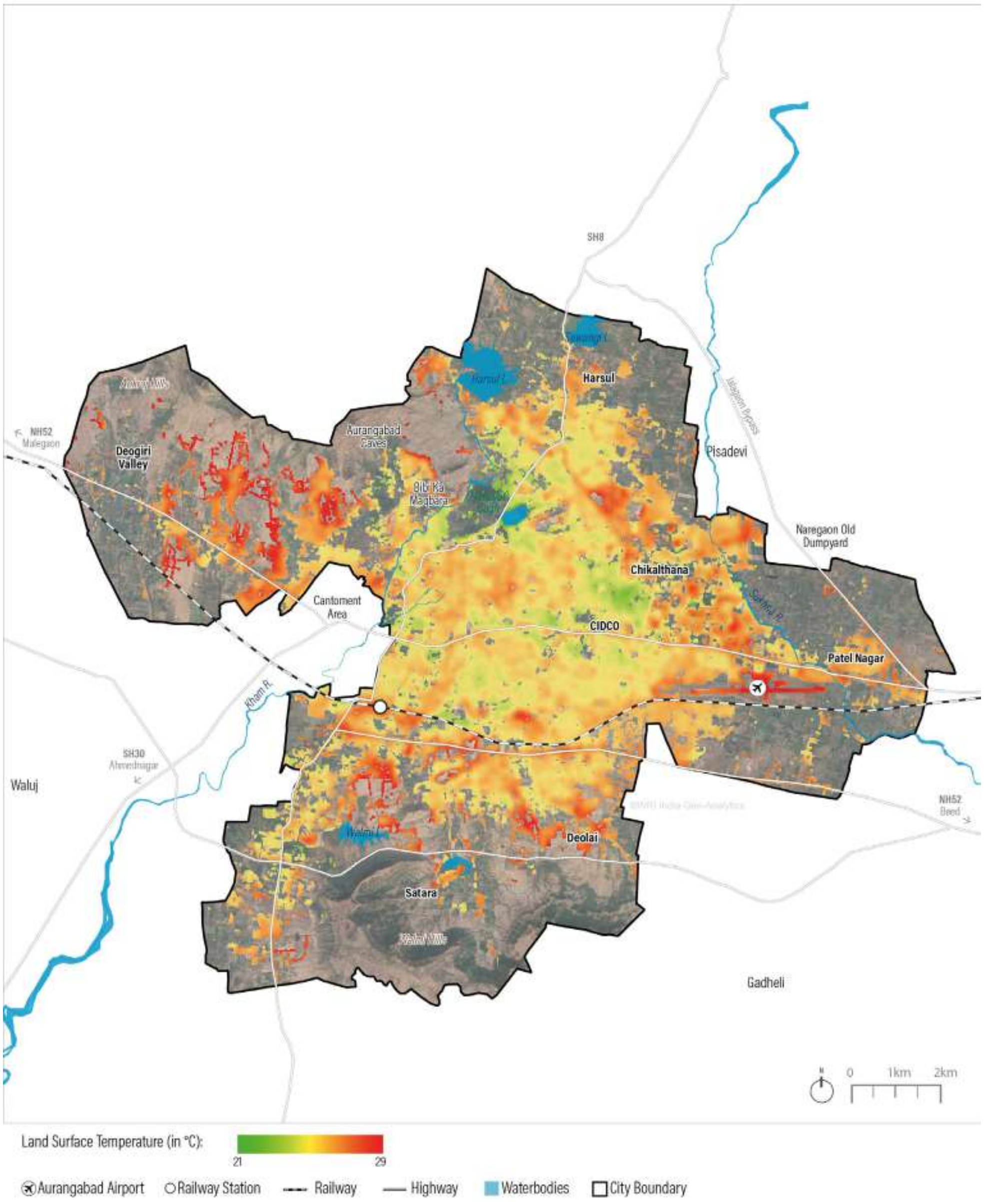
On the contrary, areas including Milind Nagar and CIDCO are observed to be reporting relatively lesser LST. These contrasting surface temperatures depend on factors such as climate zone, urban form, availability of blue-green spaces, roofing material, and albedo (Wang et al., 2022, Yin et al. 2018, Jiang et al. 2021, Deng et al., 2021).

For pre-monsoon months, the daytime LST within the city built-up areas ranges between 33°C and 45°C, and during the post-monsoon months, it ranges from 21°C to 29°C. In both these periods, the Shahganj, Chikalthana and Savitri Nagar areas are consistently hotter than the other areas within the city.

Figure 4-10: Land Surface Temperature clipped to Built-up (April-May and Nov-Dec 2019-2021)



Land Surface Temperature - 3 Years Average (2019 - 2021) for November & December



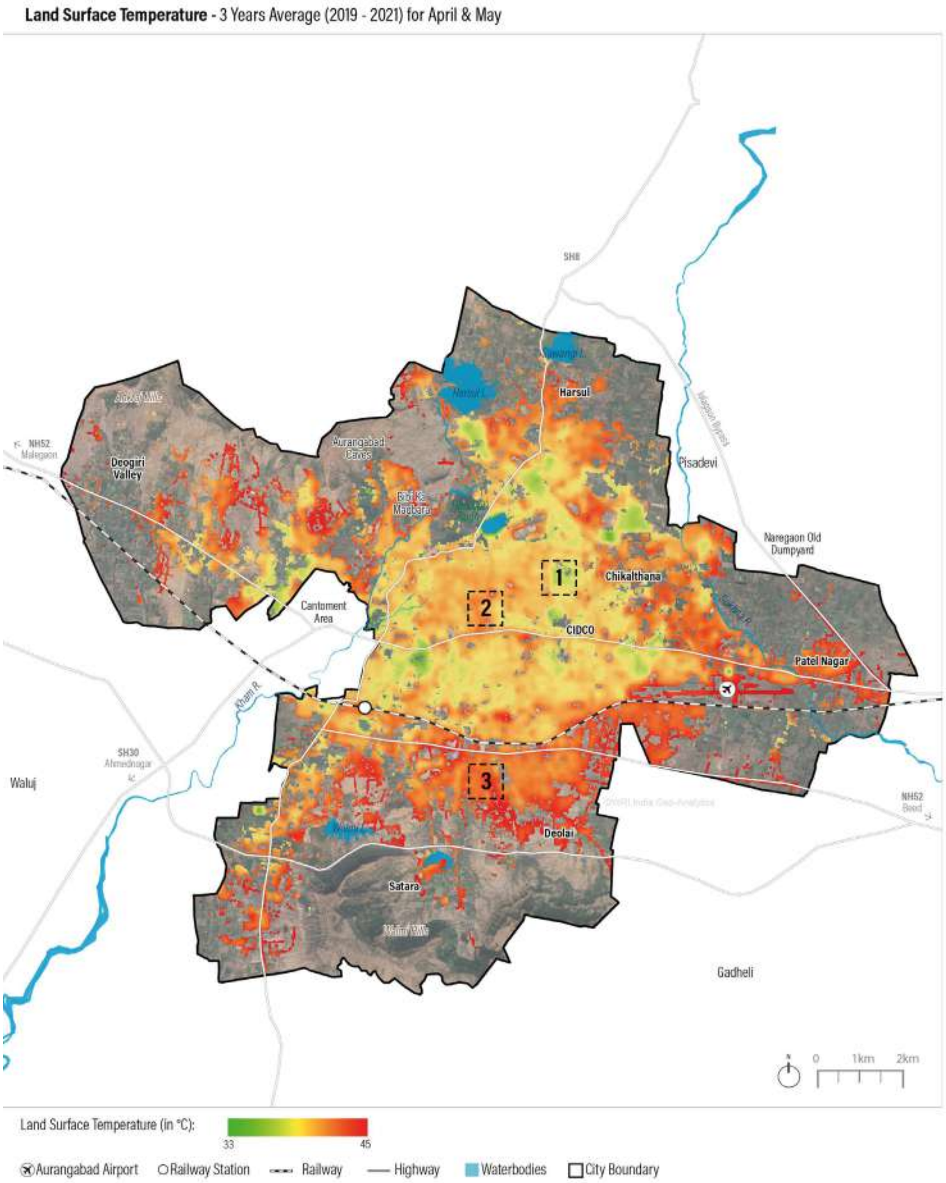
Source: WRI India analysis 2022, Landsat 8, CSMC

Example: LST hotspots at Bhavani Nagar corresponding to the difference in roofing material type and near Maulana Azad Chowk corresponding to differences in Urban form

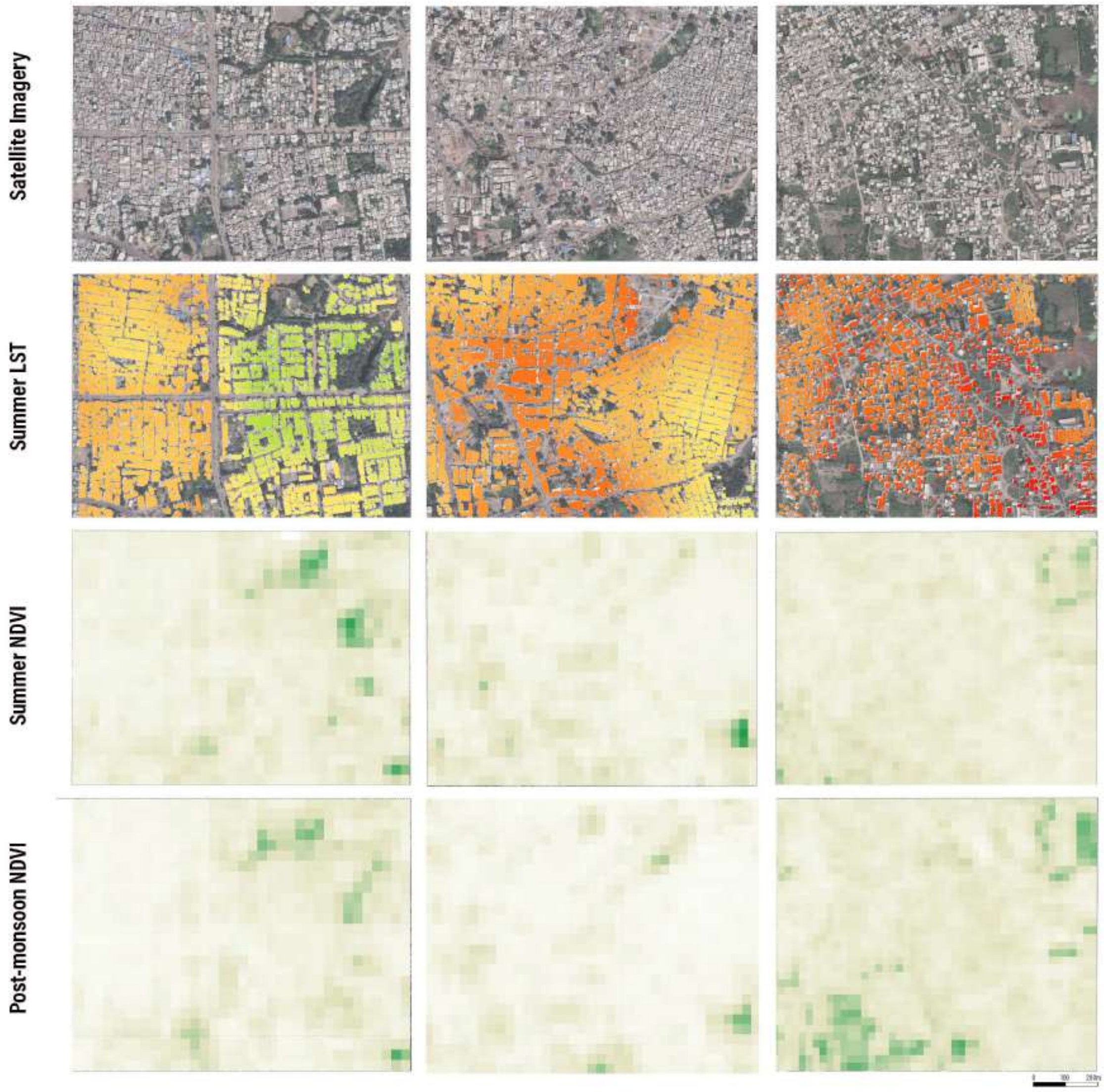
An example of drastically different LST in neighboring areas is shown in Figure 4-11. On either side of the TV Centre Road passing through Maulana Azad Chowk, a difference of about 2°C can be observed, with Rahim Nagar reporting 39°C LST and Urmila Cooperative Society reporting about 37°C of LST. When compared with the satellite imagery, it can be noticed that Rahim Nagar has a densely spaced urban form with hardly any green cover, whilst the Urmila Cooperative Society seems to show considerable green cover in the form of trees and presence of a neighbourhood level park named Nehru Udyan.

Additionally, the spacing between the buildings contribute to ventilation between spaces, which could be contributing to the local regulation of LST.

Figure 4-11: Examples of LST hotspots at Maulana Azad Chowk, Bhavani Nagar and Malhar Nagar



Source: WRI India analysis 2022, Landsat 8, Microsoft Building Footprint 2021, CSMC



1

On either side of the TV Centre Road passing through **Maulana Azad Chowk**, a difference of about 2°C can be observed with Rahim Nagar reporting 39°C LST and Urmila Cooperative Society reporting about 37°C of LST. This difference in LST, owing to difference in urban forms, presence of vegetation, is consistently observed through seasons as indicated by seasonal NDVI zoom-ins as well.

2

A difference of around 2°C is observed **between the areas with visibly different type of roofs .** The example also focuses on the LST variations based on different urban forms where a gridded form is observed to be reporting lesser LST (40°C) while the other area along the New Mondha Road seems to be experiencing an LST of 42°C.

3

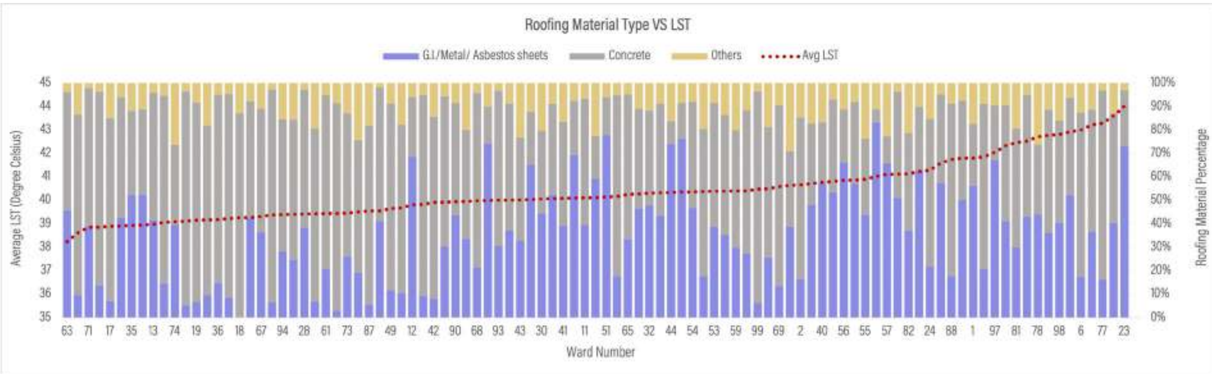
Malhar Nagar located near the periphery records a difference of around 4°C during the day making the population and settlements more heat-vulnerable. The impacts of being on the periphery become higher owing to the crop cycles in this region. The seasonal difference in vegetation doesn't help much in regulating the microclimate owing to the seasonal vegetation changes

4. Relationship between LST and Roofing Material

The type of surface materials influences the surface temperature owing to the difference in the thermal conductivity (Deng et al., 2021). Census 2011 provides the ward-wise percentage of households with certain roofing materials, which has been correlated with the corresponding ward-wise LST for Chhatrapati Sambhajinagar shown in Figure 4-12. A positive correlation, though relatively weak, is observed between roofing (considers G.I./Metal/Asbestos Sheets) and April-May LST.

The wards having a higher percentage of G.I/metal/asbestos and a lower percentage of concrete roofing are observed to be reporting higher LST. The correlation becomes considerably stronger in the city core, with a higher built-up percentage (greater than or equal to 65%) adding to the severity of the UHI effect in the dense urban areas.

Figure 4-12: Ward-wise Roofing material type versus LST in Chhatrapati Sambhajinagar



Source: WRI India analysis 2022, Census 2011, Landsat 8, CSMC

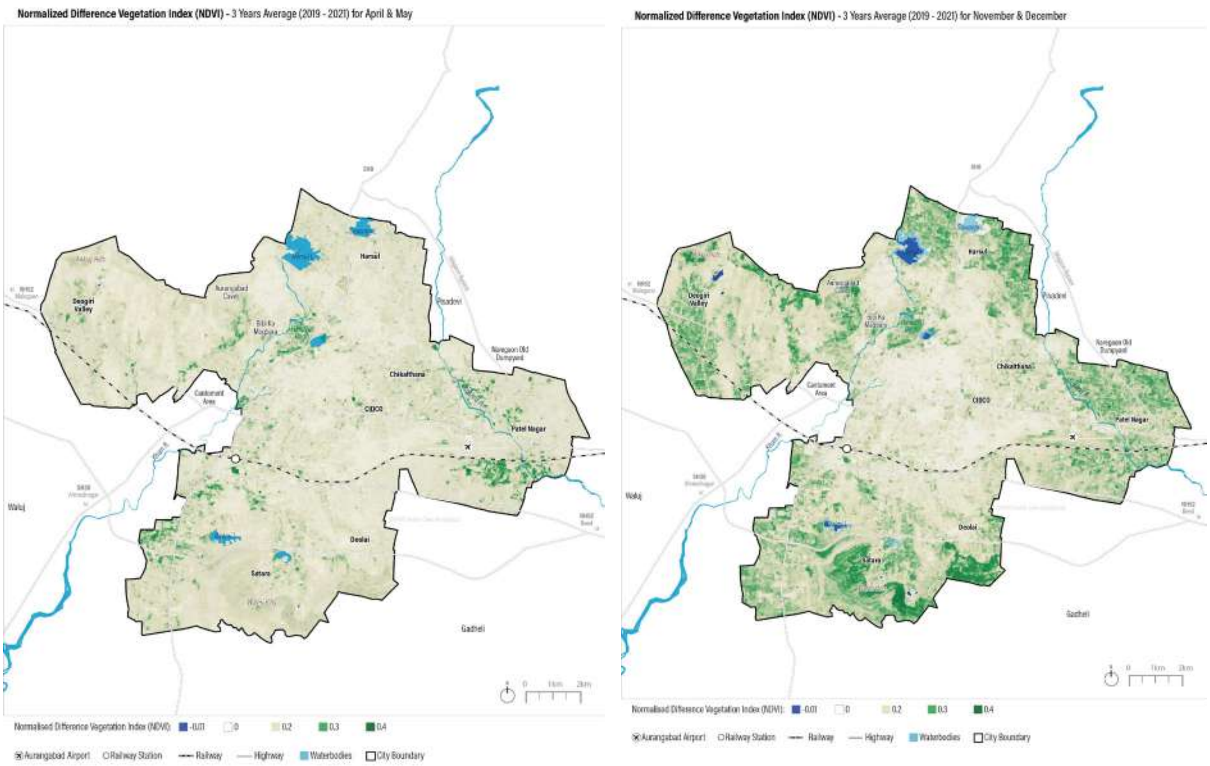
Figure 4-12 highlights an example from Ward 57 having around 66% of G.I./metal/asbestos sheets and about 11% of concrete roofs (Census 2011). A difference of around 2°C is observed between the areas with visibly different types of roofs. The example also focuses on the LST variations based on different urban forms where a gridded form is observed to be reporting lesser LST (40°C) while the other area along the New Mondha Road seems to be experiencing an LST of 42°C.

5. Relationship between LST and Vegetation

Several studies have revealed a direct inverse relationship between UHI and NDVI[9] in large urban areas, signifying better surface temperature regulation in the presence of green spaces (Weng et al., 2004, Matthew et al., 2017, Climate & air pollution risks and vulnerability assessment for Mumbai, India, WRI India, 2022). However, this relationship may not hold true for most of the tier-2 cities[10] due to the presence of comparatively more non-built areas in the form of croplands and fallow lands where the presence of green cover is highly affected by seasonality, irrigation, and cropping pattern (Guha et al., 2020).

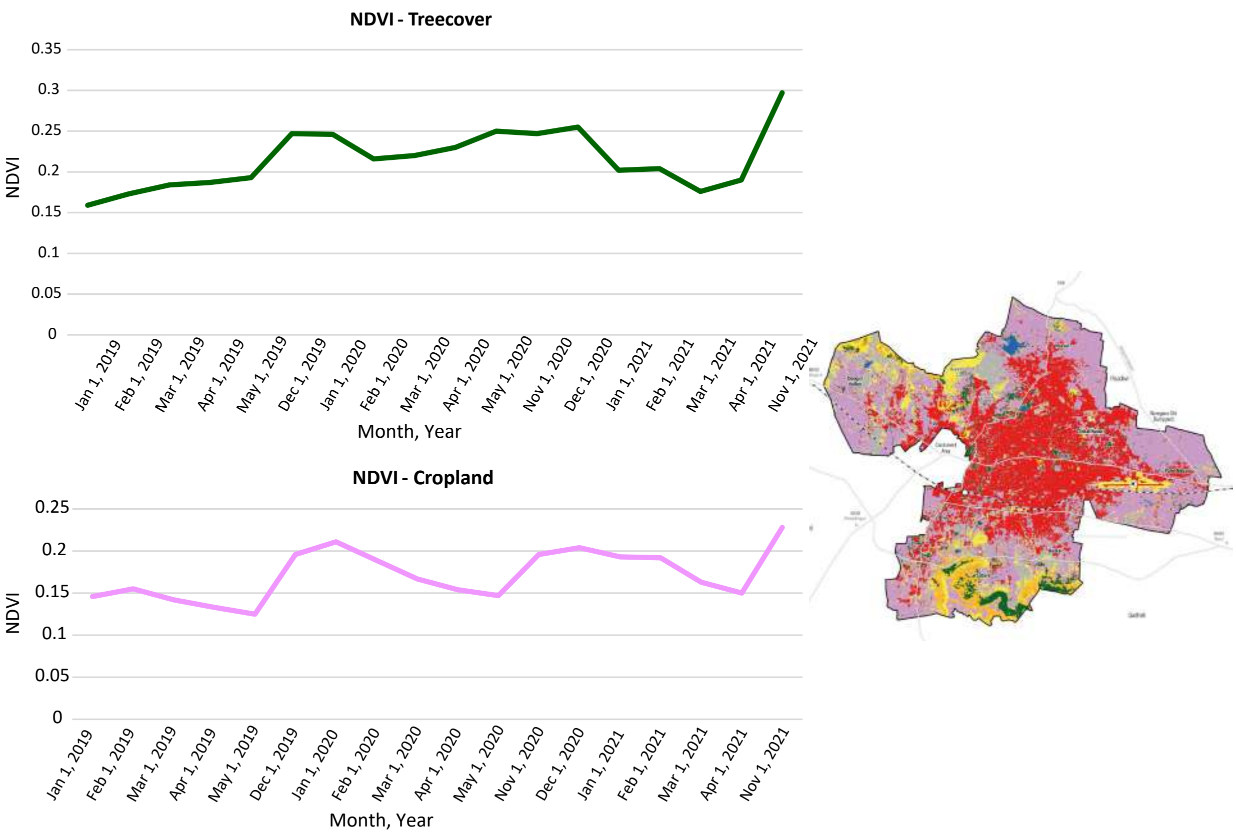
Figure 4-13 shows the satellite derived NDVI for summer and post-monsoon months, where the city core is observed to lack major green spaces in both the seasons while the periphery is highly influenced by seasonality, irrigation, and cropping pattern[11]. This is observable in the NDVI variations over croplands and tree-cover in Figure 4-14 where the seasonal variations in NDVI limit the vegetation's capacity to regulate LST[12]. The hot semi-arid climatic zone in which Chhatrapati Sambhajinagar is situated drives the presence, quality, and health of soil and vegetation, which aids in dampening UHI effects.

Figure 4-13: Seasonal NDVI Variations



Source: WRI India analysis 2022, Landsat 8, CSMC

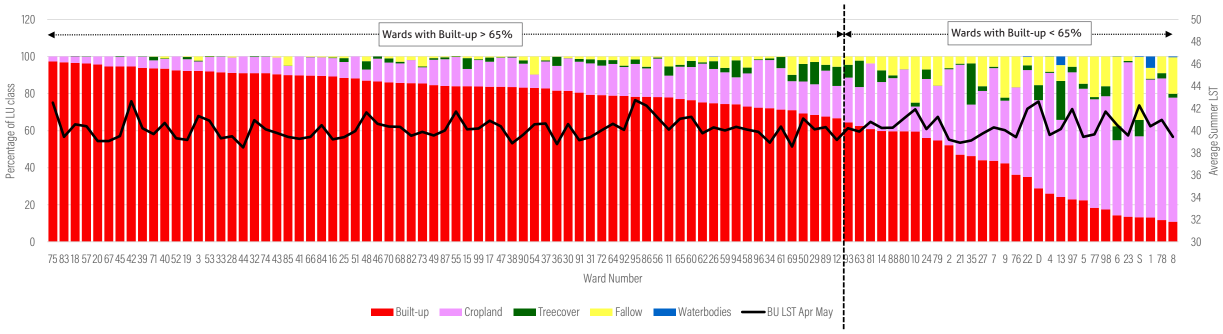
Figure 4-14: Seasonal NDVI Variations over tree cover and Cropland



Source: WRI India analysis 2022, Landsat 8, ESA WorldCover V100, CSMC

The ward-wise assessment of LST with vegetation cover in Figure 4-14 shows no correlation between them. The correlation coefficient[13] between summer LST and vegetation cover considering all the wards is observed to be 0.05, which seems to be highly influenced by the daytime LST being positively correlated with the high crop cover in the periphery. This correlation becomes positively stronger (correlation value – 0.35) in post-monsoon owing to the cropping pattern[14] observed in this season.

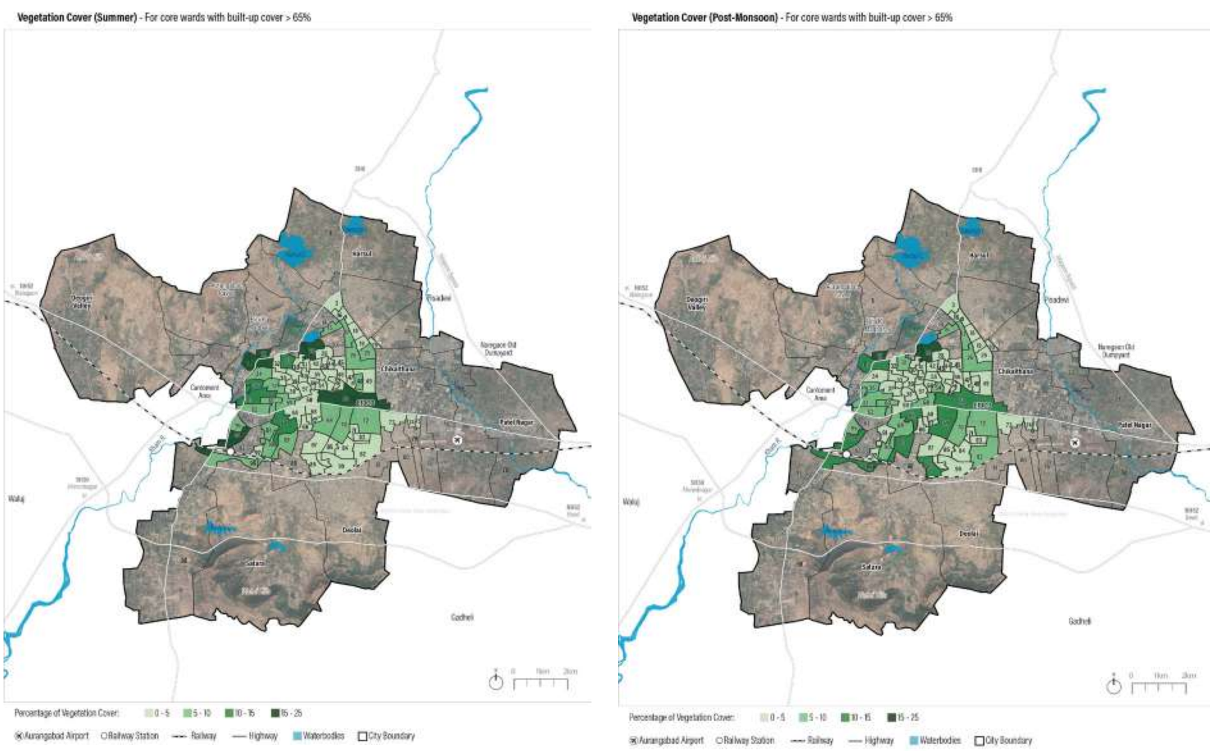
Figure 4-15: Ward-wise relationship between LST and Land-use



Source: WRI India analysis 2022, Landsat 8, ESA WorldCover V100, CSMC

The analysis of the core wards with built-up cover greater than 65% show the expected inverse relationship between LST and vegetation (correlation value of -0.18 and -0.14 in summer and post-monsoon, respectively), signifying weaker relationship of vegetation with UHI at ward level. Additionally, this depicts the need to analyse more references in terms of the quality of the vegetation along with other LST-dependent factors, such as roofing material and urban form, in the urban spaces of Chhatrapati Sambhajinagar city. Spatially, as observed from Figure 4.16, wards 12 and 29 consistently report the highest area under vegetation and yet observe relatively

Figure 4-16: Seasonal variations in vegetation cover in wards with built-up>65%



Source: WRI India analysis 2022, Landsat 8, CSMC

periphery where the agricultural land reporting high LST during the day affects the local climate. On the contrary, the wards observing percentage area under vegetation between 0% and 5% are almost consistent in the two studied timeframes, especially the wards in the Shahgunj area where the LST hotspots as shown in figure 4-10 are consistent, signifying the inverse relationship between UHI and the presence of vegetation.

4.3 DISCUSSIONS AND CONCLUSIONS

The city core observes a higher rate of the UHI effect, which depends on the climate, landscape, and urban form of the city. The current assessment analyses a limited number of parameters by isolating the relationship between LST and the corresponding parameter. The UHI effect being prominent at night-time and the relatively limited availability of satellite derived products provide a restricted understanding of the UHI dynamics in the city. The seasonal variations also add value in terms of factors such as vegetation, affecting the LST over the built-up areas where consistent hotspots can be identified at the city level. The neighbourhood level UHI dynamics needs further analysis using additional ancillary data, such as quality of vegetation.

Photo Credit: ASCDCL

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 (Agarwal et al., 2006; Karar et al., 2006).

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 (D'Amato et al., 2002).

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 (Ramachandran & Cherian, 2008).

5.1 ASSESSMENT

Air pollution risk assessment includes temporal analysis using data from the CAAQMS and manual stations established in the city and spatial analysis based on satellite imagery (Refer Annexure 1-3).

- There are six central, state, and city-led monitoring stations in Chhatrapati Sambhajinagar maintained under different programmes. The locations and details of pollutants monitored at these stations are mentioned in Table 5-1 and mapped in Figure 5-1.

- Additionally, Maharashtra Pollution Control Board (MPCB) appointed CSIR-National Environmental Engineering Research Institute (CSIR-NEERI) and Indian Institute of Technology Bombay to conduct source apportionment and emission inventory studies for all non-attainment cities in Maharashtra.

- Based on the above, city-specific air pollution micro action plans were created, which included measures for mitigating the sources and strengthening air quality monitoring in the cities. As a result, the findings from Chhatrapati Sambhajinagar's source apportionment study and micro action plan were also analysed.

The process of air pollution monitoring involves 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, Chhatrapati Sambhajinagar does not indicate non-attainment character though Respirable Suspended Particulate Matter (RSPM) levels were above the annual limit established by the Central Pollution Control Board (CPCB), which shows non-attainment[15].

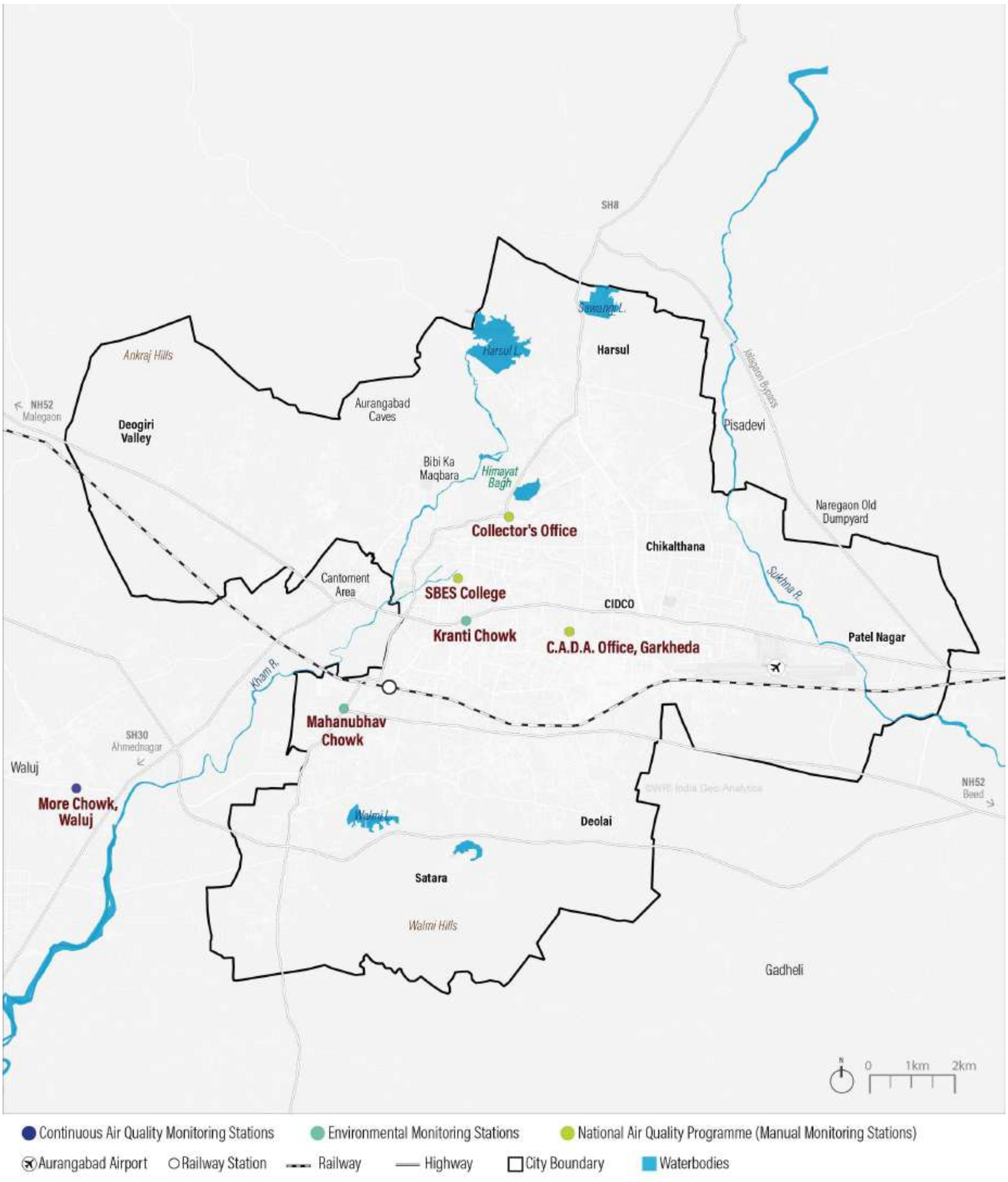
Table 5-1: Details of the six air quality monitoring stations within Chhatrapati Sambhajinagar City

Station Name	Area	Program	Location type	Pollutants	Data Range	Monitoring Frequency
More Chowk	Waluj MIDC	CAAQMS	Industrial	SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, Ozone	26/09/2017 to 23/06/2022	Hourly
C.A.D.A. Office	Garkheda	NAMP	Residential	SO_2, NO_x, RSPM, SPM	07/12/2005 to 24/03/2022	Two Days a week
Collector's Office	Alamgir Colony	NAMP	Residential	SO_2, NO_x, RSPM, SPM	28/11/2005 to 26/03/2022	Two Days a week
SBES College	Saraswati Nagar	NAMP	Residential	SO_2, NO_x, PM_{10}, $PM_{2.5}$	26/11/2005 to 22/03/2022	Two Days a week
Mahanubhav Chowk	Mahanubhav Chowk	Smart Cities Mission	Residential	SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, CO_2,	01/09/2021 to 31/12/2021	Daily
Kranti Chowk	Kranti Chowk	Smart Cities Mission	Residential	Data Not Available		

Source: CPCB, MPCB
(Note: RSPM is the same as PM_{10})

The lone CAAQMS station is in the Waluj MIDC premises outside the city boundary, with hourly data available for pollutants listed in Table 5-1 . Moreover, the Smart Cities Mission has established two new environmental monitoring sensors at Mahanubhav Chowk (Residential) and Kranti Chowk (Residential), of which data only for the former is available from September 2021. Therefore, due to the limited data available for the new stations, the detailed analysis using the same has not been included in the key findings.

Figure 5-1: Locations of air quality monitoring stations in Chhatrapati Sambhajinagar



Source: WRI India using CPCB, MPCB, CSMC, ASCDCL, 2022

5.2 KEY FINDINGS

The pollution levels for particulate matter and the 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. Moreover, the spatial analysis of the concentrations was also carried out using satellite observations. The key findings of this analysis are captured in this section.

5.2.1 Air pollution concentrations

The temporal analysis of different air pollutant levels (annual averages) for Chhatrapati Sambhajinagar city has been carried for the period starting 2006 to assess the city-wide and station-wise variations using data from the four manual stations: SBES College, Collector's Office, Waluj MIDC, and the CADA Office. All the stations except the one at Waluj MIDC are located on predominantly residential land, while the Waluj MIDC station is surrounded by industrial activity.

Using the hourly data from the Waluj MIDC CAAQMS station, hourly, weekly, monthly, seasonal, and annual scale analyses were carried out. However, for the same station and the remaining three stations, only annual averages were calculated using the limited data (one or two 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.

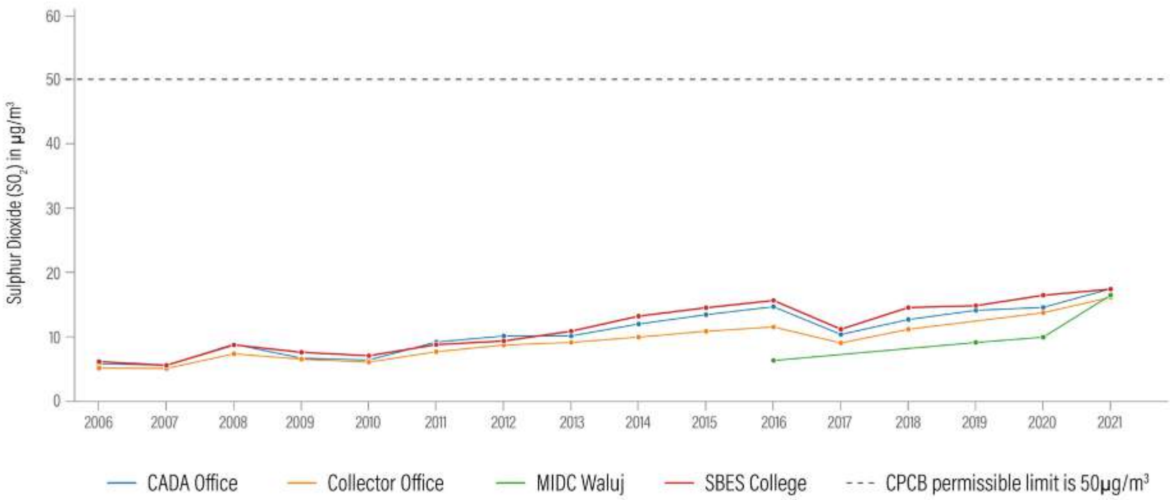
On the other hand, the spatial analysis includes the study of the spread of concentration of each pollutant in the region of interest. Each time the Sentinel satellite flies over a particular region, it records the concentrations of various pollutants. By averaging all the observations collected during each year, annual averages were calculated and displayed on maps. It must be noted, however, that higher concentrations in a region, as seen from 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 broader areas in the city where the concentrations of pollutants are relatively higher.

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

1. Analysis of concentration of sulphur dioxide

Since 2006, annual average SO_2 concentrations are observed to be much lower than the stipulated regulatory limit (50 μg/m^3), indicated by the black dashed line in Figure 5-2. This indicates that SO_2 is not one of the major pollutants in Chhatrapati Sambhajinagar.

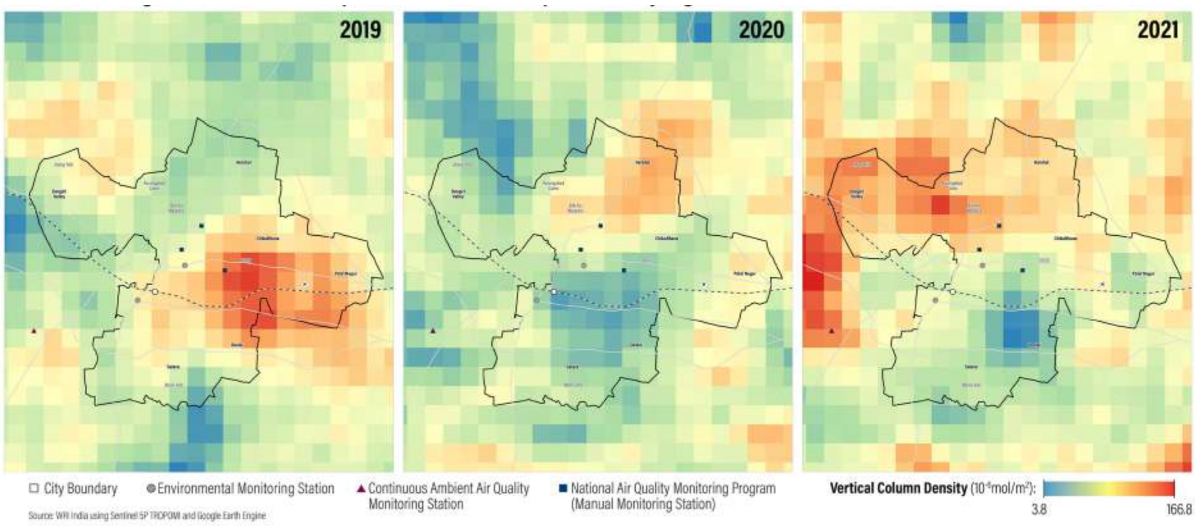
Figure 5-2: Annual avg. concentrations of Sulphur Dioxide (SO_2) across all the manual AQMS in Chhatrapati Sambhajinagar between 2006 and 2021



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, a hotspot was situated over the CIDCO area near the airport where the landuse is a combination of residential and industrial. The map also shows a major highway, which carries moderate to heavy traffic, in the east-west axis in this hotspot. In 2021, the hotspot shifted to the west towards Waluj MIDC where the continuous air quality monitoring station is located. In the same year, a hotspot can be seen to the north, near Aurangabad caves. This location is 2 km east of the Padegaon compost unit, which could be the cause of these high concentrations in the area. A few brick kilns are also observed in the same are, which could also be the cause of higher SO_2 concentrations.

Figure 5-3: Annual average concentrations of SO_2 in Chhatrapati Sambhajinagar during 2019-2021



Source: WRI India using Sentinel data

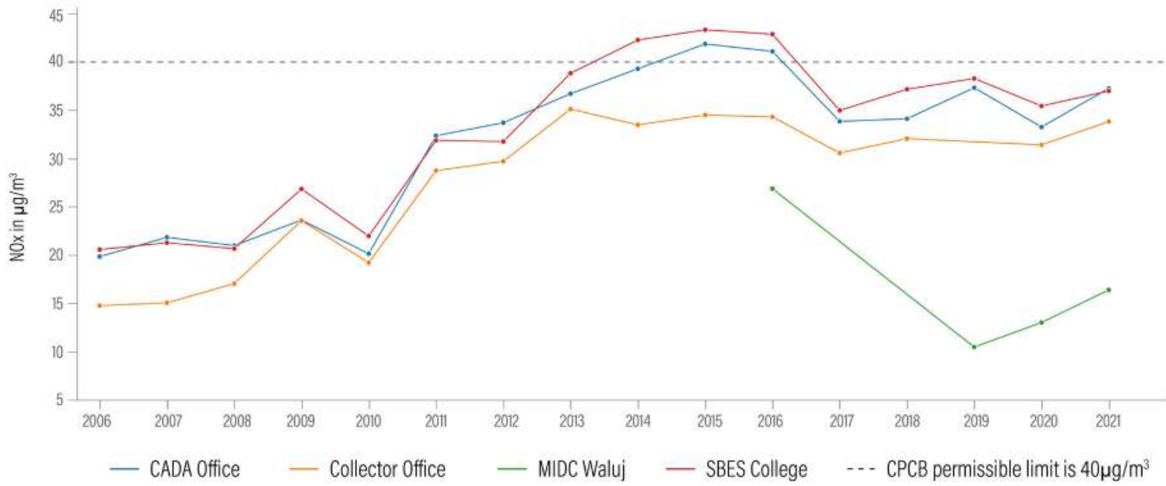
Annexure 2-4 shows the monthly average concentrations of SO_2 in 2019. The pattern of these values is also consistent with the observations from the temporal analysis with high concentrations in the winter and low concentrations in the monsoon. The city centre predominantly shows the worst air quality in most of the pre and post monsoon months (see January, April, November, December).

The hotspot at CIDCO (2019) is also seen prominently in January 2019, February 2020, December 2020, and January 2021.

2. Analysis of nitrogen oxide

Figure 5-4 shows annual NO_x averages at the four manual stations and are observed to be reaching dangerously close to the safety threshold of 40 μg/m^3, with SBES College and CADA Office crossing the threshold between 2014 and 2016.

Figure 5-4: Annual average concentrations of NO_x across all the manual air quality monitoring stations in Chhatrapati Sambhajinagar from 2006 to 2021



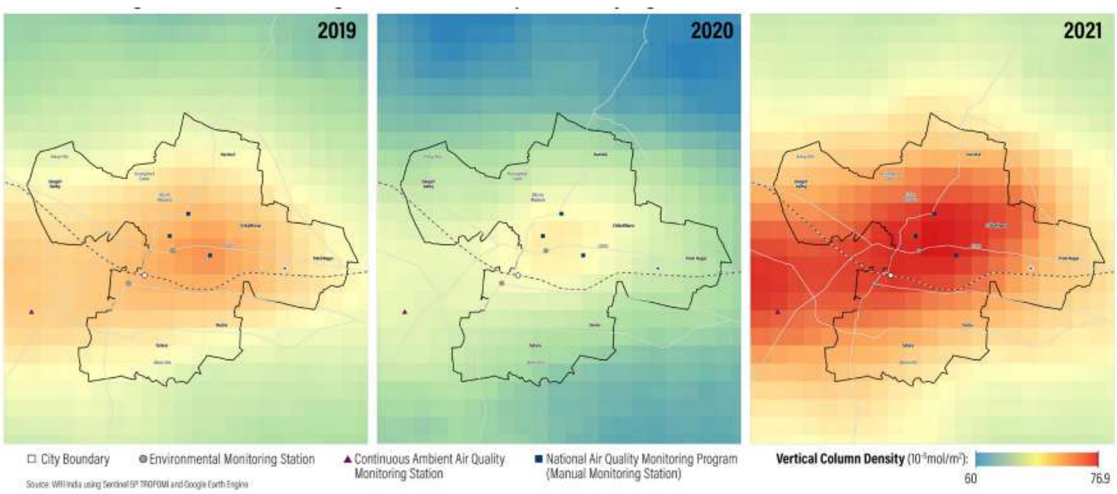
Source: Maharashtra Pollution Control Board

Although this data contains considerable noise, the last 3 months of 2017 have recorded 26 days when the CPCB daily threshold was crossed.

Annexure 2-5 shows the measured hourly concentrations of NO_2 at the continuous monitoring station in Waluj MIDC.

Vehicular emissions are the most important source of Nitrogen Dioxide (NO_2). As such the maps in figure 5-5 below show relatively high concentrations in the middle of the city. The Waluj MIDC area to the west also shows high concentrations in 2019 and 2021. Lastly, the effects of COVID-19 related 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.

Figure 5-5: Annual average concentrations of NO_2 in Chhatrapati Sambhajinagar from 2019 to 2021



Source: WRI India using Sentinel data

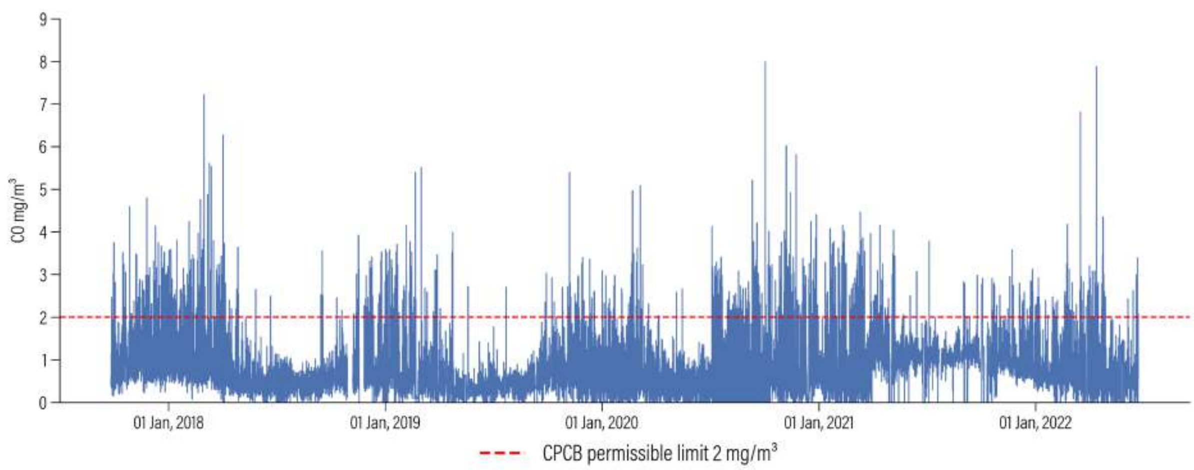
Figure 5-5 shows the annual average concentrations of NO_2 from 2019 to 2021 in the city. Higher values are consistently seen over the city centre, as mentioned before, as well as the Waluj MIDC. Moreover, the seasonal variations are once again consistent with those in the other pollutants, with highest concentrations in the winter and lowest in the monsoon (Refer to Annexure 2-6).

3. Analysis of concentration of carbon monoxide

Figure 5-6 shows the measured hourly concentrations of CO at the Waluj MIDC station. The winter months typically show spikes in CO values whereas concentrations are the lowest during the monsoon season.

Throughout this period, the daily CPCB threshold for carbon monoxide cross on 571 days, with a majority of the crossings taking place between November and May.

Figure 5-6: Hourly Carbon Monoxide (CO) concentrations at the Waluj MIDC air quality monitoring station between September 2017 and June 2022



Source: Central Pollution Control Board

Annexure 2-7 shows the annual average concentrations of CO in Chhatrapati Sambhajinagar. The hotspot appears to have an east-west trend in all the three years and is situated in the centre of the city along with the Waluj MIDC area to the west. Uncharacteristically, the annual average CO concentrations appear to have increased during the COVID-19 lockdown and even further in 2021. Stubble burning happened frequently during the summer of 2020 all over Maharashtra, which may explain these high annual average concentrations (Mohite & Sawant, 2022). 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 (Refer Annexure 2-7).

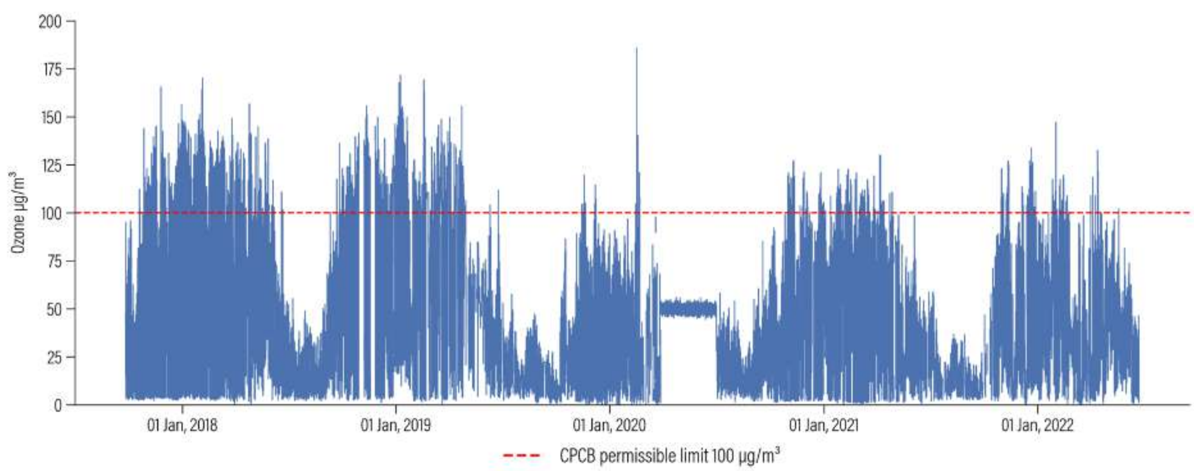
The monthly average concentrations of CO from 2019 to 2021 are shown in Annexure 2-8. The increasingly high annual average concentrations in 2020-2021 are most likely due to particularly elevated CO concentrations in the months of March, April, and May. This can be attributed to the stubble burning during this season.

4. Analysis of Concentration of Ozone

Figure 5-7 shows the measured hourly concentrations of ozone at the Waluj MIDC station. Like the other pollutants discussed above, winter months show higher concentrations (note the values around January for all the years).

Throughout this period, the daily CPCB threshold for ozone cross on 509 days, with a majority of the crossings taking place between November and May.

Figure 5-7: Hourly Ozone (O_3) concentrations at the Waluj MIDC air quality monitoring station between September 2017 and June 2022



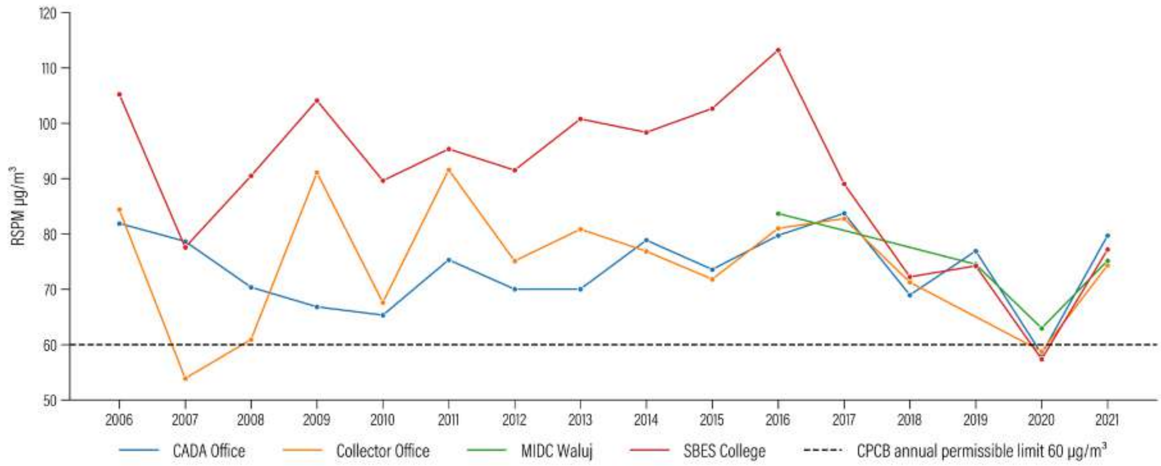
Source: Central Pollution Control Board

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

Figure 5-8 shows annual average concentrations of RSPM at the four 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. Lastly, the sudden drop in values in 2020 at all the stations is most likely a clear effect of COVID-19 lockdowns.

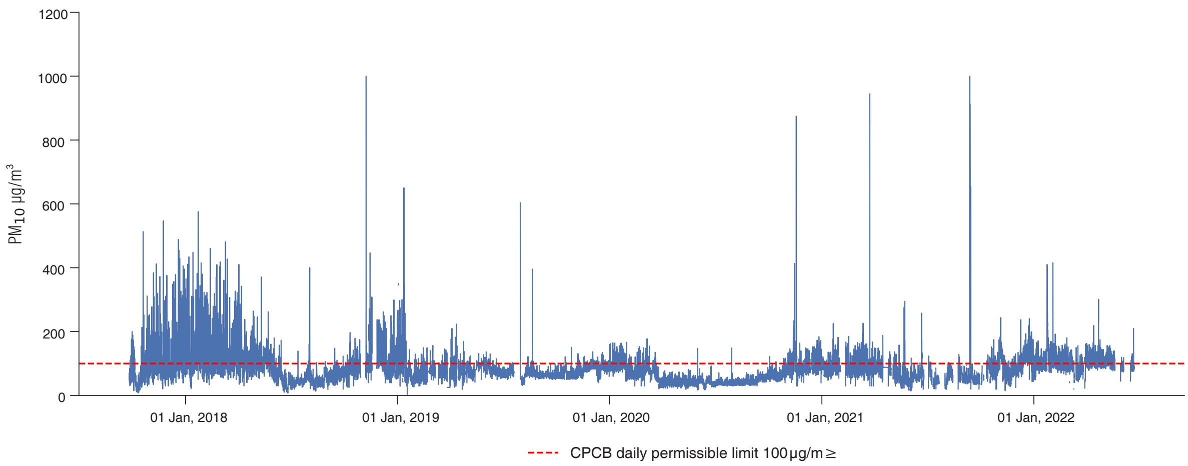
The station at SBES college shows markedly high concentrations of RSPM during this period. This is most likely because it is located in the middle of the city and surrounded by residential land, with plenty of vehicular traffic and footfall.

Figure 5-8: Annual average concentrations of RSPM/ PM_{10} across all manual AQMS between 2006 and 2021



Source: Maharashtra Pollution Control Board

Figure 5-9: PM_{10} concentrations at the Waluj MIDC AQMS between Sept 2017 and June 2022



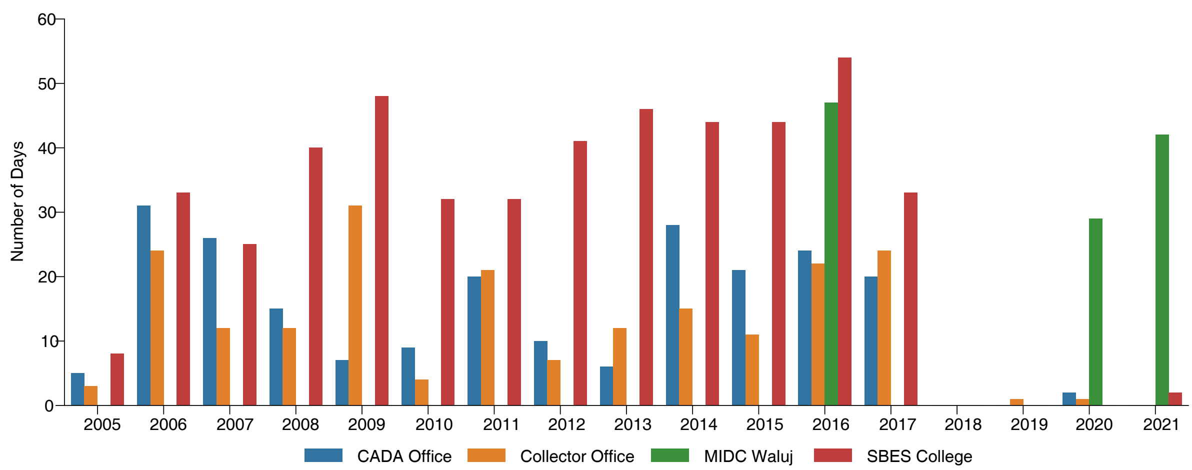
Source: Central Pollution Control Board

Figure 5-10 below shows the number of days each year that the CPCB threshold limit of 100 μg/m^3 was crossed at each of the four stations between 2005 and 2017. Since these are manual monitoring stations[16], the observations are recorded approximately twice a week. Therefore, each year, the ideal number of daily observations should be around 105. The station at SBES college consistently shows more than 30 days of threshold violations per year throughout the study period, which could be due to its location and the surrounding land use, as explained previously in this section.

Similarly, the analysis of timeseries of hourly concentrations of PM_{10} (i.e., RSPM) at the Waluj MIDC station shows numerous instances of concentrations breaking above the stipulated daily safety limit of 100 μg/m^3 (Refer Annexure 2-9).

Precisely, when aggregated to the daily scale, on 25% of the days, the daily averages were above the threshold. This amounts to a total of 920 days, with a majority of these crossings observed between November 2018 and May 2022.

Figure 5-10: No. of days PM_{10} crossed threshold each year at all manual AQMSs (2005-2021)



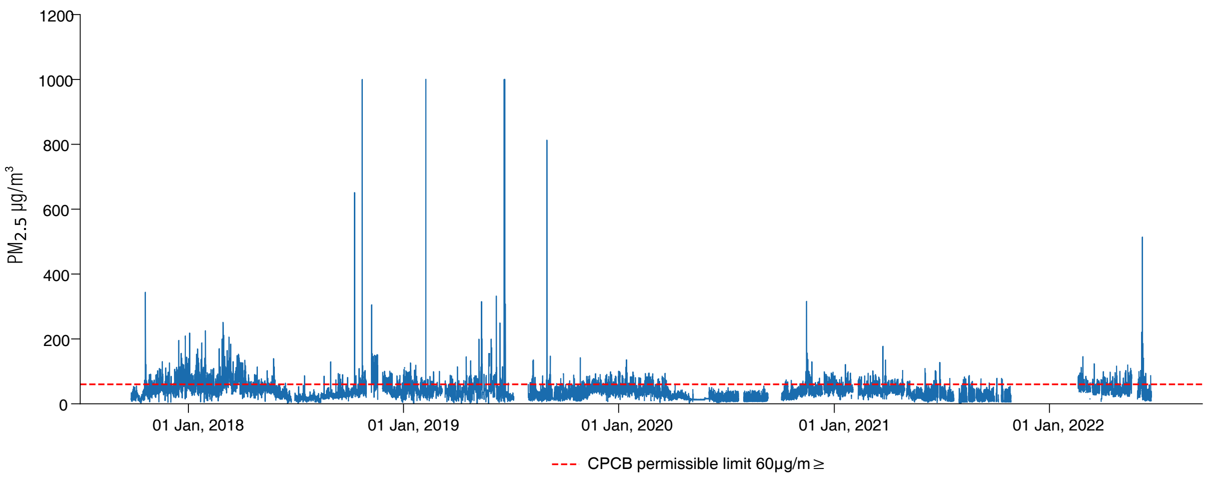
Source: Maharashtra Pollution Control Board

6. Analysis of concentration of $PM_{2.5}$

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 (sulfate, nitrate, and ammonium), and trace metal compounds (iron, aluminum, nickel, copper, zinc, and lead) largely formed from combustion and vehicular emissions (CPCB, 2020). Due to their extremely small size, these are easily breathable and give rise to a variety of health issues.

In Chhatrapati Sambhajinagar, 9% of the daily average concentrations are above the daily threshold of 60 µg/m^3 in the time period considered (from September 2017 to June 2022, see Figure 5-11). Specifically, based on the 3D charts shown in Annexure- 2-11, the winter months of November, January, and February and the morning-evening hours of 6 AM and 6 PM show relatively higher concentrations of $PM_{2.5}$. The total activity shutdown during the COVID-19 lockdown also led to a decrease in the highest concentration value, as seen from the colour scale in Figure 5-12.

Figure 5-11: Hourly $PM_{2.5}$ concentrations at the Waluj MIDC AQMS between Sept. 2017 and June. 2022

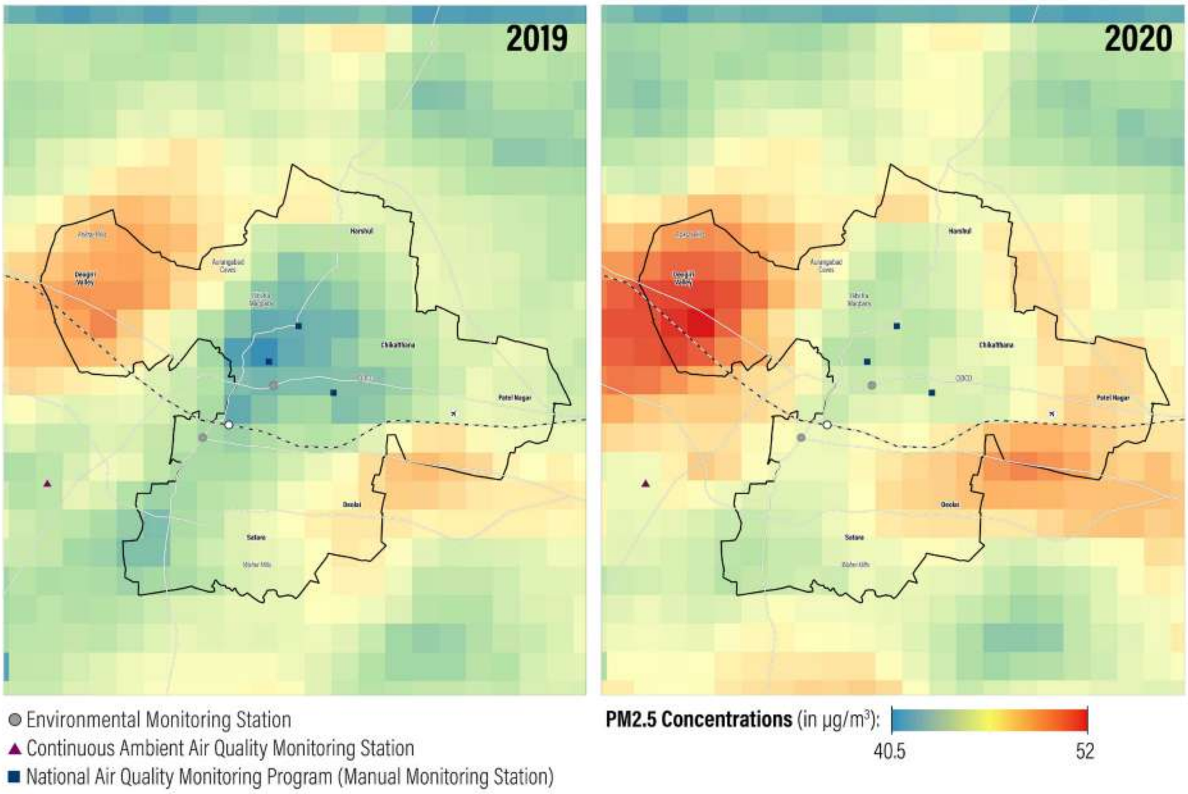


Source: WRI India using CAAQMS, CPCB, 2022

With regard to the spatial analysis, unlike other pollutants, $PM_{2.5}$ dataset is available until December 2020 only. As seen in Figure 5-12, the hotspot to the northwest is situated over a few industrial buildings. The SO_2 hotspot of Padegaon garbage depot and brick kilns is also close to this hotspot. Moreover, satellite imagery shows a lot of barren land and unpaved roads in this area, which could be suspending dust particles into the air, causing higher $PM_{2.5}$ emissions.

The hotspot to the southeast is also located over an industrial cluster on the city boundary. On another note, the low concentrations in the city center could be arising due to wind tunnel effect caused by mountain ranges to the north and south. This may be producing winds in the northeast-southwest direction.

Figure 5-12: Annual average concentrations of $PM_{2.5}$ in Chhatrapati Sambhajinagar between 2019 and 2020



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

5.2.2 Source apportionment study – key findings

The source apportionment study, which was carried out by IIT Bombay and NEERI, specifies the city's contribution of PM_{10} and $PM_{2.5}$ via various sources. Ambient air quality monitoring was conducted to understand the levels of particulate matter at four locations within the city.

Key findings from the ambient air quality monitoring:

- At Padampura, University campus, and Garkheda site, it was observed that PM_{10} concentrations were high and that they surpassed the CPCB threshold of 100 μg/m3. This may be due to the high traffic amalgamation concentration and industrial activities in the area.

Table 5-2: Location of Sampling sites

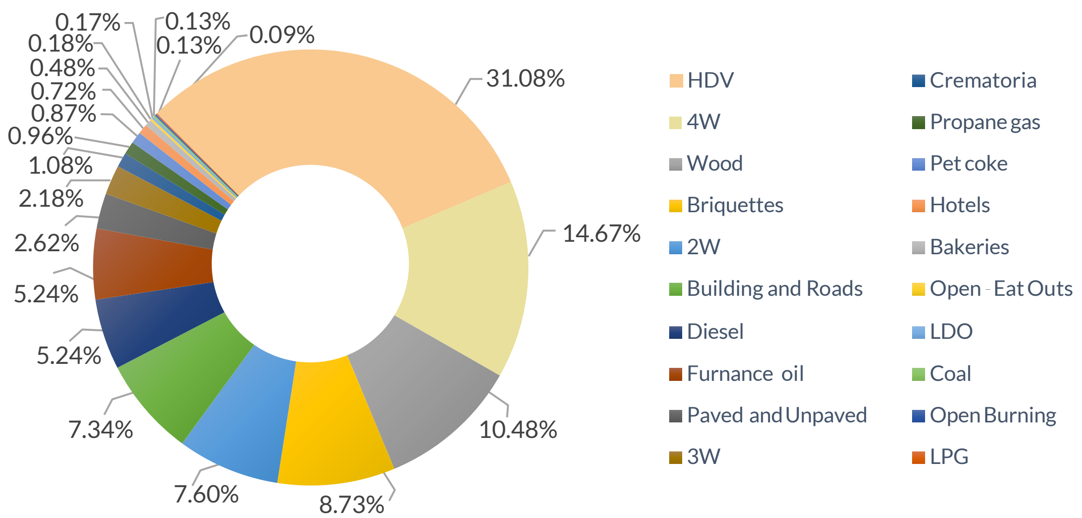
S.N.	Location	Type	Geographic Location
1	University Campus	Reference	19°53'45.30"N 75°18'43.61"E
2	Garkheda	Residential area	19°51'40.23"N 75°20'42.35"E
3	Padampura	Commercial area	19°51'57.58"N 75°19'7.27"E
4	MPCB office	Industrial area	19°52'26.07"N 75°23'10.64"E

- The $PM_{2.5}$ concentrations were well below the threshold of 60 µg/m3 at all the sites except at commercial area of Padampura.

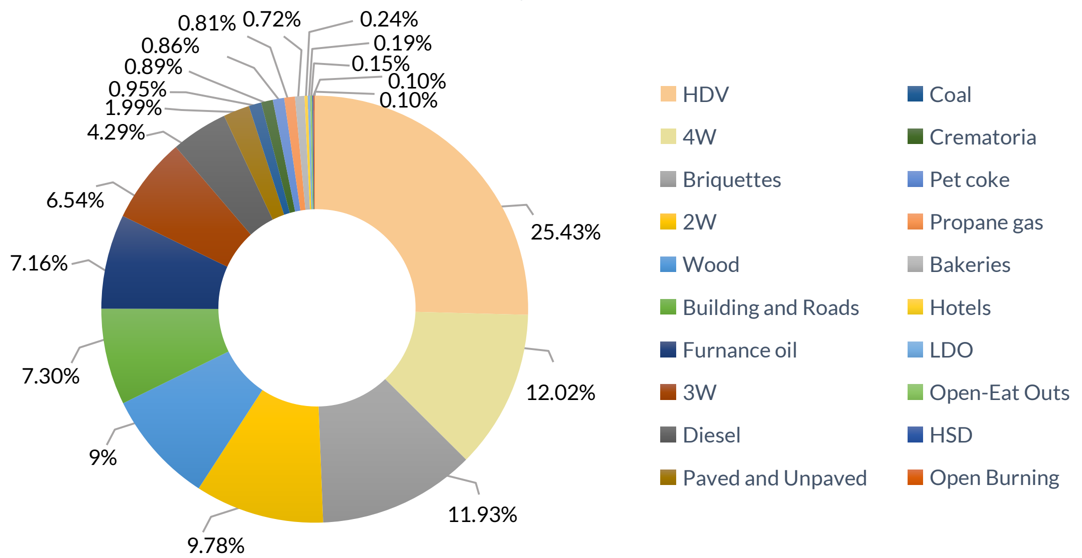
The source apportionment study categorises the emission inventory into three sources: area, line, and point. Area source includes emissions from domestic fuel consumption such as bakeries, hotels, dhabas, and open eateries. It also includes solid waste emissions. Line sources consist of vehicular emissions, and point sources include emissions from major air polluting industries within the city limits. The classification of the area, line, and point sources is given in Figure 5-13. For all the three sources, PM_{10} and $PM_{2.5}$ load is calculated.

Figure 5-13: Sector-wise contribution of PM_{10} and $PM_{2.5}$ in %

Source wise contribution to $PM_{2.5}$ load

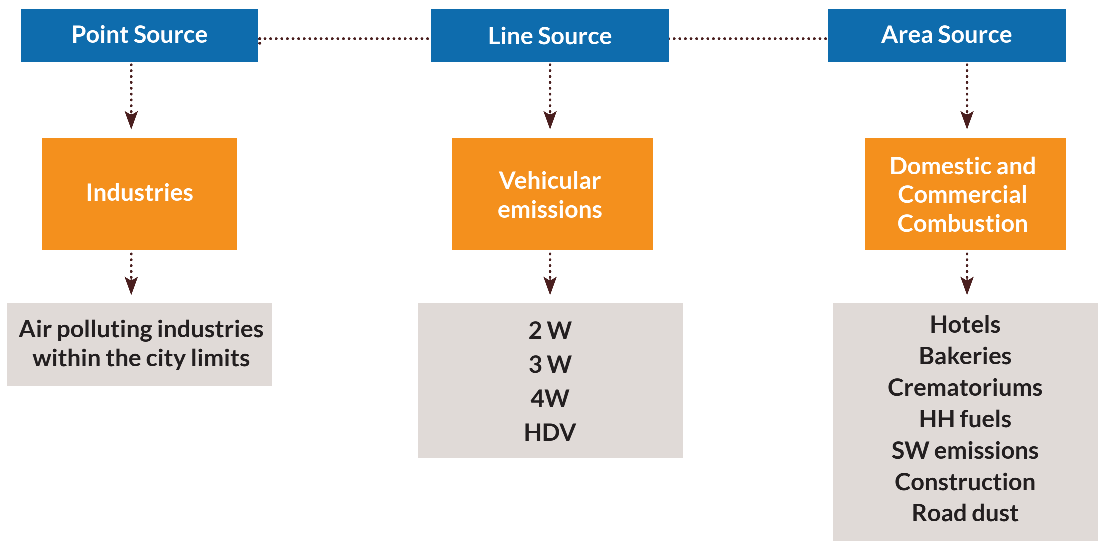


Source wise contribution to PM_{10} Load



Source: Air Quality and Emission Source Apportionment Studies for Aurangabad (2020)

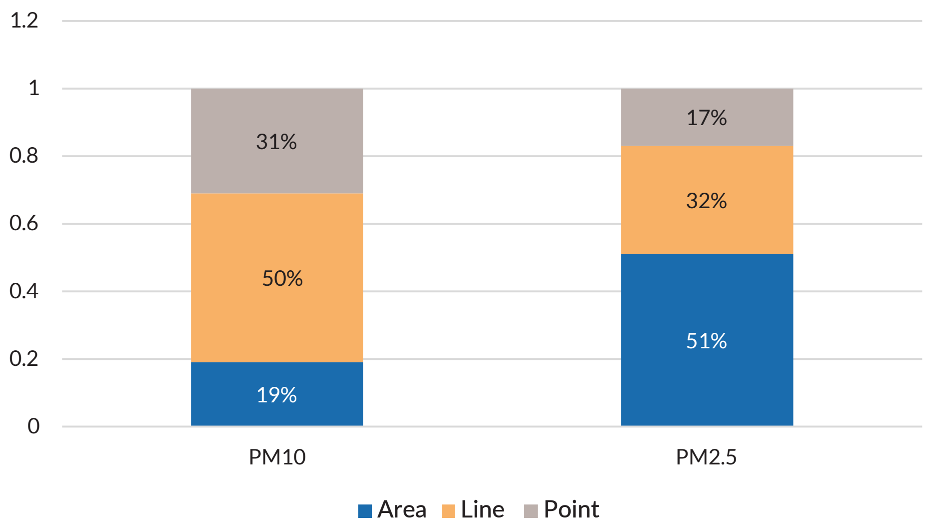
Figure 5-14: Categorisation of air pollution sources for the emission inventory study



Source: WRI Analysis, Air Quality and Emission Source Apportionment Studies for Aurangabad (2020)

The emissions inventory has calculated the percentages of PM_{10} and $PM_{2.5}$ load for all three sources is given in Figure 5-15.

Figure 5-15: Percent emission load from PM_{10} and $PM_{2.5}$ for the three sources



Source: WRI Analysis, Air Quality and Emission Source Apportionment Studies for Aurangabad (2020)

1. Key findings from the emissions inventory

From the above analysis, it is observed that:

- The line source is the highest polluter of PM_{10} in the city, while the area source is the highest polluter of $PM_{2.5}$ in the city.
- The highest PM_{10} emissions are from line sources (50%). Within the line sources, 50% of emissions are from Heavy Duty Vehicles (HDV), followed by 4-wheelers.
- Area sources emit the highest $PM_{2.5}$ emissions in Chhatrapati Sambhajinagar (51%). Within this, the highest emissions are contributed by building construction sites (58%).

2. Source and pollutants

- In the area sources, highest PM_{10} and $PM_{2.5}$ emissions are emitted due to building construction activities within the city (64% and 58%, respectively).
- In lines sources, the highest percentages of PM_{10} and $PM_{2.5}$ emissions are contributed by heavy duty vehicles (47% and 56%, respectively). This could be attributed to the high number of industries in and around the city and diesel as a fuel usage by the HDVs.
- For point sources, the highest percentages of PM_{10} emissions are emitted by industries using briquettes (34%), while the highest percentages of $PM_{2.5}$ emissions are coming from industries that use wood (33%)

5.2.3 Indoor pollution analysis

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

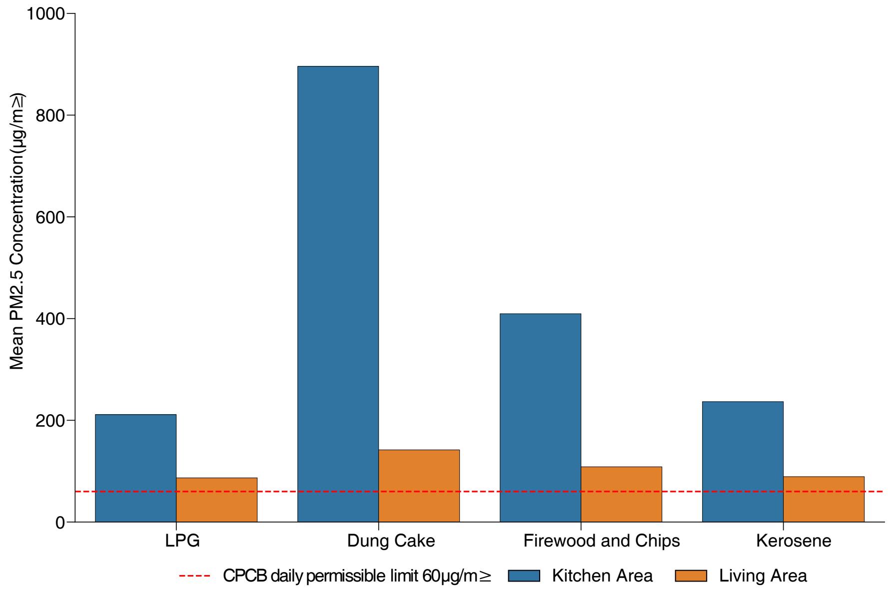
Indoor air pollution is often a forgotten aspect of air quality. However, various studies have shown that high concentrations of pollutants pervade Indian households. Of all the common domestic fuels, LPG, PNG, biogas, and electricity are considered as clean fuels while cow dung cakes, kerosene, coal, 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 based on the methodology adopted from Balakrishnan, et al. (2013). The effect of the polluting fuels on the indoor concentration of $PM_{2.5}$ is clearly seen, with cowdung cake showing the highest $PM_{2.5}$ levels due to its usage, followed by firewood/chips and kerosene.

As per Census 2011 data, in Chhatrapati Sambhajinagar, about 70% of the households use clean cooking fuel (LPG/PNG, biogas, electricity) as the daily cooking fuel. However, the city is yet to achieve the benefits of the PM Ujwala Yojana targeting 100% LPG prevalence.

About 20% of the households use kerosene as the daily polluting cooking fuel with households in wards 92 (Surana Nagar), 20 (Triveni Nagar), and 44 (Raheem Nagar) having the highest usage at 68%, 63%, and 54%, respectively. Firewood is the next most commonly used polluting cooking fuel, with 10% of the city households using it daily. The Satara locality and wards 21 (Aarati Nagar) and 23 (Savitri Nagar) have the highest consumption of firewood, at around 88%, 50%, and 42%, respectively.

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



Source: WRI India analysis using Census 2011 data

5.2.4 Health risk

Air pollution can have short and long term effects, both on human health and on the regional climate. Around four million people died in 2019 from exposure to fine particulate outdoor air pollution, with the highest death rates occurring in East Asia and Central Europe. In 2019, exposure to $PM_{2.5}$ reduced average global life expectancy by approximately one year[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 other illnesses, such as diabetes, and can hinder cognitive development in children and cause mental health problems.

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 dissolution of gaseous and physical particles. These conditions have impacts on humans inhabiting that 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 highest in order to implement solutions in the most efficient manner while ensuring economical use of resources.

In Chhatrapati Sambhajinagar, nitrogen dioxide (NO_2) and PM_{10} are the pollutants that have either crossed or have been reaching close to the safety thresholds defined by CPCB. NO_2 emissions primarily come from vehicular traffic, while PM_{10} are dust particles sourced primarily from construction, suspended road dust, stone crushing sites, etc. The source apportionment study also confirms that vehicular emissions are the primary source of PM_{10} in the city.

The temporal and spatial analyses show 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 carbon monoxide (CO), the summer of 2020 also shows unusually high concentrations.

Photo Credit: ASCDCL

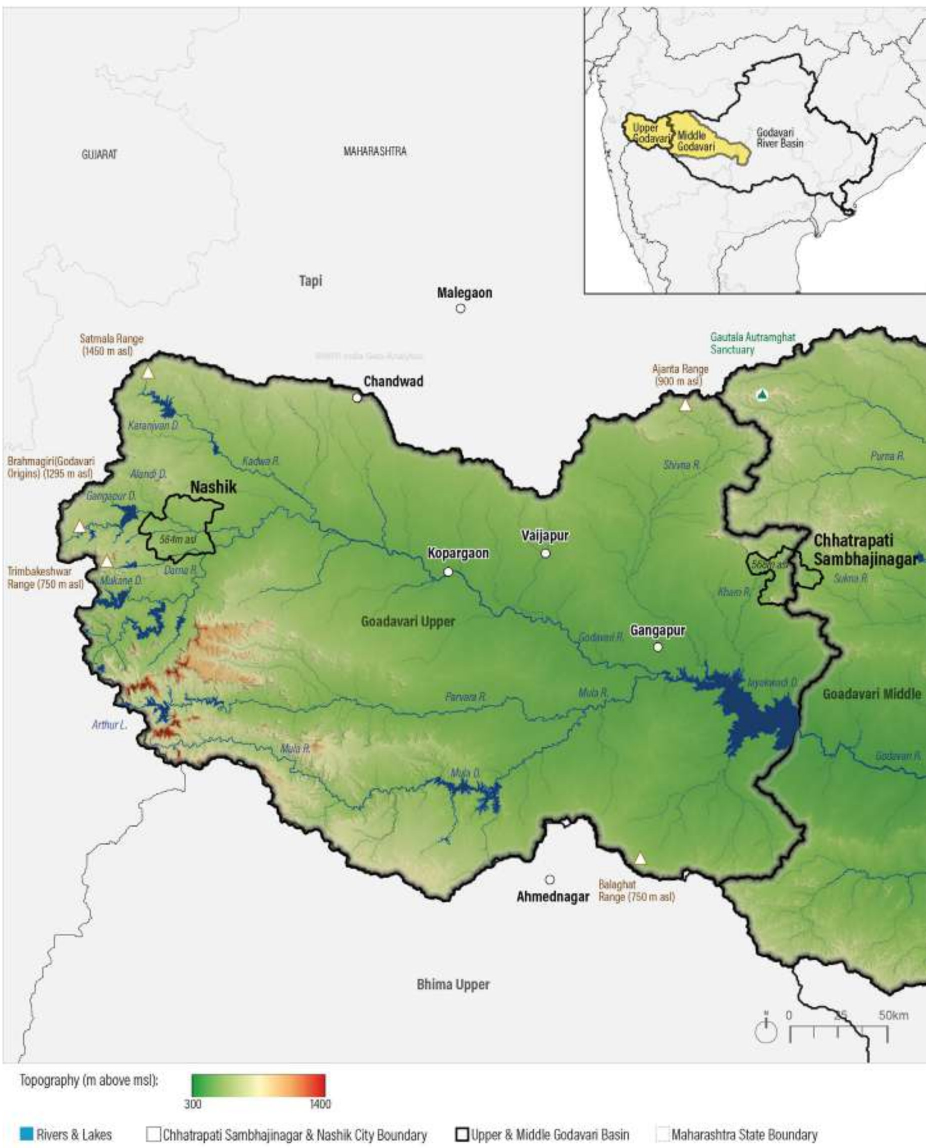
6. RAINFALL VARIABILITY AND WATER LOGGING

6.1 RAINFALL VARIABILITY

6.1.1 Regional Setting

Chhatrapati Sambhajinagar lies at an elevation of 568 m asl, along the divide of the Upper and Middle Godavari sub-basin. It fulfils its water demand from the Jayakwadi Dam located ~40 km south of the city. Two rivers, Kham and Sukhna, pass through the city, these are first-third order streams. The topography of the city is mostly plain, with a few hilly undulations lying towards the north and south of the city. In order to understand the risks of water availability for the city, analysis is done at a regional (sub-basin) scale (Refer to Figure 6-1). The dynamics of the surface and

Figure 6-1: Regional setting of Chhatrapati Sambhajinagar city located on the ridge line of the Upper and Middle Godavari River basin



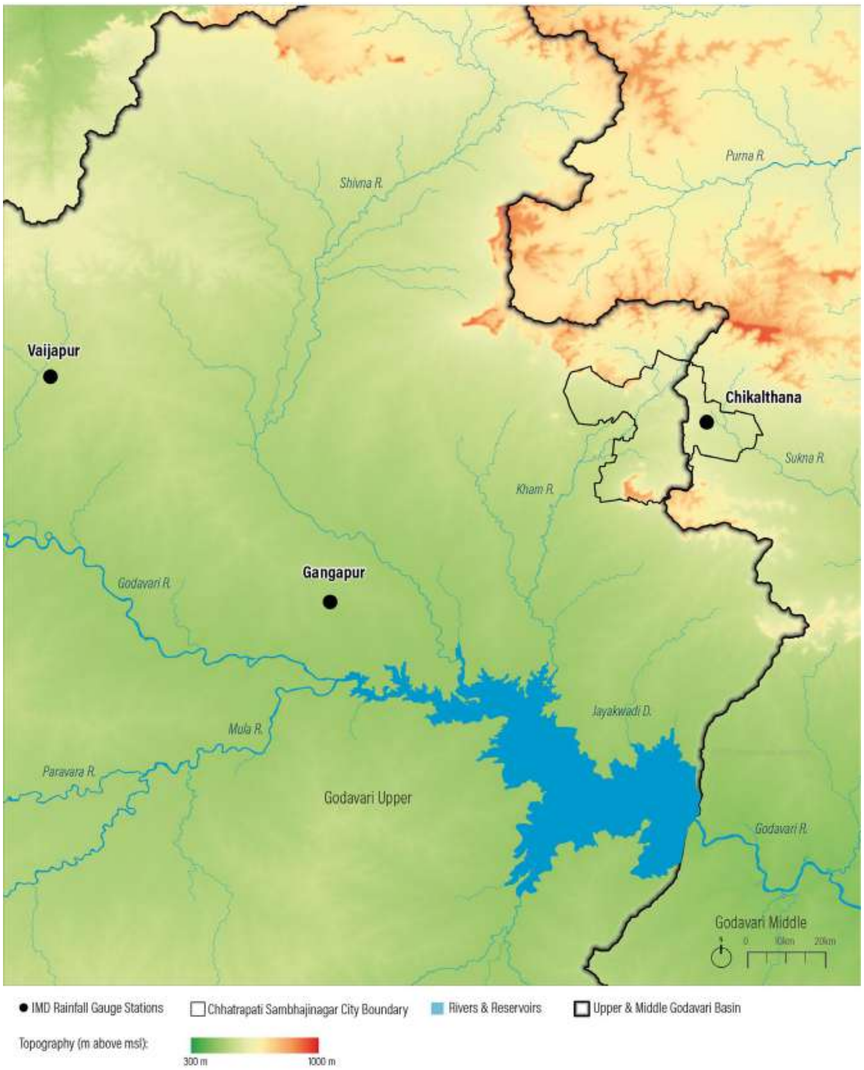
Source: WRI India using SRTM(USGS), CWC Streams, HydroBASINS level 4, HydroLAKES sub-surface water in the Upper Godavari basin (extending from the origins of the Godavari at Tribakeshwar to Jayakwadi Dam) has a direct impact on the water security of Chhatrapati Sambhajinagar.

6.1.2 Assessment

The assessment of rainfall variability is based on analysing two parameters: extreme rainfall events and its impact on Chhatrapati Sambhajinagar and the larger region. This analysis is carried out using rainfall data from IMD rain gauges in and around Chhatrapati Sambhajinagar to assess the long-term variation of rainfall patterns, including intensity, duration, and frequency (Refer to Annex 1-4).

Data from one IMD station within the Chhatrapati Sambhajinagar Municipal Corporation limit and two other IMD stations (one at Gangapur and another at Vaijapur) varying at 20-100 km in the region has been analysed (Refer to Figure 6-2).

Figure 6-2: Rainfall Gauge Network in and around Chhatrapati Sambhajinagar (along the lower reaches of Bhima River)



Source: WRI India using IMD Station Rainfall data and SRTM topography

Climate trends are in general described as the average weather conditions of a particular place over a 30-year period. Therefore, analysis is carried out using daily rainfall data from Chikalthana (51 years) located within the limits of the city boundary.

6.1.3 Key Findings

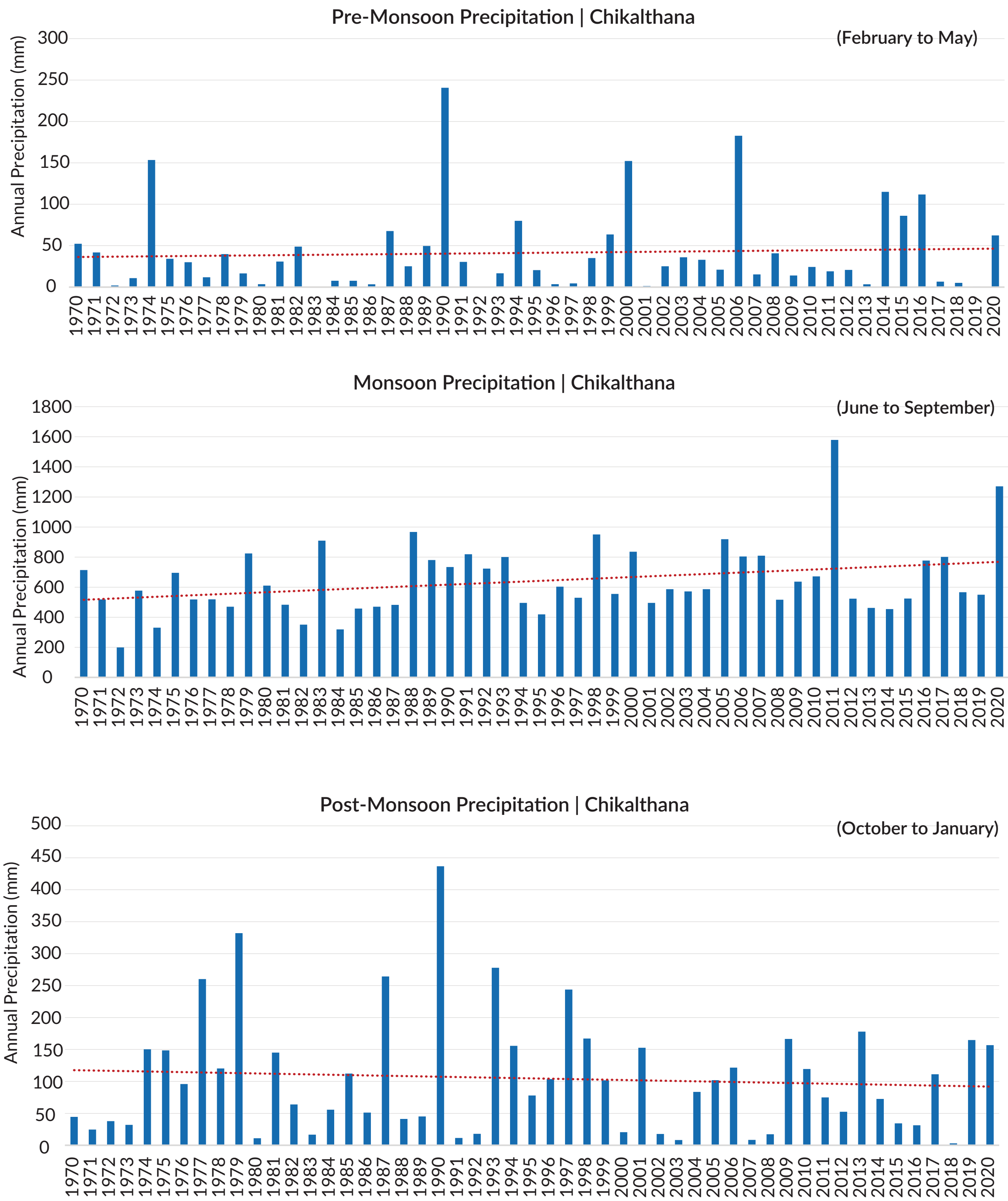
1. Long-term Rainfall Trends

The mean annual rainfall in Chhatrapati Sambhajinagar is ~788 mm, showing no significant trend. The average seasonal (accumulated) rainfall is ~40 mm during pre-monsoon, ~640 mm during monsoon, and ~100 mm during post-monsoon. The seasonal rainfall does not show any significant trend (Refer to Figure 6-3).

Chhatrapati Sambhajinagar receives low intensity rainfall between February and May (pre-monsoon). There are a few years where the pre-monsoon rainfall is > 100 mm. It does not rain for ~95% of the time during this time. In the five decades of daily accumulated rainfall, during monsoon, there were five instances of Very Heavy to Extremely Heavy Rainfall and during post-monsoon, there were five instances of Heavy Rainfall. Pre-monsoon rainfall included bouts of extreme rainfall events during the first three decades (Refer to Annexure 1-5). The contribution from these extreme events has significantly decreased in the last two decades.

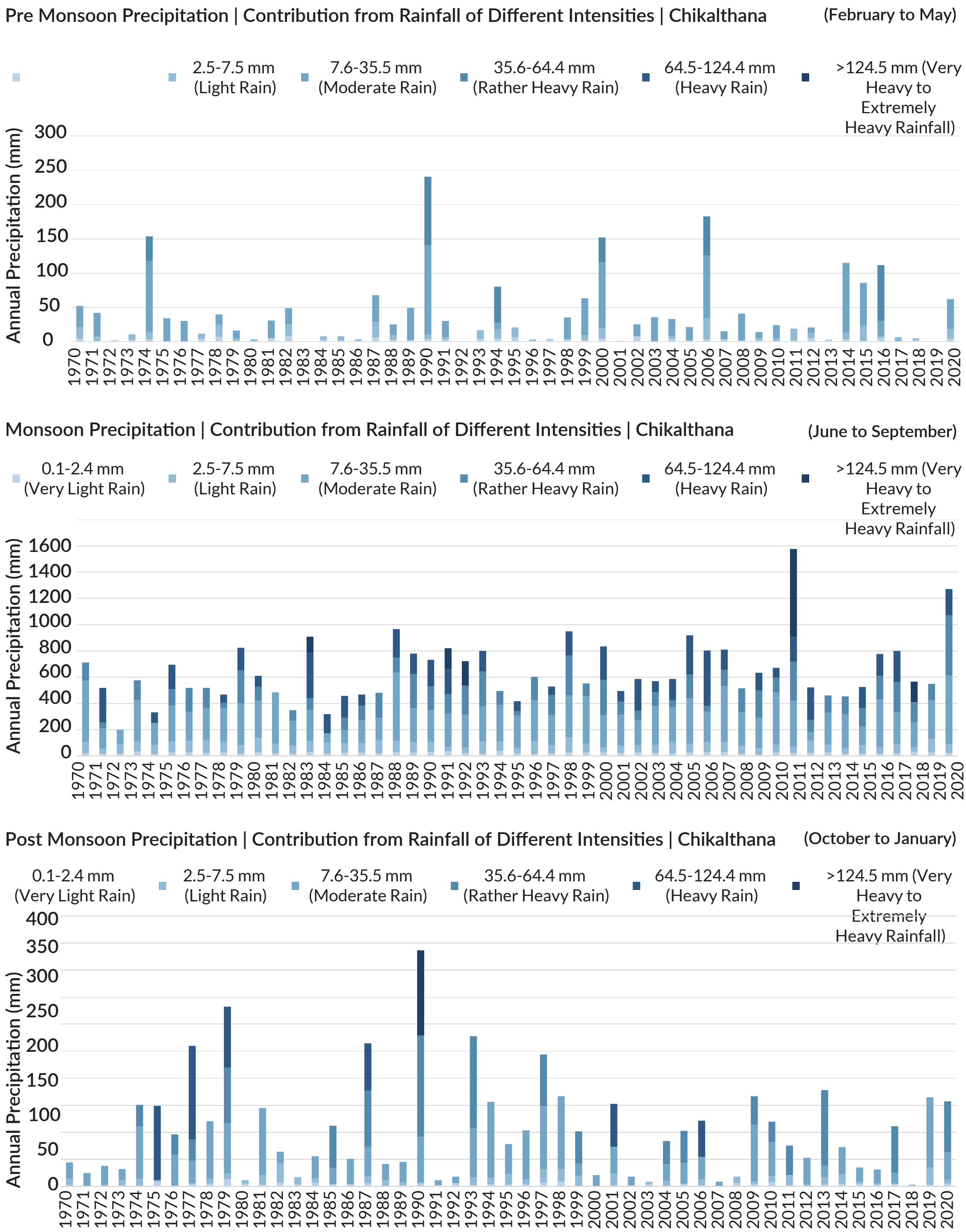
During monsoon, it does not rain 48% of the time, low intensity rainfall events occur for another 48% of the time, and extreme rainfall events for the remaining 4% of the time.

Figure 6-3: Annual Accumulated Rainfall by seasons between 1970- 2020, Chhatrapati Sambhajinagar Observatory



Source: WRI India using meteorological data from IMD

Figure 6-4: Seasonal Accumulated Rainfall with Contribution from Different Intensities at Chikalthana gauge station in Chhatrapati Sambhajinagar



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.

- **Frequency and Intensity of Extreme Rainfall Events**

The ERE (rainfall more than 35 mm per day) in Chhatrapati Sambhajinagar is usually of Rather Heavy intensity. There were six Very Heavy and Extremely Heavy intensity events in the years 1983, 1990-1992, 2001, and 2018. Chikalthana recorded 6 single extreme events (<1% frequency) of "Rather Heavy rainfall" intensity in the past 51 years during the pre-monsoon months Feb.- 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.

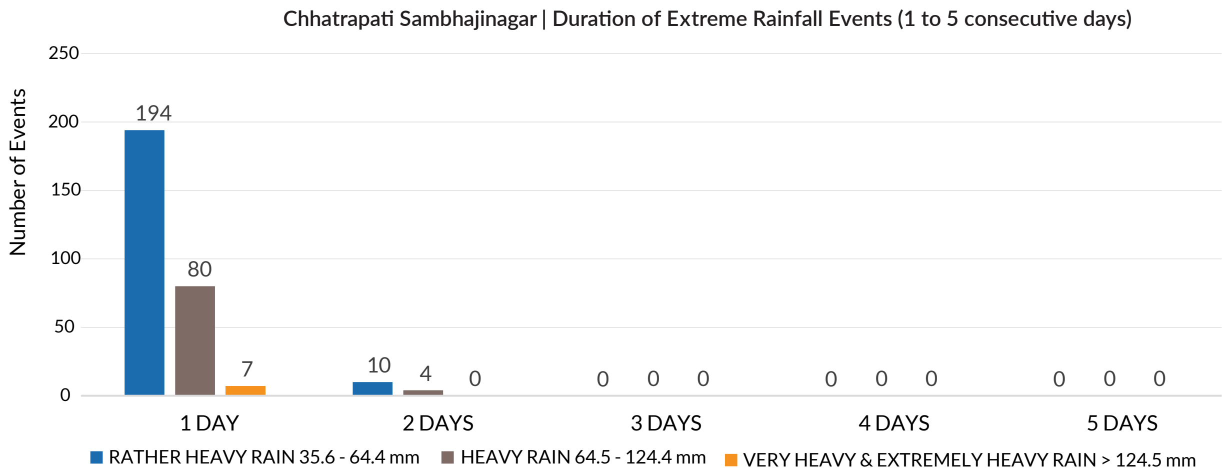
When it comes to understanding the dependency of the city on water resources and climate change, it is important to understand the spatial variation of rainfall in the watershed where the city is located. The rainfall patterns of the three IMD stations in and around Chhatrapati Sambhajinagar were analysed to observe the inter-annual variation of different frequencies of EREs (rainfall more than 35 mm per day) detailing the recurrence of different intensity rainfall events in the region. The city frequently receives rainfall of intensities varying from Moderate to Extremely Heavy Rainfall. On the other hand, we see that the stations located to the west of the city, along the Upper Godavari River recorded relatively lower frequencies of different rainfall intensities (Refer Annexure- 2-13).

- **Duration of Extreme Rainfall Events**

Analysis shows that the region receives rainfall that lasts for one or two days, with no occurrences where the rainfall continued for 3-5 days. Most ERE tend to last only a single day, as seen in Figure 6-5. 1% of all Rather Heavy ERE in the last five decade were not one-off events. Similarly, 0.4% of Heavy ERE lasted more than a day (Refer to Figure 6-5). EREs that last for more than a single day are responsible for waterlogging in areas where the drainage infrastructure capacity gets overwhelmed by excess overland flows (Refer to Annexure 1-5).

The majority of the rainfall occurs during the monsoon months June- September. The number of extreme events with frequencies of 1 – 9 % during monsoon in the last two decades has increased. The number of extreme events during post-monsoon (from Oct. to Jan.) has decreased and has frequencies of 1 – 3% in the last two decades (Refer to Annexure 2-12).

Figure 6-5: Duration of Extreme Rainfall Events based on Intensity and Number of Events (1970 – 2020)



Source: WRI India using meteorological data from IMD

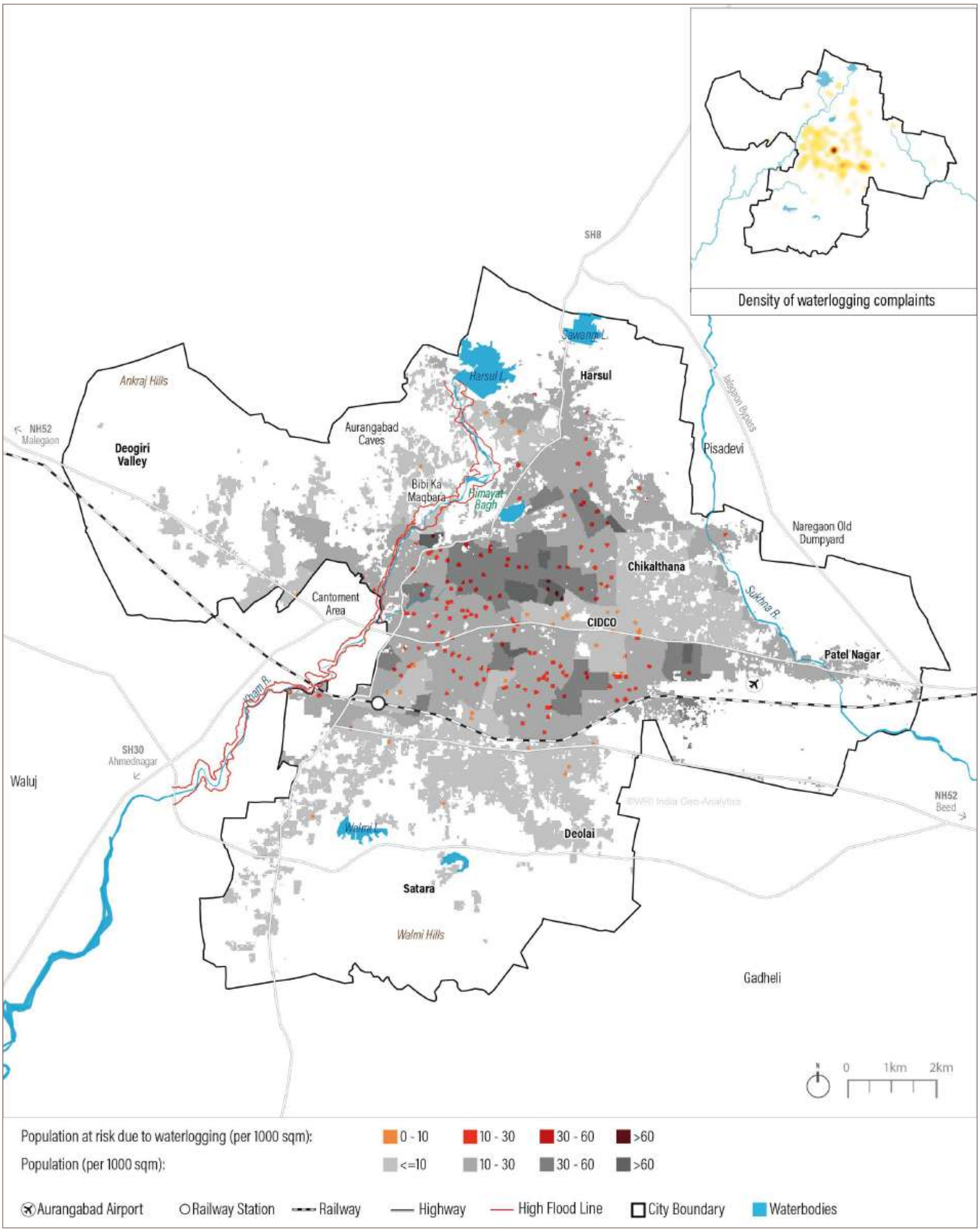
6.2 URBAN WATERLOGGING RISK

This parameter is used to spatialise the risk due to waterlogging. Identifying differential impact would be facilitated by correlating waterlogging hotspots with population density, informal settlement locations, and the degree of jobs and public transportation that would be affected. The Fire Department, Chhatrapati Sambhajinagar Municipal Corporation, has compiled a list of places that have experienced recurrent flooding in the form of pumping calls received from waterlogged areas. The effects of waterlogging on the population, informal settlements, jobs, and public transportation have been assessed using a 50-meter buffer zone surrounding the affected areas.

6.2.1 Waterlogging Hotspots and Population Affected

Based on the waterlogging data from CSMC, it can be observed that the concentration of waterlogging hotspots is scattered within the central region of the city. This region is densely populated as compared with the periphery of the city. Overlaying the hotspots with the population density and subsequent intersection with the ward boundary helps in identifying vulnerable communities to streamline action on ground. Within CSMC, 2.7% of the population is within a 50m buffer of these flooding hotspots (Refer Figure 6-6).

Figure 6-6: Population Potentially at Risk due to Waterlogging

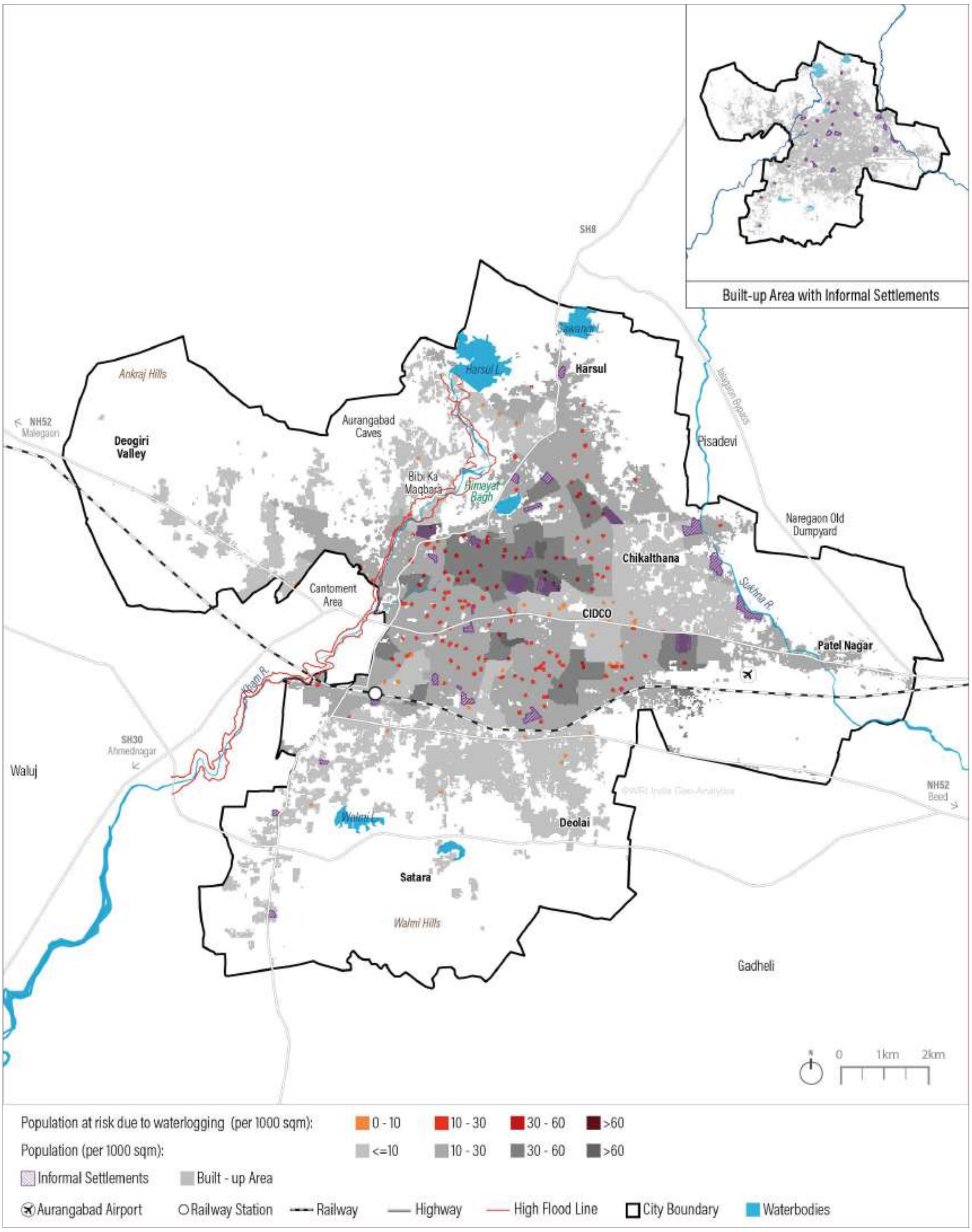


Source: Census 2011, WSF Evolution 2019, Chhatrapati Sambhajinagar Municipal Corporation, WRI India 2022

1. Waterlogging Hotspots and Informal Settlements

There are 25 locations for informal settlements identified by the CSMC, where nearly 5% of the population dwells. Amongst the 25 informal settlements, 5 of them (at Ghati, Gautam Nagar, Ambedkar Nagar, Shanoorwadi, and Indira Nagar) are exposed to recurrent waterlogging. The population that is at a risk of waterlogging within these informal settlements is about 3% (Refer Figure 6-7).

Figure 6-7: Population along with Informal Settlements Potentially at Risk due to Waterlogging



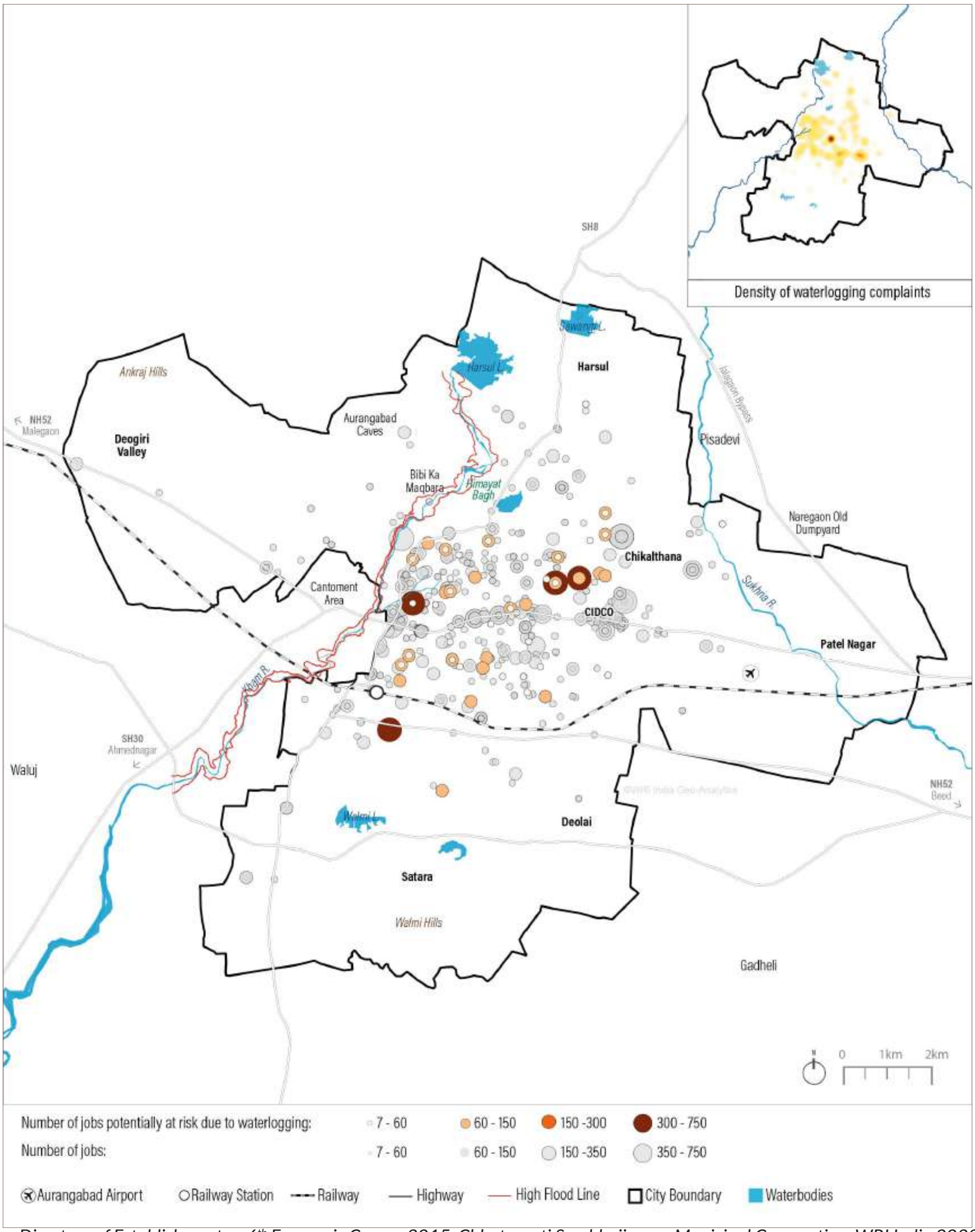
Source: Census 2011, WSF Evolution 2019, Chhatrapati Sambhajinagar Municipal Corporation, WRI India 2022

2. Jobs affected due to waterlogging

The 50m buffered waterlogging hotspots was overlayed with employment data obtained from Directory of Establishments. Recurrent waterlogging events limits the means to access business centres, impacting the daily wage/ industrial jobs the most (UNICEF, 2021).

A majority of the jobs that are affected by waterlogging are in four wards (59, 60, 62 and 68), which includes areas of Nutan Colony, Vijay Colony, and Ajabnagar (Refer Figure 6-8).

Figure 6-8: Job Potentially at Risk due to Waterlogging

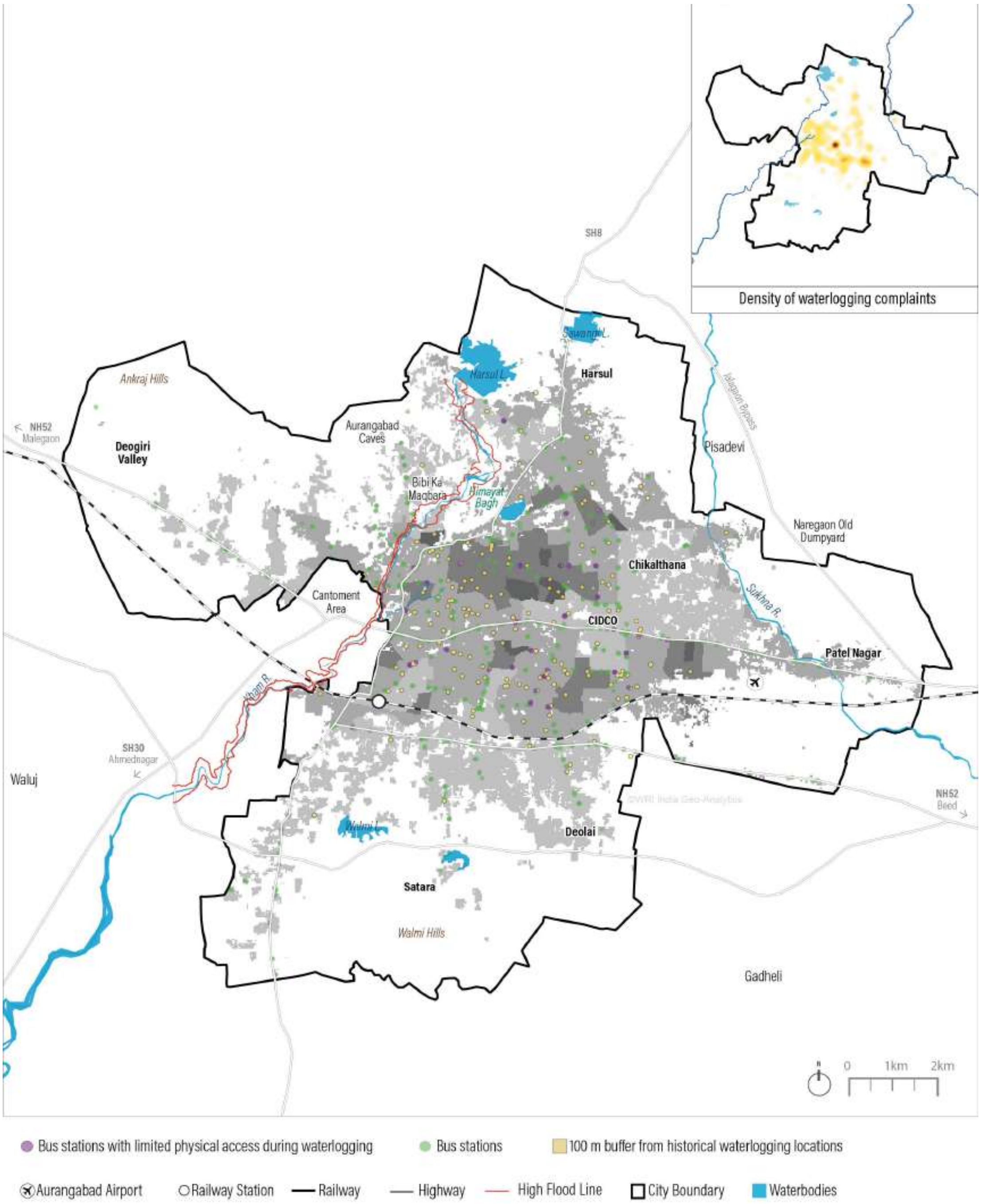


Source: Directory of Establishments – 6th Economic Census 2015, Chhatrapati Sambhajinagar Municipal Corporation, WRI India 2022

3. Public Transport affected due to water-logging

The city has a total of 584 bus stops out of which 55 are located within the 50m buffered waterlogging zones. That is, nearly 9.5% of the public transport system is compromised when there is excess rainfall that causes waterlogging. These affected locations would cause a hindrance to the daily commute of the population that are being serviced with the help of the public buses (Refer Figure 6-9).

Figure 6-9: Public transport stations potentially at Risk due to Waterlogging



Source: Chhatrapati Sambhajinagar Municipal Corporation, WRI India

Photo Credit: ASCDCL

7. DROUGHT RISK

A drought occurs when it rains less than usual in a place for a long period of time. When it does not rain for a long period of time, the amount of water available decreases. This means that 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 how long there isn't enough water, droughts happen in this order: meteorological drought, hydrological drought, agricultural drought, and then 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:

- 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.
- 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 water.
- 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.
- 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 can also be irregular and unpredictable. So, it is important to be prepared to face them.

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 considered for the analysis (Refer to Annex 1-6).

7.2 PROBABILITY OF METEOROLOGICAL DROUGHT

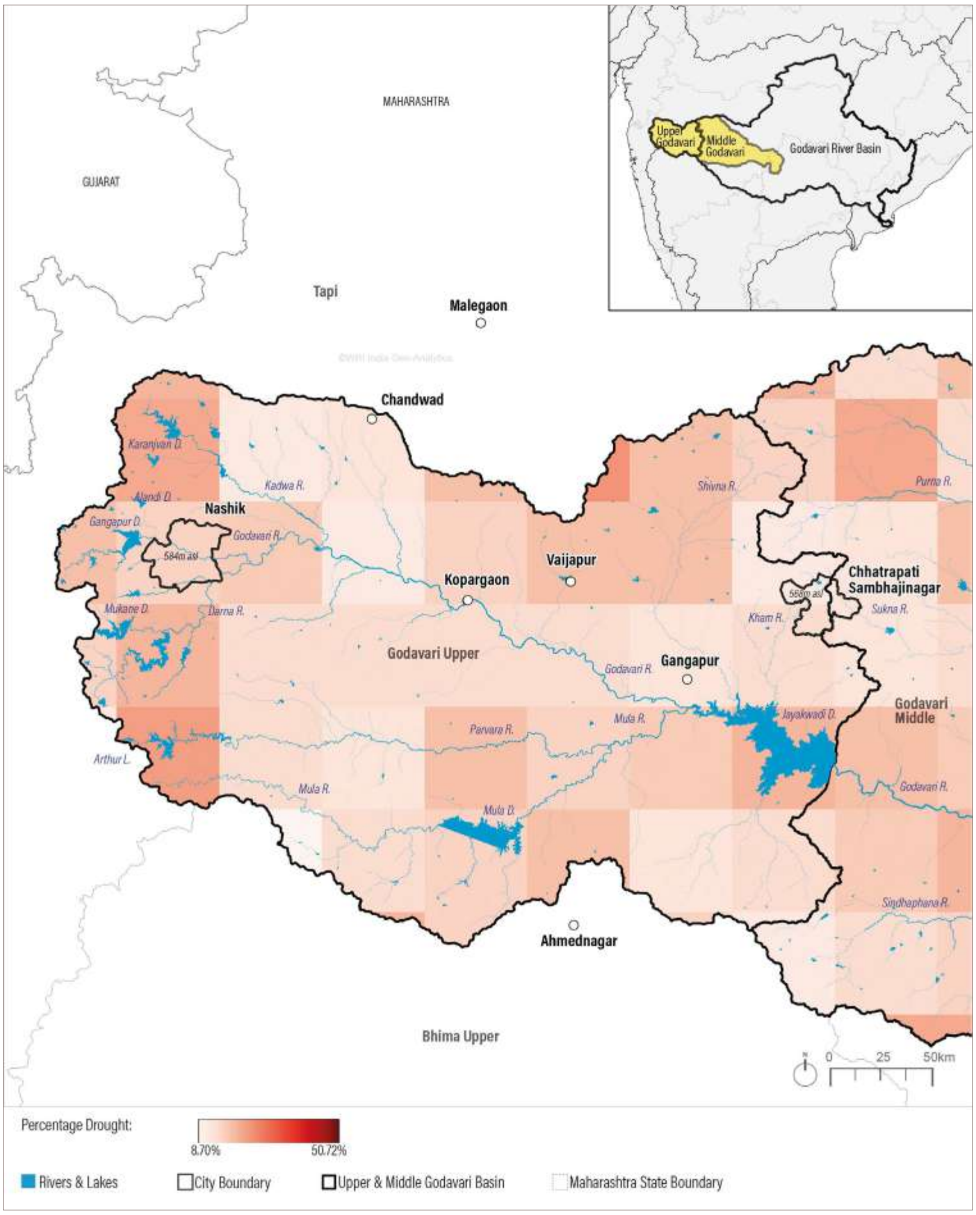
The probability (expressed as a percentage) of meteorological drought is calculated for each grid in the Upper and Middle Godavari sub-basins.

For the catchment, the chance of drought is between 8% and 50%. Chhatrapati Sambhajinagar is located near the outlet of the Upper Godavari at the Jayakwadi Dam.

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 12%.

Since the probability of drought is less than 25%, the city falls within the 'normal' condition. The region in the upper stretches of the Godavari River, near Nashik, have several reservoirs that impound water and feed the Jayakwadi Dam downstream. Any water stress experienced in these upper stretches of the river 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

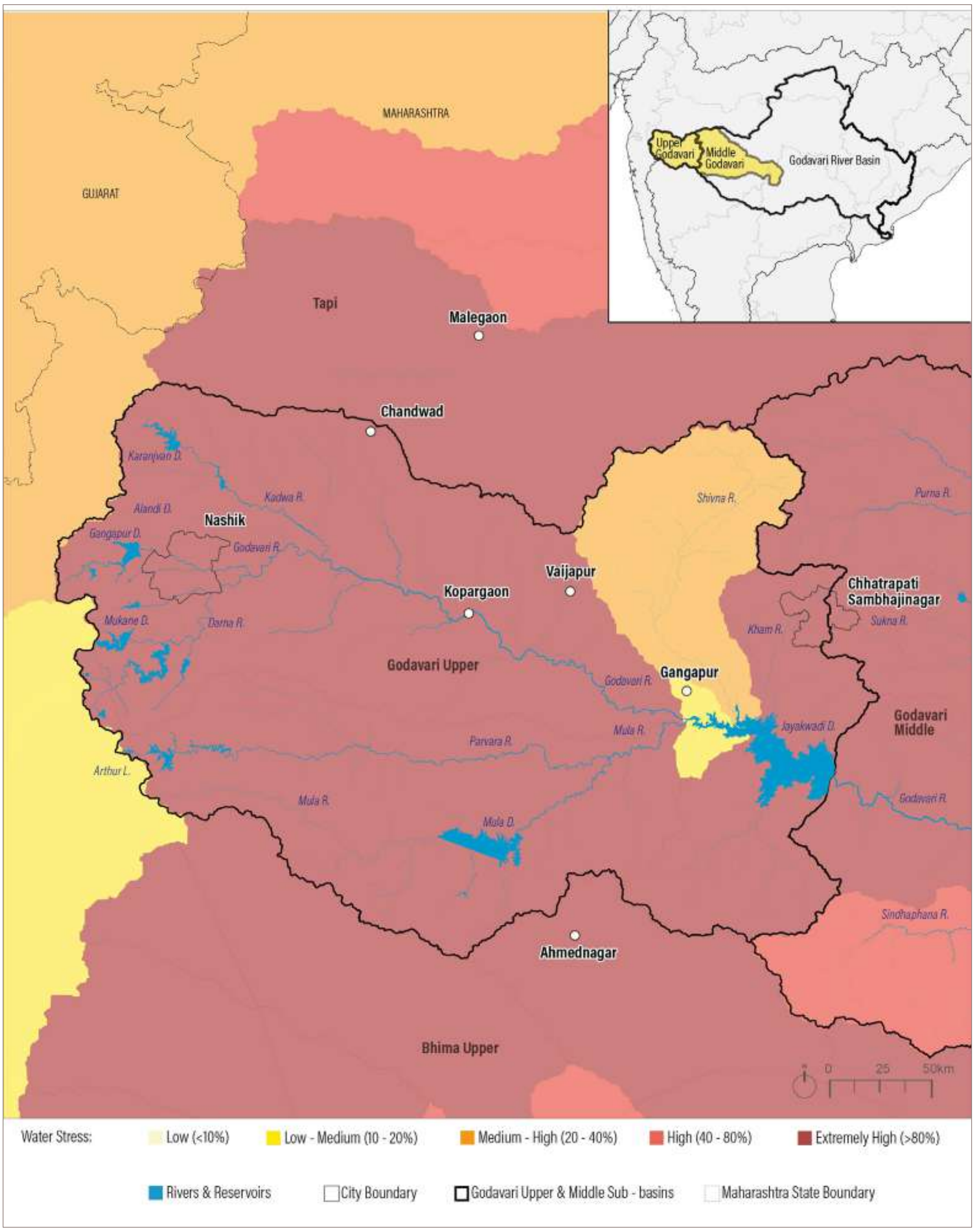


Source: WRI India using IMD Gridded Rainfall, SRTM (USGS), CWC Streams, HydroBASINS level 4, HydroLAKES

7.2.1 Water Stress and Drought Risk

According to WRI Aqueduct, Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar 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 (Refer to Figure 7-2). This can lead to a shortage of water for various uses and may also cause conflicts between different users of the water.

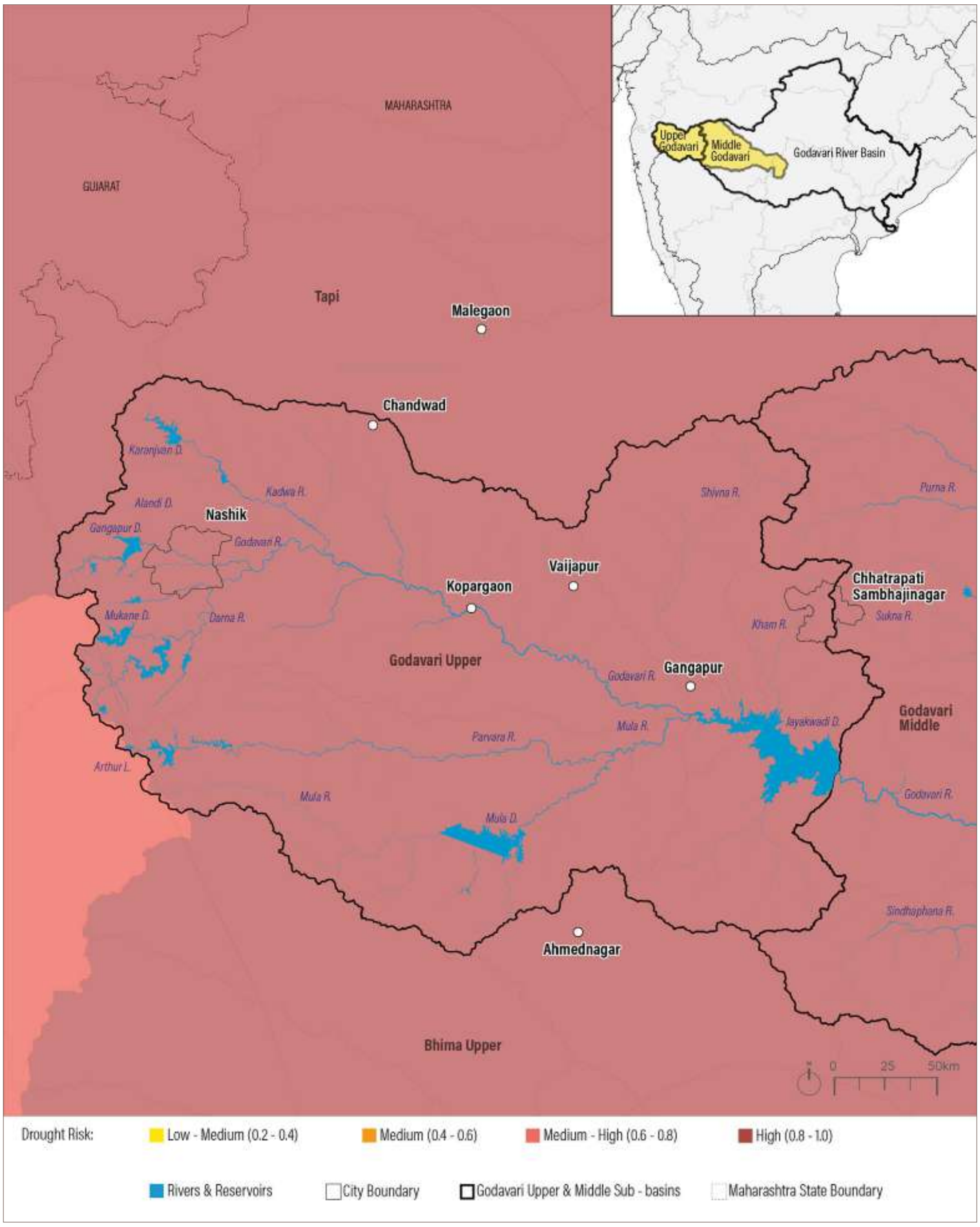
Figure 7-2: Water Stress



Source: WRI India using WRI Aqueduct

The state of Maharashtra, including Chhatrapati Sambhajinagar, is facing severe drought conditions. The Upper-Godavari sub-basin, in which Chhatrapati Sambhajinagar city is located has a high (0.8 – 1.0) drought risk (Refer to Figure 7-3). Drought risk measures 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 this can be attributed to the decrease in rainfall and over-extraction of groundwater. Drought conditions can lead to crop failures and loss of livelihoods for farmers, water scarcity for drinking and other daily uses, as well as exacerbate poverty and food insecurity in the region.

Figure 7-3: **Drought Risk**



Source: WRI India using WRI Aqueduct

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.

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%) (Refer to Annex 1-7 and Figure 7-4).

1. Variation in Stage of GW Development for Aurangabad District

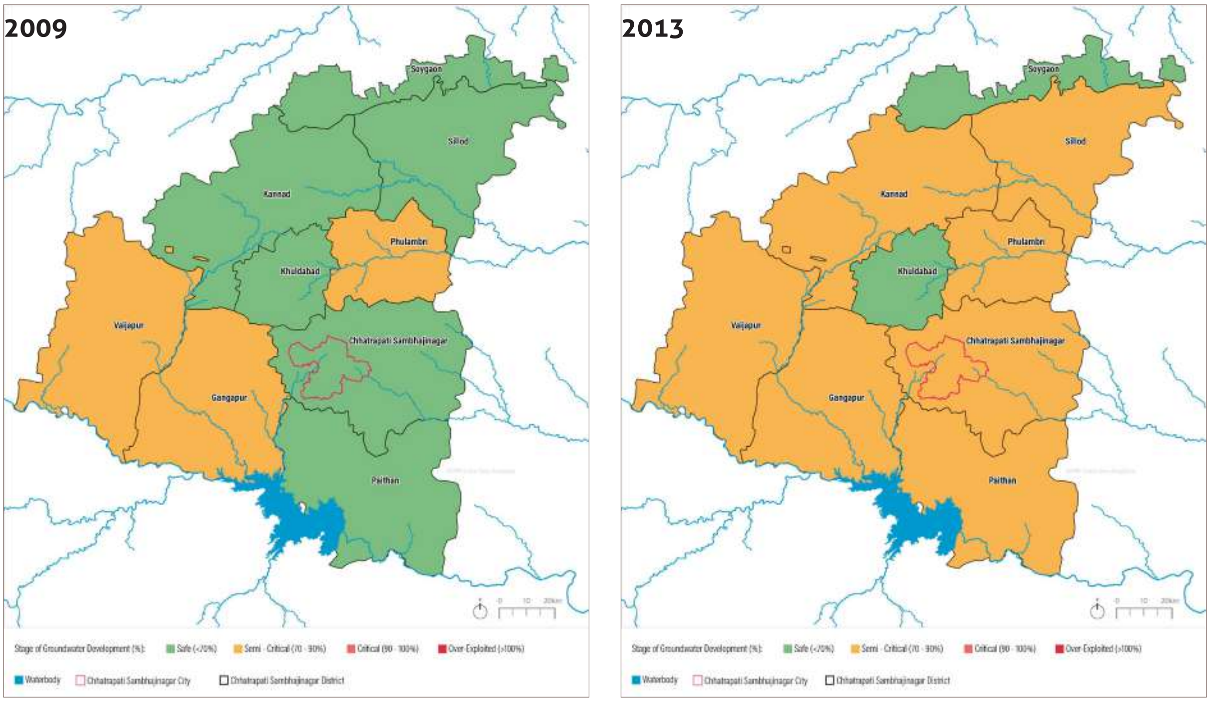
The stage of groundwater development was obtained from various CGWB reports. The several districts of Aurangabad exhibit a variation from safe to semi-critical. The Table 4-8 shows the variation in the stage of GW development for two years – 2009 and 2013. The overall stage of groundwater development decreased from 92 to 76 percent in 5 years. Khuldabad and Soygaon are two districts that are 'safe' while the remaining 7 districts are 'critical'. Aurangabad city lies in the 'critical' zone. Although Soygaon is classified as 'safe', the stage of groundwater development nearly doubled in 4 years from 35 to 65 percent. More recent data regarding the stage of groundwater development is not available.
If history must be an indicator of the present, it is highly probable that most of the districts have moved from 'semi-critical' to 'critical' or 'over-exploited'. Figure 7-4 shows the variation in the stage of GWD for Aurangabad district as published in CGWB reports.

Table 7-1: Evolution of Stage of Groundwater Development in Aurangabad District.

Year	2009	2013
Administrative Unit	Stage of GW Development	
Aurangabad	66.92	76.34
Phulambri	84.34	83.24
Gangapur	76.59	84.75
Kannad	56.65	71.89
Khuldabad	54.66	65.13
Paithan	49.00	71.97
Sillod	57.55	74.27
Soygaon	34.88	65.76

Year	2009	2013
Administrative Unit	Stage of GW Development	
Vaijapur	72.65	83.76
District Total	91.99	75.92

Figure 7-4: Stage of GW Development for Chhatrapati Sambhajinagar District



Source: WRI India and CGWB publication 2019

7.3.2 Groundwater Recharge Potential

1. Assessment

One of the major problems faced by Chhatrapati Sambhajinagar is that it is water stressed. Most of the water resources available from the Jayakwadi Dam is utilised for domestic and irrigation purposes. 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.

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, which is represented by NDVI (Refer to Figure 4-13, 4-14). Depending on the rainfall, slope, and NDVI classification, a weighted mean is used to calculate the GWRP on a scale of 0 to 5; 0 is no recharge, 1 is low recharge potential, and 5 is high recharge potential. The GWRP for Chhatrapati Sambhajinagar 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).

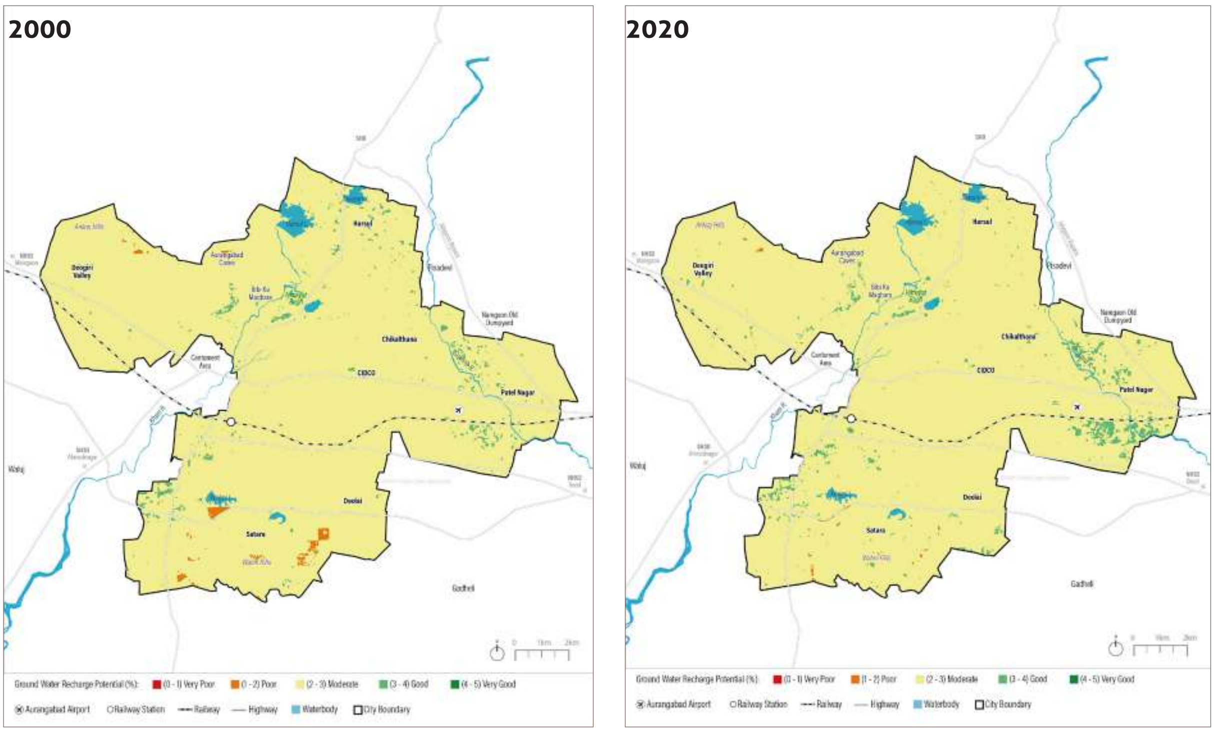
Table 7-2: Parameters used to calculate GWRP

Dataset	Description	Resolution	Reference Period
Historical Rainfall	Long-term mean annual rainfall	0.25 degrees	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 groundwater recharge potential throughout its limits while the recharge potential improves to good around the waterbodies as well as towards the east of the city along the Sukhna river. The region to the south of the city had areas that had 'poor' recharge potential in the year 2000, which has improved to 'moderate' in the year 2020 (Refer to Figure 7-5). The region to the east of the city has also seen an increase in GWRP. This is due to the nature of the agriculture fields in this region, which must have been devoid of green cover for the period 1999-2000 as compared with 2019-2000.

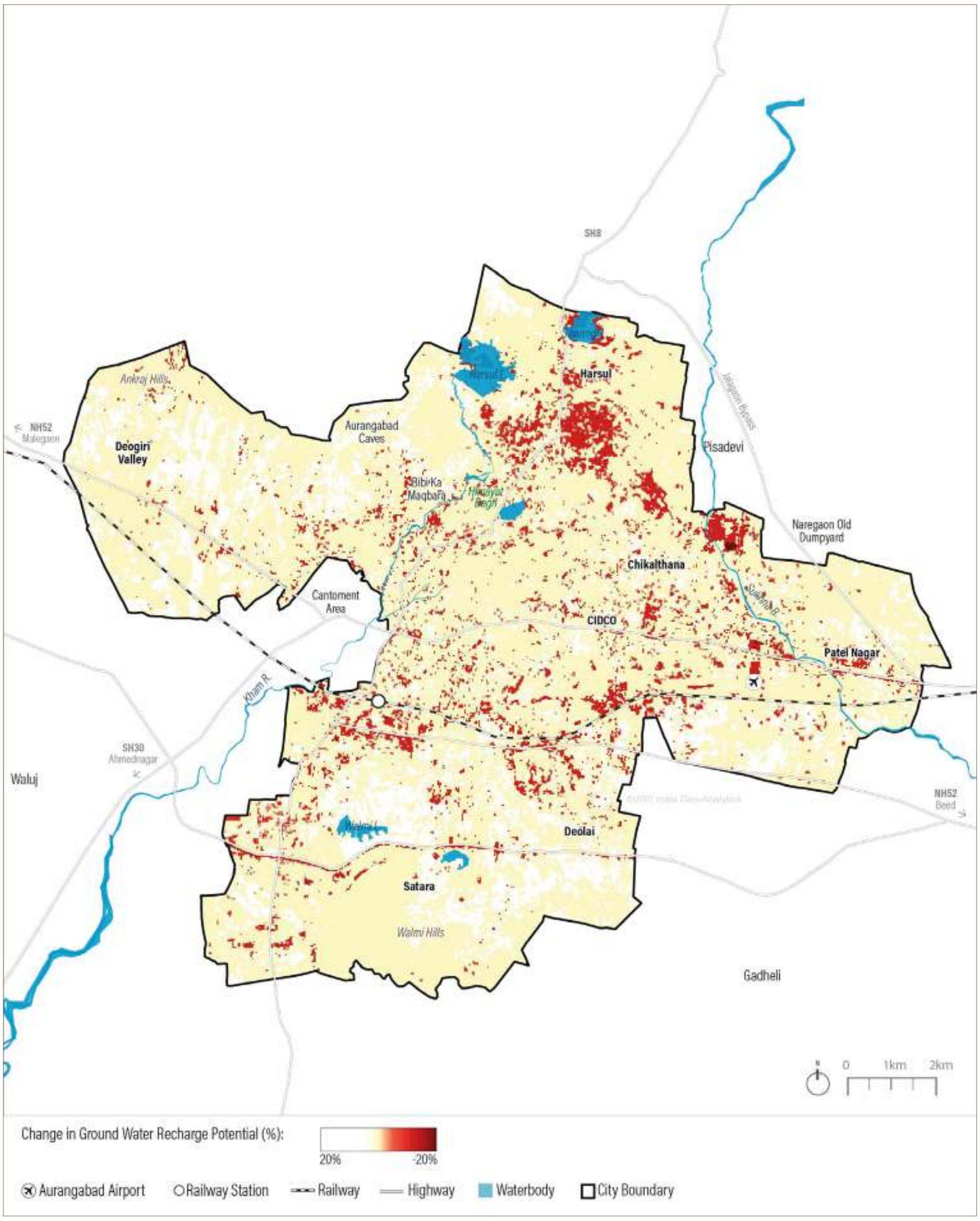
Figure 7-5: GWRP for two time-periods, two decades apart



Source: WRI India, SRTM topography, Landsat 7 NDVI, IMD Gridded Rainfall

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 has a negative change in GWRP i.e. the excess water on the ground in no longer infiltrating into the GWT due to the impervious nature of the recently developed areas. The development of the region towards the north-east of the city, areas of Misarwadi, Harsul, Ramabai Chowk, etc. (wards 2, 7, 8, 33, 34, and 35) has caused a significant decrease in GWRP, as shown in Figure 7-6. There has been significant development of real estate in this region, which has resulted in a concentrated decrease of GWRP in the form of three clusters.

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



Source: WRI India, SRTM topography, Landsat 7 NDVI, IMD Gridded Rainfall

Photo Credit: ASCDCL

8. MULTI-HAZARD ANALYSIS

Certain zones of the city are at a risk of more than one hazard. The concept of 'multi-hazard risk' refers to the overlap of urban neighbourhoods that are especially at danger from more than one climate-related threat. 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.

8.1 CONTEXT

Chhatrapati Sambhajinagar experiences higher LST during the summer months and recurrent waterlogging during monsoon. These hazards are persistent to the population for nearly half of the year. In this regard, we use these two layers to assess the city's vulnerability to these hazards.

8.2 METHODOLOGY

The layers mentioned in Table 8-1 are overlaid for multi-hazard analysis where city's average LST is 32.5°C.

Table 8-1: Parameters used to calculate Multi-Hazard Risk

Layer	Source	Method Used
Land Surface Temperature	Landsat 8 (30m)	The pixels from the population layer falling in areas exposed to LST greater than 32.5°C are extracted.
Waterlogging	Chhatrapati Sambhajinagar Fire Department	A buffer of 50m is considered from the identified hotspot.

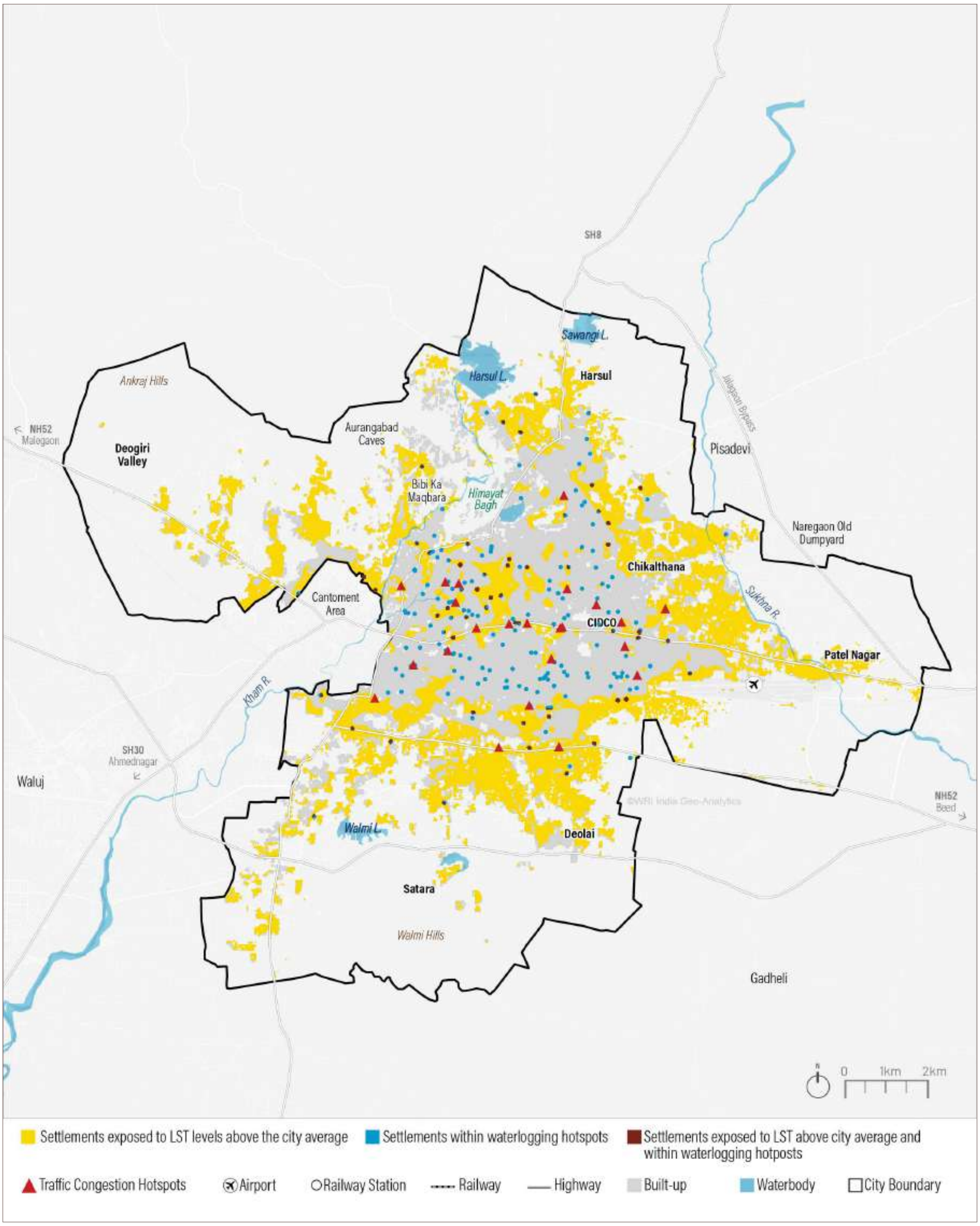
8.3 KEY FINDINGS

The analysis shows that nearly 36% of Chhatrapati Sambhajinagar's population is exposed to the LST levels above 32.5°C. A majority of this population reside on the periphery of the city rather than the central part. Also, 2.9% of the population live within the waterlogging hotspots that are well distributed across the central city, as identified by the officials of the fire department. There is significant overlap of higher temperatures and waterlogging incidents towards the core of the city.

Higher temperatures dry out the top layer of soil, significantly slowing down the percolation of water, adding to waterlogging, depletion of groundwater, and urban flooding. A combination of high temperatures and waterlogging also proves detrimental to plant health, leading to root rot and stem decay. Diminished green cover leads to higher temperature and retention of heat.

Approximately 0.7% of Chhatrapati Sambhajinagar's population is vulnerable to both above average LST and waterlogging. Some of these population reside around Juna Mondha, Rengatipura, east of CIDCO, etc. A significant portion of Shanoorwadi slum is exposed to both risks. 6 schools and 10 hospitals are at multi-hazard risk (Refer Figure 8-1).

Figure 8-1: Multi-hazard Risk Zones for Chhatrapati Sambhajinagar City



Source: Chhatrapati Sambhajinagar Municipal Corporation, Landsat 8, WRI India 2022

SECTION -III: Vulnerability Assessment

Photo credit: WRI India

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 demographic, social, economic, and physical-environment related indicators in depth. This analysis helps 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, and education, and how it manifests spatially in the city.

9.1 ASSESSMENT

The framework consists of a wide range of indicators related to demographic characteristics to represent the complex dimensions of socio-economic vulnerability in the city of Chhatrapati Sambhajinagar. Using Census 2011 population series data, ward-level assessment (99 Census wards and 2 outgrowths in the case of Chhatrapati Sambhajinagar)[19] and mapping are carried out to evaluate the dynamics of literacy, gender, and social composition in the city (Refer to annex 1-8, 1-9) .

9.2 KEY FINDINGS

Table 9-1: Key findings - Demographic context

Indicator	Vulnerability Analysis
Gender Profile	The trend in the sex ratio of Chhatrapati Sambhajinagar Municipal Corporation (CSMC) shows that the average sex ratio (number of females per 1000 males) of the city (including Satara and Deolai) has improved from 901 in 2001 to 928 in 2011. When compared with Maharashtra, the sex ratio of Chhatrapati Sambhajinagar is slightly higher than the state-level ratio of 925. Ward 4 near Harsul Lake in the extreme northern boundary of the city, ward 11 near Quazi Wada, and ward 93 near the Osmanapura area in the western part of the city are wards with less than 850 women per 1000 males. Satara, towards the southern boundary of the city, has a sex ratio of 576. (Annexure 2-1)

Indicator	Vulnerability Analysis
Literacy (Refer to Annex 1-8, 1-9)	While the overall effective literacy rate of Chhatrapati Sambhajinagar is 87.46% (Annex 2-2), the effective female literacy rate is lower, at 82.44%. Areas in the eastern boundary of the city, Ambedkar Nagar (ward no. 20), Misarwadi (ward no. 21), Sultanpur (ward no. 22), Savitri Nagar (ward no. 23), Bajrang Nagar (ward no. 78), along with areas near Milind Nagar (ward no. 92), and Satara near the southern boundary perform poorly, with an effective overall literacy rate of below 79%. The areas near Misarwadi (ward no. 21), Milind Nagar (ward no. 92), and Satara also perform poorly in terms of effective female literacy rate, which is below 65%. It is incidentally one of the wards with reduced access to schools as well. (Annex 2-14).
Access to School (Refer to Annex 1-8, 1-9)	This includes all the public and private schools in the city. It was seen that 89% of population have ease of access (within 10 minutes walkable distance) to schools. Areas in the south-west of the city core, such as Shahshokta Colony, and along the northern boundary of the city and southwards of Harsul Lake, etc. are beyond ease of access (10 minutes walkable distance) (Annex 2-15). Deolai is the most vulnerable, with only 47% of the population having ease of access to schools.
Social Composition (Refer to Annex 1-8, 1-9)	Data shows that the city has overall 20.73% of the population belonging to the Scheduled Castes and Scheduled Tribes communities. Areas close to Bhausingpura (Ward No. 7), Ambedkar Nagar (Ward No. 20), Sanjay Nagar (Ward No. 75) and Milind Nagar (Ward No. 92), have more than 56% of population belonging to SC and ST communities (Annex 2-3).

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 even within a household, such differential experiences exist based on demographic characteristics. Incorporating this with the vulnerability assessment will further help in identifying areas that need immediate action.

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

10.1 ASSESSMENT

Availability of various services, such as information (broadcast media and telephone), drinking water, sanitation, and electricity, at household level using Census 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. meters 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 that superimposes spatial layers of areas with climate risks on the areas that have ease of access to different infrastructure, such as hospitals, fire station, and schools. Based on the results from Climate Risk Context Section, urban heat poses maximum threat to the population living in Chhatrapati Sambhajinagar over other hazards. This gives a quantifiable-spatially located figure, either by the percentage of persons or households at risk, at a city or ward level, which lack access to facilities and is also under the risk of heat stress and, thus, provide for evidence-based mitigation and adaptation measures.

10.2 SOCIO-ECONOMIC ASPECTS

In this section of socio-economic aspects, access to information and house ownership is included, which spatializes such areas at risk of intensified climate disaster impact. (Refer to Annexures 1-10, 1-11 and 1-12).

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

Indicator	Vulnerability Analysis
Access to information (Refer to Annex 1-10, 1-11)	Based on Census 2011 analysis, areas around Osmanpura (ward no. 93 – 38.9%) and Satara (1.2%) have the lowest percentage of households owning mobiles and households owning landlines, with the city-wide average being 68.06% and 7.73%, respectively. Similarly, Savitri Nagar (Ward no. 23 - 0.8%) has the lowest percentage of households owning both mobiles and landlines (10.69%), which is much below the average in Chhatrapati Sambhajinagar city (Annex 2-16). In the case of access to broadcast media, areas close to Sharif Colony (Ward no. 44 - 50.6%) has the least percentage of households having access to television while the average in Chhatrapati Sambhajinagar is 78.11%. The lowest percentage is observed in parts of Milind Nagar (ward no. 92), with only 4.1% of households owning radio/transistor, while the citywide average is 19.31%. Lastly, Indira Nagar, Devgiri (ward no. 79) and Satara has the least percentage of households having access to computers with Internet (0.4%) while the average in Chhatrapati Sambhajinagar is 8.14%. (Annex-2-17).
House Ownership (Refer to Annex 1-10, 1-12)	On average, 64.48% of CSMC's population lives in their 'own' houses. Police Colony (ward no. 27), Jaswantpura-Altamash Colony (ward no. 46), Kailash Nagar (ward no. 58), Chintamani Colony (ward no. 62), and Devgiri Colony (ward no. 79) have less than 50% of households living in their own houses and Satara and Deolai have the highest percentage of households, at more than 80%, living in 'own' houses. (Annex 2-18).

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 public green spaces is one of the reasons for mental stress and anxiety among many, especially for those who live in potentially unserviced, informal settlements in the city and are covered in physical environment aspect. The population living in these areas become more vulnerable to climatic risks because of their inability to recover from extreme events quicker than others. The following section deals with the physical environment aspects of house condition and access to public recreational spaces.

10.3.1 Assessment

Census of India 2011 house listing and housing data have been used for Census ward-level analysis to understand the percentage of households in each ward with predominant roofing material, presumably considered 'Temporary'1 as it has limited constructional durability, especially during extreme weather events. (Refer to Annex 1-13, 1-14)

Public recreational spaces, such as parks, gardens, playgrounds, and maidans, 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 higher air pollution levels and high surface temperatures. On the other hand, greener areas have more significant carbon sequestration potential and are needed for any climate-resilient city. (Refer to Annex 1-13, 1-16)

10.3.2 Key Findings

Table 10-2: Key findings- Physical environment aspects

Indicator	Vulnerability Analysis
Housing Condition (Refer to Annex 1-14, 1-15)	On average, 42.68% of Chhatrapati Sambhajinagar's households live in houses with temporary roofing material. Parts of Ambedkar Nagar, Sharif Colony, New Baijipura and Milind Nagar (ward nos 20, 44, 51) have more than 80% of households with temporary roofing material and a high population density, making them more vulnerable (Annex 2-19). In Indira Nagar (ward no. 51), 73.02% of settlements are slums, 81.20% of households live in houses with temporary roofing materials, and 30.27 % and 6.27% of the population here at risk due to heat and flooding, respectively.
Access to Public Recreational Spaces (Refer to Annex 1-16, 1-17)	While 82.5% of Chhatrapati Sambhajinagar's population has access to public recreational spaces within the threshold values distance of 1 km within 10 minutes walkable distance, 17.5% does not have access to any parks, gardens, playgrounds, or maidans within 1km. Higher density areas in the north-west of Chikalthana and the vicinity of Kiradpura lack ease of access to such facilities (within 10-minute walkable distance or 1 km service radius) (Annex 2-20). In the majority of the eastern limits of the city, including areas of Ambedkar Nagar, Misarwadi, and Ramabai Chowk, no population has ease of access to recreational spaces within 1km walkable distance, exposing them more to extreme events such as extreme heat stress in spite of having higher population density of 10 - 60 persons per 1000 sq. metres. During a flood event, the population having access to public recreational spaces reduces by 2.79% as compared with 82.66% serviceable population during a normal day. Wards no. 38 (Banjara Colony), 40 (Ranmastpura) in the inner city, and 75 (Sanjay Nagar Mukundwadi) lose complete access to public recreational spaces during a flood event.

10.4 INFRASTRUCTURE AND SERVICE ASPECTS

The infrastructure and service aspect section helps to identify neighbourhoods lacking access to amenities/ services within 15-20 minutes and household-level (from Census 2011) and within 15-20 minutes 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 an extreme heat event (Refer to Annex 1-18).

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

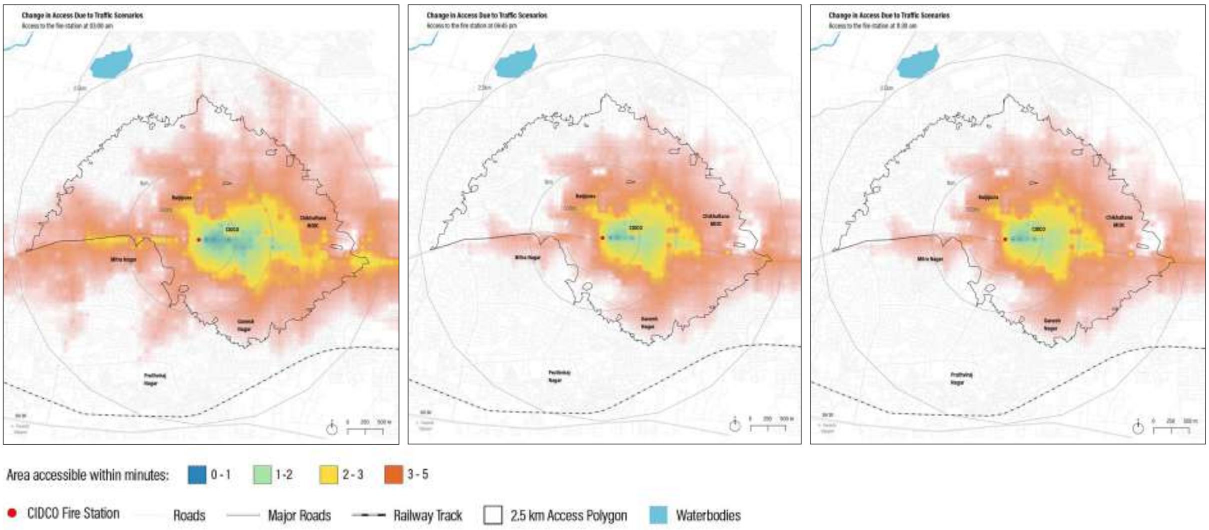
Indicator	Vulnerability Analysis
Access to Drinking Water (Refer to Annex 1-19, 1-20)	With regard to source of drinking water, 18.30% of households (HHs) in Chhatrapati Sambhajinagar do not have provision of treated drinking water (Figure 5.12) (Annex 2-22). Parts of Misarwadi (ward no. 21), Satara, and Deolai are the most vulnerable since more than 75% of households do not have treated water facility (Annex 2-21). Evaluating the proximity of drinking water source, 42.68% of HHs have a drinking water source outside their premises. Misarwadi (ward no. 21), Satara, and Deolai have more 72% HHs with non-availability of drinking water within premises along with higher population density. Misarwadi (ward no. 21) with a higher population density has 86% and 70.8% of households without access to treated drinking water and without drinking water inside premises, respectively. It also has 59.51% population at risk due to heat and 2.19% of the population at flood risk. Hence, this area has a higher health risk due to contamination of drinking water during flood events or drying up of drinking water sources during extreme heat events, etc.
Access to Clean Cooking fuel (Refer to Annex 1-21)	Overall, 31.41% of households do not have access to clean cooking fuel. The areas in the outskirts of the city, including Misarwadi, Ambedkar Nagar, Milind Nagar, Satara (wards 92, 21, 20) and in and around Sharif Colony (ward no. 44) have more than 70% households without access to clean cooking fuel (LPG/PNG, biogas and electricity) (Annex 2-23).

Indicator	Vulnerability Analysis
Access to Sanitation (Refer to Annex 1-22)	Assessing the proximity of latrines, it was found 7.07% of households have a latrine outside the premises (Annex 2-24). In terms of access to public toilets, approximately 45.79% of the slum area is within 5 minutes walkable distance of public toilets while 54.21% of the area lacks ease of access to it (Annex 2-26). A total of 4.57% of households have lack of access to treated sewage disposal methods, while 16.01% of households dispose wastewater in an untreated manner. Parts of Misarwadi, Savitri Nagar and Satara (ward nos 21, 23) have the maximum percentage of households (more than 30%) with a latrine outside the premises and with a high population density. 12 out of 25 slums in Chhatrapati Sambhajinagar lack ease of access to public toilets within 5 minutes walkable distance, which is mainly located in the periphery of the city. The areas around Greaves Colony and Triveni Nagar (ward no. 25), Osmanpura (ward no. 93) in the inner city has the maximum percentage (more than 4.57%) of households with a lack of access to treated sewage disposal methods. Misarwadi, Savitri Nagar, Sundewadi, Milind Nagar, and Satara (Ward no. 21, 23, 78, 92) have a higher population density and more than 16.01% of households disposing their wastewater in an untreated manner. In Misarwadi (ward no. 21), 4.6% of the households have no treated sewage disposal, 84% have no wastewater disposal methods, and 51.3% do not have a latrine inside the premises. During an event of a flood, this area might face severe consequences in terms of hygiene and sanitation, as 2.33% area is covered by slums and 2.19% population is estimated to be affected by floods as physical access to many of the services might be hampered. (Annex 2-27).
Access to Electricity Grid (Refer to Annex 1-23)	Overall, 2.09% of households do not have access to electricity as the main source of lighting. The peripheral areas of Satara have more than 15% of households without access to the electricity grid. (Annex 2-28).
Access to Public Transit (Refer to Annex 1-24, 1-25)	Around 68% of Chhatrapati Sambhajinagar's population lives within 5 minutes access radius of each bus stop in the city. Areas namely Sanjay Nagar and New Baijipura in the core of the city are the higher density areas that are outside ease of access (within 5 minutes walkable distance). Only 2% population around Taksheel Nagar (ward no. 57), followed by Devgiri Colony (ward no. 79) with only 7%, and Bhimwadi Chowk (ward 80) with 7.9% population has a bus stop within 500 metres walkable distance. Overall, during a flood event, the population in Chhatrapati Sambhajinagar having ease of access to bus stops (5 minutes walkable distance) reduces by 2.14%. In ward no. 60, Nutan Colony, 100% population has ease of access to bus stops during a normal day, but during a flood event, 86.5% of the population loses access. (Annex 2-29).

Indicator	Vulnerability Analysis
Access to Emergency Healthcare Services (Refer to Annex 1-26, 1-27)	Approximately 90% 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 areas in the extreme east and northern parts of the city (Annex 2-30). The areas in and around Bakal Patil Vasti and Rushikesh Nagar (ward no. 78) have the least ease of access to emergency hospital services, with only 68.43% of the population being able to access such services within 8 minutes response time on normal days. Also, 25.82% of its population has limited ease of access to hospitals and, at the same time, is potentially at risk due to extreme heat (> 32.5°C). During a flood event, the population of Chhatrapati Sambhajinagar's with ease of access to hospitals (8 minutes response time) reduces by 1.16%.
Access to Emergency Fire Services (Refer to Annex 1-28, 1-29) (Figure 8-1)	Only 34% of the population has access to fire stations within five minutes. Chhatrapati Sambhajinagar currently has only three fire stations. Accessibility has been calculated for the CIDCO, Seven Hills Fire Station, which lies in the centre of the city. Areas to its east, including Vishnu Nagar, Mitra Nagar and Ahinsa Nagar, although lie in proximity, remain beyond five-minute serviceable response time due to lack of road connectivity (Annex 2-31). Areas of Nath Nagar and Buddh Nagar do not have ease of access to emergency fire services, with no one being able to access these services within 5 minutes response time despite the higher population density in the city. 35.65% of wards do not have any ease of access. Areas on Jalna road towards the west of the fire station and north of the airport towards the west are within an accessible radius and can be reached within 8 minutes by vehicle at 3:00am although access is lost at 11:30am and 6:45pm considering travel time with regard to traffic (refer Figure 10-1). There is a total reduction by 47% in terms of service area in peak hours, thereby increasing the potential risk. However, ward no. 78 (area of Vidhya Nagar) on the eastern extremity of the city has 87.58% of population with limited ease of access to fire stations and, at the same time, potentially at risk due to extreme heat (> 32.5°C). In the case of a flood event, the population of Chhatrapati Sambhajinagar serviced by the fire station drastically reduces by 2.32%. For example, ward nos 51, 53, and 56, which had 100% of its population accessible by fire stations during a normal day, completely loses access during floods. Being predominantly slum locations, slums also see a reduction in serviceable settlements, from 53.05% to 25.07%.

Indicator	Vulnerability Analysis
Access to Relief Shelters (Refer to Annex 1-30, 1-31)	Nearly 78% of the population has access to relief shelters within 10 minutes of walking distance. These are majorly municipal schools, which are currently used as relief shelters during climatic hazards such as flooding. Higher density areas in and around Railway Station, MIDC Chikalthana fall beyond 10-minute serviceable distance of these relief shelters. (Annex 2-32). Satara has the least percentage of population (4.14%) having ease of access to relief shelters within 10 minutes walkable distance. Ward no. 48(Shubhashree Colony) with high population density has only 33.47% population having access to relief shelters, which loses access completely during flood events. In the event of a flood, the population in Chhatrapati Sambhajinagar with access to a flood shelter within 10 minutes of walking distance is reduced by 1.99%. However, the slums are most affected, as there is a reduction in serviceable settlements from 91.34% to 79.17% during floods.

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



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

11. VULNERABILITY ASSESSMENT - IMPACT ANALYSIS

11.1 IMPACT ANALYSIS – IMPACT DUE TO HEAT

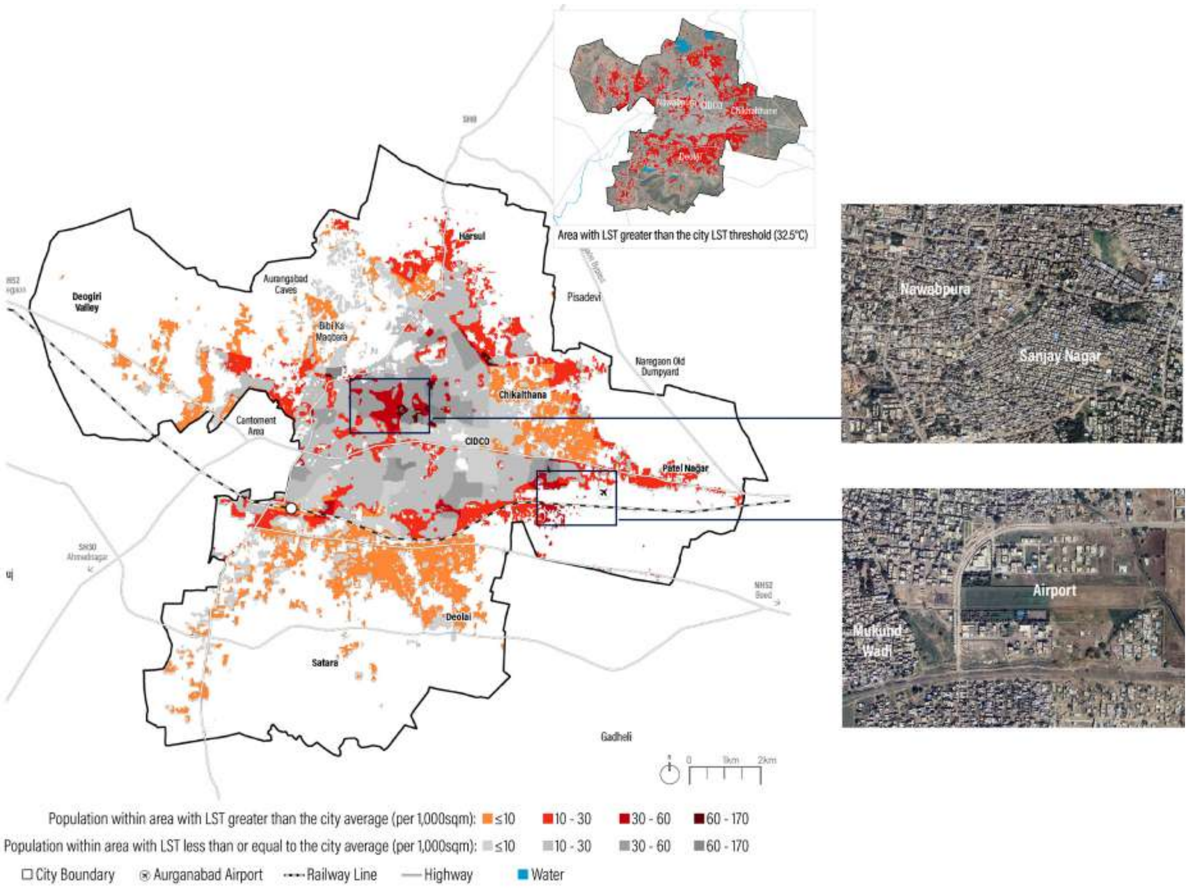
The climate of Chhatrapati Sambhajinagar city can be categorised as hot semi-arid. The annual average LST within the city ranges between 27 and 38°C. In summers, LST can reach 48°C during the daytime. The city has 38.7% built-up area. These areas have LST hotspots, which contribute to the vulnerability due to heat.

11.1.1 Impact on the population

Chhatrapati Sambhajinagar city has a total population of 11,88,059 (Census of India 2011). The heat threshold LST[20] for Chhatrapati Sambhajinagar has been considered as 32.5°C. However, 35% of the city's population lives within the area with LST higher than 32.5°C. This population is at higher risk due to heat.

Figure 11-1 represents the population vulnerable to heat and its density distribution. Shahganj, Nawabpura, Sanjay Nagar, and Mukundwadi are a few high population density areas that are at higher heat risk.

Figure 11-1: Population vulnerable to heat risk

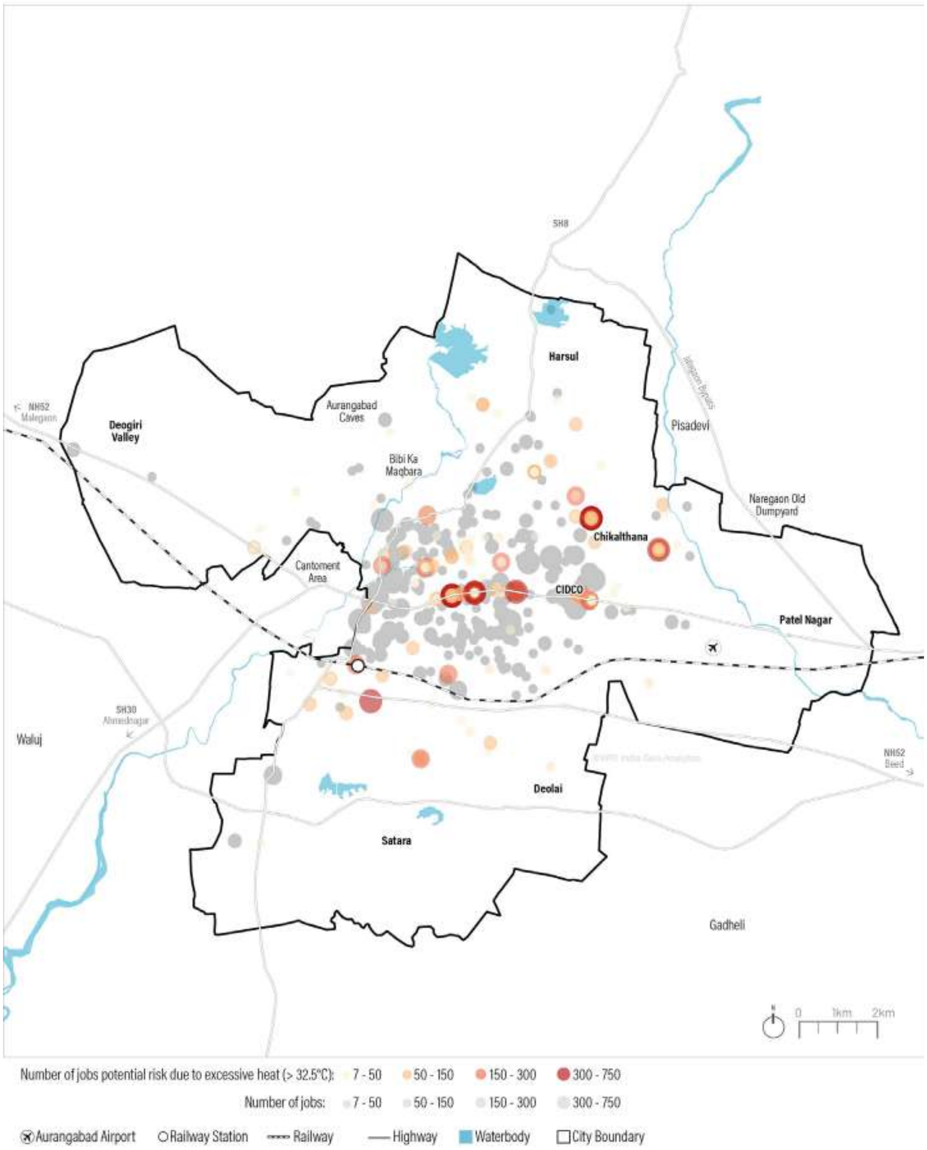


Source: WRI India,2022, WSF, Census 2011, Landsat 8 (2019-2021)

11.1.2 Impact on livelihood

To understand the opportunities available and the spatial distribution of these job opportunities within Chhatrapati Sambhajinagar city, the Directorate of Establishments sample data from Economic Census 2015 was used.[21] Chhatrapati Sambhajinagar has (Maharashtra Industrial Development Corporation (MIDC) area near Chikhalthana towards the east of the city. The commercial and industrial areas within heat risk can expose employees to the adverse effects of heat. In manufacturing and construction establishments, workers work in high temperatures, usually within metal and tin structures that have been proved to get heated up. In other sectors, such as malls, banks, hotels, and the hospitality industry, cooling equipment such as air conditioners and coolers are used, which result in high energy demand.

Figure 11-2: Jobs vulnerable to heat risk



Source: WRI India,2022, Economic Census 2015, Landsat 8 (2019-2021)

In the risk areas, 30% of establishments fall in the education category and 20% in the manufacturing category, contributing 20% and 24.7% to the jobs share, respectively. The education category consists of schools, colleges, coaching classes, vocational training centres, etc. This also indicates that the students at these facilities are also experiencing a higher heat risk.

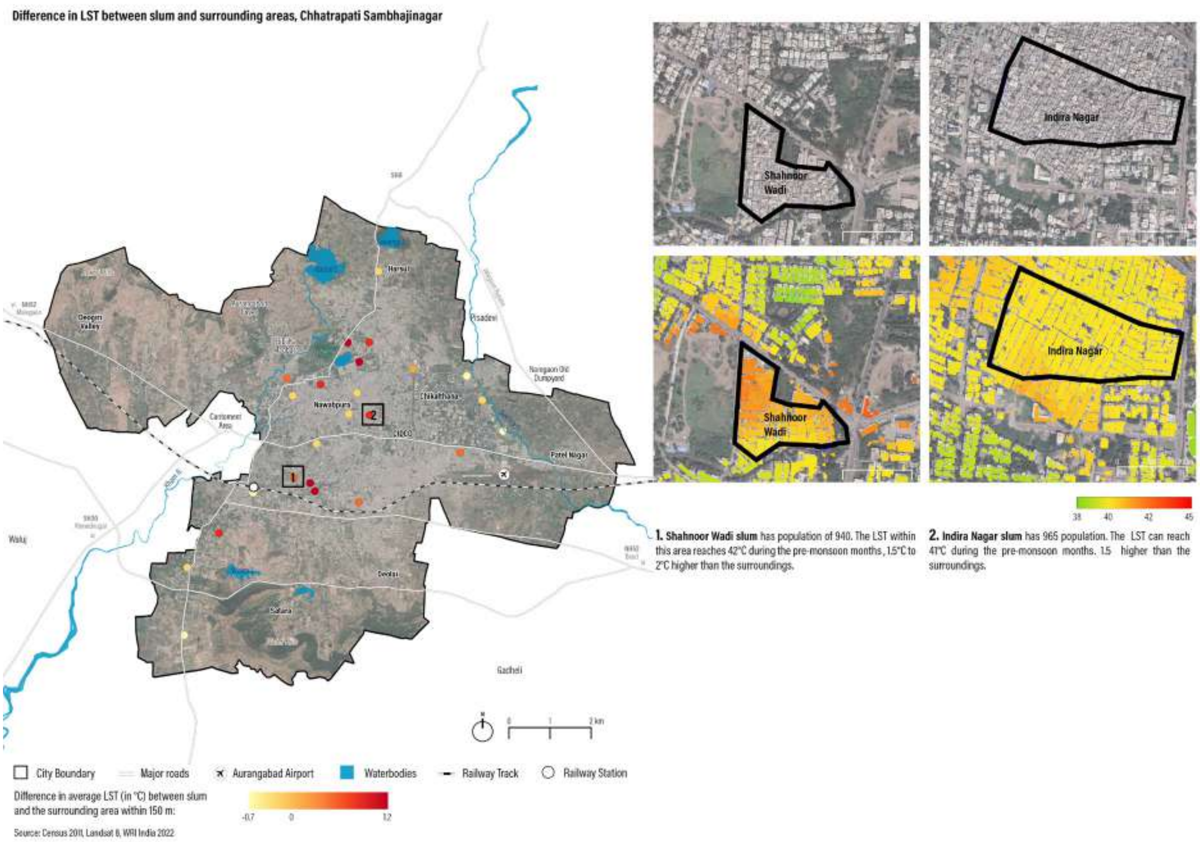
11.1.3 Impact on slums

Slum areas experience higher temperatures and are more susceptible to heat. Slums have densely packed built units, usually have fewer number of trees or other vegetation. Often, materials such as metal or asbestos sheets are used for roofing. These factors cause heat hotspots within the slum areas. Hence, slums usually have higher temperatures as compared with their surroundings. Slums usually have a high population density as well, which increases the impact of heat within the slum areas.

Chhatrapati Sambhajinagar has 52 notified slums out of which 25 were marked spatially. The slum occupies a total area of 4.5 sq.km within the city (Refer Figure 11-3). The slum population of the city is 2,21,001 (Census 2011).

Out of the 25 located slums, 13 experience higher temperatures than the surrounding areas.

Figure 11-3: Difference in LST in slums and its surrounding areas

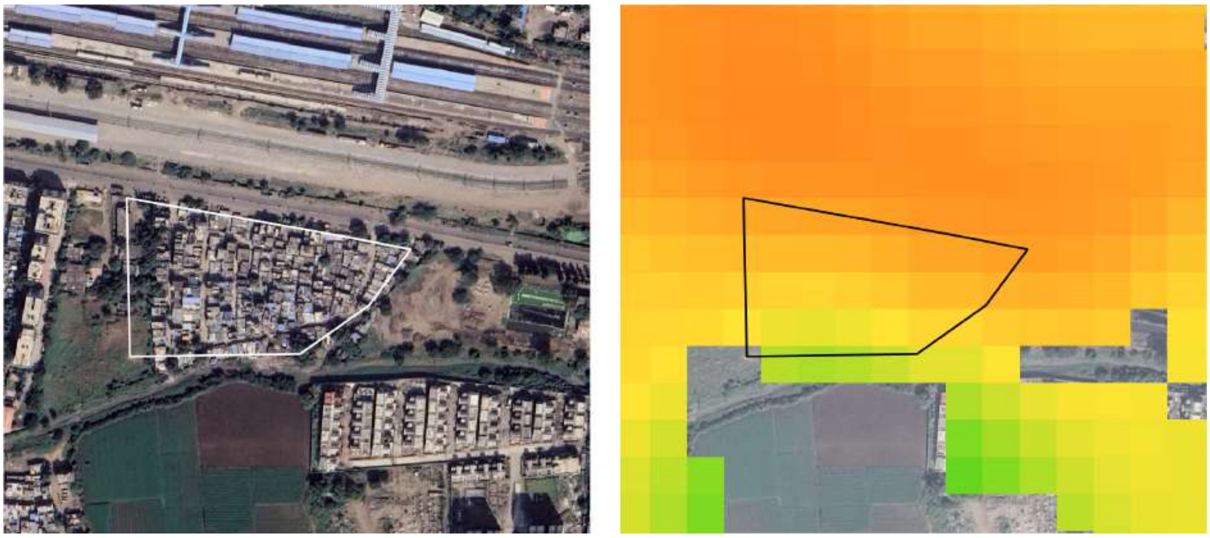


Source: WRI India,2022, Chhatrapati Sambhajinagar Municipal Corporation, Landsat 8 (2019-2021)

Shahnoor wadi slum has a population of 940. The mean annual average LST within this area is 33°C, which is 1.5°C higher than the surroundings. Indira Nagar slum has a population of 965. The average LST within this area is 32°C. In summers, the LST can reach 40°C. It was observed that the remaining 12 out of 25 slums, which appeared at a lower temperature as compared with the surrounding areas, have industrial, commercial or transport land uses around them, which have a higher LST than the slum area. One of these is the Hamalwadi slum, which is near the railway track and station, due to which the slum appears comparatively at a lower LST. This slum experiences 40°C, which is very high for a residential area.

Although visually, these slums appear at a lower LST than the immediate surroundings, these areas experience high temperatures as compared with the other residential areas.

Figure 11-4: Informal settlemets experiencing high temperatures



Source: WRI India,2022, Chhatrapati Sambhajinagar Municipal Corporation, Landsat 8 (2019-2021)

11.2 IMPACT ON SERVICES

Heavy rainfall and flooding hinder physical access to most of the essential services, thereby causing a city to come to a standstill. For example, the transport infrastructure in a city during flood-like events not only hampers the operational costs, travel time, and regularity of service but also compromises the safety of its citizens.

- Access to public transit in Chhatrapati Sambhajinagar reduces by 2.14% during a flood-like event.
- Access to relief shelters, which service 77.84% population of the city on a normal day, also reduces to 75.85% during a flood event.

Extreme heat stress also 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.

- Out of 35.93% of the total population of Chhatrapati Sambhajinagar that is impacted by heat, 25.82% of population falls beyond the serviceable radius of 8- 10 minutes drivetime distance of hospitals.
- Excessive heat can cause fire hazards, especially in closely packed neighbourhoods, such as Sanjay Nagar Wasti at the heart of the city and near the railway station. However, Chhatrapati Sambhajinagar lags behind in provision of fire services.
- 26.28% of population lives beyond the serviceable radius of 5- 7 minutes and are also at heat risk, making them more vulnerable due to potential fire hazards.
- 48% of informal settlements remain without ease of access to public toilets, even during a normal day.
- 7.69% of public toilets fall in a completed flooded area, which may lead to sanitation issues as physical access to these gets restricted. Hence, the coverage area of slums declines to 41.65%, from 42.89%.

Table 11-1: Summary of Service Indicators

Indicator	Population having access on a normal day	Population having access on a flood event	Un-serviced Population also exposed to extreme heat
Access to Public Transit	68.87%	66.73%	
Access to emergency healthcare facility	97.53%	96.37%	0.68%
Access to emergency fire services	35.42%	32.1%	26.28%
Access to public recreational spaces	82.66%	79.87%	11.88%
Access to All Schools	96.27%	95%	7.81%
Access to Relief Shelters	77.84%	75.85%	--
Access to Public Toilets (with respect to slums)	42.89% (settlements)	41.65% (settlements)	

SECTION -IV: Projected Risks and GHG – Emissions Scenario

Photo credit: ASCDCL

12. PROJECTED CLIMATE SCENARIOS

There is a distinct difference between a projected trend and the observed variability; in climate science, projections are, in general, suitable for informing long-term mitigation plans, while temporally and spatially nuanced observed variability amongst the decadal, inter-annual, and seasonal variations are critical to make adaptation-savvy decisions. This chapter details the projected climate change scenarios[22], while their implications and observed variations in climate and environmental characteristics are discussed in Chapter 4.

12.1 TAKEAWAYS FROM MSAAPC AND CHHATRAPATI SAMBHAJINAGAR GHG EMISSIONS INVENTORY

The Maharashtra State Adaptation Action Plan on Climate Change (MSAAPC) outlines sector-specific adaptation recommendations along with the associated departments to ensure a sustainable development pathway. The city would have to implement and enhance these recommendations in various sectors, such as agriculture, water resources, ecosystems, and health, to safeguard 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

12.2.1 Analytical:

The current assessment studies minimum and maximum temperatures and precipitation changes for two climate scenarios – RCP 4.5 and RCP 6 up to year 2100, with intervals of short-term (2020-2050) and long-term (2071-2100), to align with the targeted strategies in the Chhatrapati Sambhajinagar Climate Action Plan. Each scenario plots a different emissions trajectory (called pathways) and the resultant cumulative Carbon Dioxide (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, in order to consider how robust different decisions or options may be under a wide range of possible futures (IPCC, 2014).

12.2.2. Geographical:

Chhatrapati Sambhajinagar lies at an elevation of 568 m above sea level, along the divide of the Upper and Middle Godavari sub-basin. It fulfils a majority of its water demand from Jayakwadi Dam located ~40 KM south of the city. Jayakwadi collects water from series of rivers and streams originating along Godavari, near Trimbakeshwar. Any upstream developments and changes to climate patterns can heavily influence water flows to the dam, challenging the overall water security of CSMC. Kham and Sukhna, locally originating streams, network with other small water bodies, such as Harsul, Sawangi lakes. In order to understand the risks of water availability in terms of temperature and precipitation changes for the city, RCP scenario-based projections are analysed at the regional (sub-basin) scale with the city limits in focus.

12.3 ASSESSMENT

The future projected changes based on RCP 4.5 and 6[23], respectively, are analysed for climatic parameters of precipitation, minimum air temperature, and maximum air temperature based on ECMWF ERA5 daily data. Variations with respect to the historical baseline for each of the two study domains and the entire study area collectively are computed as per the envisaged epochs.

Table 12-1: **RCP analysis: contributing parameters**

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[24]) For RCP 6: Temporal Variations in minimum air temperature from the baseline (Magnitude of change based on 13 models[25])	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) for RCP 4.5 CMIP5 daily data for RCP 6 ECMWF ERA5 daily data for historical baseline
Maximum Temperature	*For RCP 4.5:* Temporal Variations in maximum air temperature from the baseline (Magnitude of change based on 21 models[24]) *For RCP 6:* Temporal Variations in maximum air temperature from the baseline (Magnitude of change based on 13 models[25])	
Precipitation	*For RCP 4.5:* Temporal Variations in precipitation from the baseline (Magnitude of change based on 21 models[24]); 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[25]);	

Source: WRI India analysis 2022

12.4 KEY FINDINGS

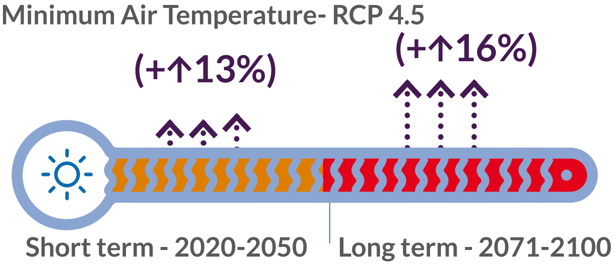
12.4.1 Minimum Air Temperature

Minimum air temperature is a concept associated with temperature during the night, early in the day, and in winter season. It is a critical parameter for physical and psychological health of humans. A dramatic rise in minimum air temperature can also be deadly for plants and the overall ecosystem functioning. 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 fuelling climate change woes, if dependency on fossil-fuel consumption is not regulated. For a Tier II city such as Chhatrapati Sambhajinagar, with a significant share in the industrial economy, this can also lead to 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:

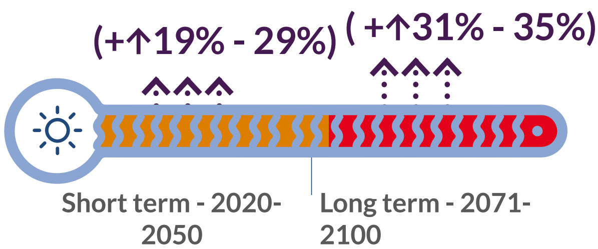
1. RCP 4.5: The 'intermediate scenario' shows maximum projected increase in minimum air temperature by +↑13% for the short-term epoch and +↑16% for the long-term within the CSMC study limits.
1. RCP 6: The 'high greenhouse gas emission scenario' projects higher rise in the average minimum temperature as compared to RCP 4.5. The maximum air temperature for short term epoch is projected to soar between +↑19% and +↑29% for the CSMC and Upper Godavari study area respectively. For the long-term epoch, the maximum projected increase is projected to soar between +↑31% and +↑35% for the CSMC and Upper Godavari study area respectively.

Minimum Air Temperature- RCP 4.5



Study area: CSMC

Minimum Air Temperature- RCP 6

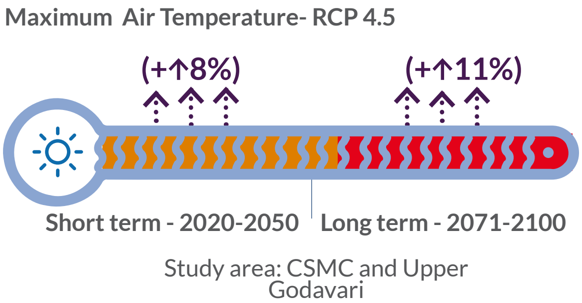


Study area: CSMC and Upper Godavari

12.4.2 Maximum Air Temperature

The maximum air temperature is applicable for the relatively active part of the day, especially increasing the heat risk for the outdoor workers. A fatal maximum temperature of above 35°C (Sherwood & Huber, 2010) in CSMC is observed for three months (March-May) every year on an average, as per NCEI data. Resonating with MSAAPC, for both RCP 4.5 and 6, a majority of models project a high likelihood of rise in temperature by 5°C (~+↑15%) to 9°C (+↑28%). The city has already been facing more than 20 days of heatwave since 2019. The projected rise, as accounted in the state action plan, can lead to prolonged heat waves, especially 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 minimum air temperature rise, an increase in maximum air temperature can lead to intense and frequent forest/ bush fires in the affected region, which could hamper air and water quality. The scenario-wise details are as follow:



1. RCP 4.5: The maximum air temperature for both the study extents, that is Upper Godavari and CSMC, during the short term epoch and long term epoch is estimated to rise by an average of +↑8% and +↑11% respectively.
2. RCP 6: Both the study extents, that is Upper Godavari and CSMC, record up to +↑21% of increase in maximum air temperature in the short-term and increase up to +↑28% in the long-term epoch.

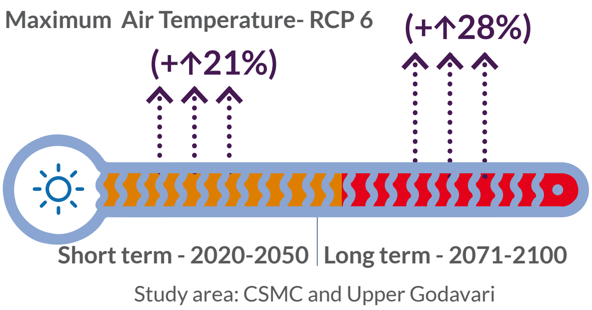


Table 12-2: Range of temporal variations observed in Minimum Air Temperature based on RCP 4.5 and 6 across study area and domains during 2021

Study domain	Short-term (in °C) *(2020-2050)*		Long-term (in °C) *(2071-2100)*		81-year long period (in °C) *(2020-2100)*		Projected Average (in °C)		
	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Short-term	Long-term	80 year long period *(2020-2100)*
RCP 4.5									
Godavari Upper	7%	10%	4%	14%	7%	14%	0%	5%	3%
CSMC	6%	13%	3%	16%	6%	16%	2%	7%	5%
RCP 6									
Godavari Upper	5%	29%	0%	35%	5%	35%	11%	19%	15%
CSMC	10%	19%	4%	31%	10%	31%	6%	14%	10%

Source: WRI India analysis 2022

Table 12-3: Range of temporal variations observed in Maximum Air Temperature based on RCP 4.5 and 6 across study area and domains during 2021

Study domain	Short-term (2020-2050)		Long-term (2071-2100)		81-year long period (2020-2100)		Projected Average		
	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Maximum Projected Decrease	Maximum Projected Increase	Short-term	Long-term	80 year long period *(2020-2100)*
RCP 4.5									
Godavari Upper	0%	15%	0%	16%	0%	17%	8%	11%	10%
CSMC	0%	16%	0%	17%	0%	18%	8%	11%	10%
RCP 6									
Godavari Upper	7%	21%	6%	28%	7%	28%	3%	6%	5%
CSMC	9%	21%	9%	28%	9%	28%	4%	7%	5%

Source: WRI India analysis 2022

12.4.3 PRECIPITATION

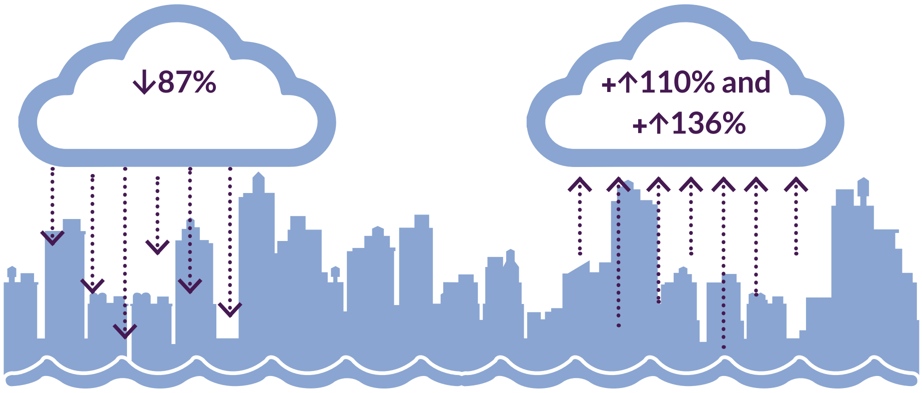
An increasingly important subject, rainfall continues to be a major regional and micro-climatic factor for cities. Being vulnerable to rainfall extremes, cities witness both floods and droughts and are at the intersection of various socio-economic vulnerabilities induced by rainfall variations. The range of temporal variations in precipitation (Table 14-4) has been consolidated for the 81 years of the analysis period. The magnitude of the projected increase is lesser than the projected decrease for RCP 4.5, as also projected in the MSAAPCC.

The spatial representation of four selected models 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. A majority of the models project the region far-upstream to Jayakwadi Dam to be majorly recording a rainfall deficit, which is also seen as per the baseline estimation of meteorological drought, (refer per Section 4.4.2, Chapter 4). A decrease in rainfall could impact air quality, sanitation and hygiene, and food and nutrition. It could also cause long-term public health problems due to shortage of drinking water, especially with the heightening air temperature across the study area. Precipitation is a highly local phenomenon dependent on a range of atmospheric and anthropogenic activities. Both the scenarios showcase no significant consensus among the range of models used for the precipitation changes. Scenario-wise details are as follow:

3. RCP 4.5: Most models project the precipitation to be decreasing than increasing in both study areas, Upper Godavari and CSMC. Models record nearly a decrease of ↓87% to a rise of about ↑110-136% in the upper Godavari and CSMC city limits for short-term epoch.

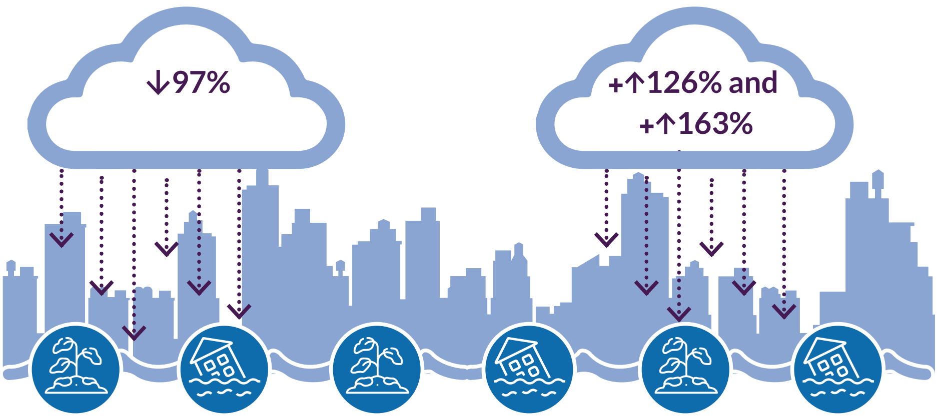
4. RCP 6: While majority models in RCP 4.5 project decrease in rainfall, RCP 6 scenario indicate no consensus.Models record nearly ↓97 decrease to rise of about ↑126-163% across the Upper Godavari and CSMC study area for short term epoch.

Precipitation- RCP 4.5



Short term -2020-2050
Study area: CSMC and Upper Godavari

Precipitation- RCP 6



Short term - 2020-2050
Study area: CSMC and Upper Godavari

Table 12-4: Range of temporal variations observed in Annual Accumulative Precipitation based on RCP 4. 5 and 6 across study area and domains during 2021-2100

Study domain	Baseline Average *(in mm)*	Short-term *(2020-2050)*		Long-term *(2071-2100)*		81-year long period *(2020-2100)*		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										
Godavari Upper	33884	87%	110%	76%	235%	87%	235%	-13%	-1%	-7%
CSMC	286	88%	136%	88%	227%	88%	227%	-16%	-5%	-10%
RCP 6										
Godavari Upper	33884	97%	163%	99%	171%	99%	178%	14%	21%	19%
CSMC	286	97%	126%	99%	152%	99%	152%	2%	7%	6%

12.5 CONCLUSION

Most of the models are observed to have consensus in terms of air temperature rise for both the scenarios, indicating proof of rising air temperature and alternate drought and flood pattern observed in the precipitation changes as alternative dips and peaks. Excessive expanse of heat stressed areas and longer extreme heat waves is projected to increase in terms of both spatial scale and frequencies.

While scenarios do not provide high confidence results in the case of precipitation, especially for RCP 6, it could give rise to potential precipitation related hazards. Lack of commitment to preparedness can lead to overwhelming of the city's storm water, medical, and emergency infrastructure, persistently give rise to water logging and flooding crisis in the city. In order to implement adaptation strategies, there is a need for more localised projections using information from the network of monitoring stations and water flow metres/ stormwater sensors across the city as well as the broader region.

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). Methane and nitrous oxide emissions are converted into CO_2 equivalent (CO_2e) emissions by multiplying with their Global Warming Potential (GWP).

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

For example, methane (CH_4) is estimated to have a GWP of 27-30 over 100 years[26]. 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 the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH_4 is a precursor to ozone and ozone is itself a GHG.

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

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 GREENHOUSE GAS 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. This 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 keeping within the goals of the Paris Agreement and Chhatrapati Sambhajinagar'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 them to direct funding towards high emitting sectors. Moreover, it would help cities meet reporting requirements, such as disclosing GHG emissions data through voluntary reporting platforms such as Carbon Disclosure Protocols (CDP), and funding criteria that require a baseline inventory. GHG emissions inventories also serve as a benchmarking tool for cross comparisons 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 CHHATRAPATI SAMBHAJINAGAR CITY

The GHG emissions inventory for Chhatrapati Sambhajinagar 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

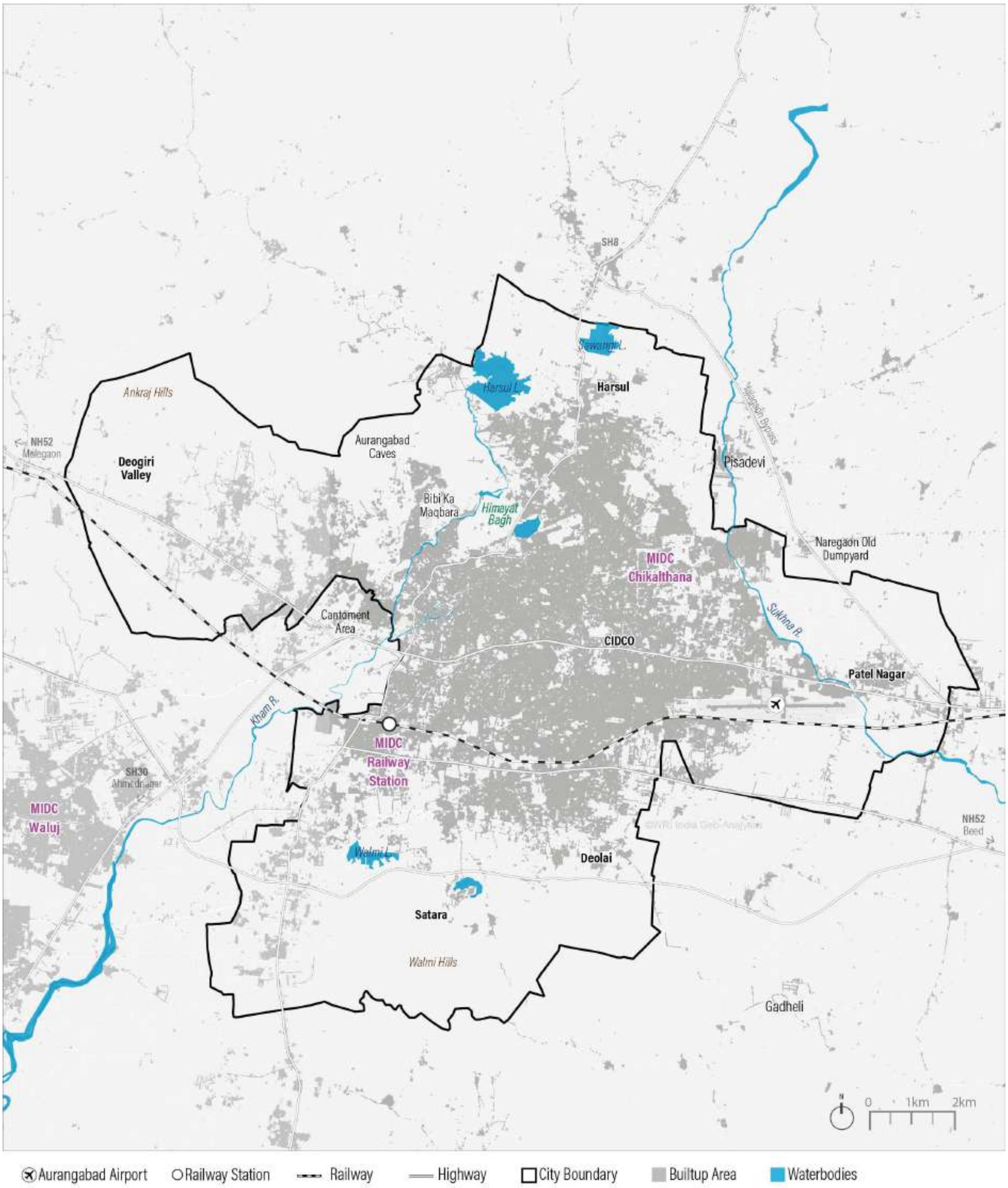
The GHG emissions inventory for Chhatrapati Sambhajinagar is aligned with the GPC framework, a robust GHG accounting and reporting framework for cities prepared by the World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI – Local Governments for Sustainability (ICLEI).[27]

- The year 2021 was taken as the base year for the inventory, and the inventory boundary was limited to Chhatrapati Sambhajinagar Municipal Corporation (CSMC), which covers a land area of 176 km^2 and has a population of 15,95,346 people as of 2021, based on projections using Census 2011 and 2001 growth rates. The inventory includes emissions from the two industrial clusters of MIDC located within CSMC limits, namely Railway Station MIDC and Chikalthana MIDC (figure 14-1).
- The GHGs covered includes CO_2, CH_4 and N_2O. The inventory aligns with the BASIC inventory (Refer to Table 14-1) comprising emissions from stationary energy, inboundary transportation, and solid waste management and wastewater treatment in the city.
- Scope-1 emissions include emissions occurring due to activities within the city, while scope 2 covers emissions from grid supplied electricity. Scope 3 emissions includes emissions occurring outside the city boundary due to activities happening within 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 suppled to the grid, which shall be reported in the scope 1 total)
• Scope 1 emissions from transportation sources
• Scope 1 emissions from waste sources (excluding emissions from imported waste, which 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 depicting the MIDCs in and around CSMC limits.



Source: WRI India analysis; CSMC

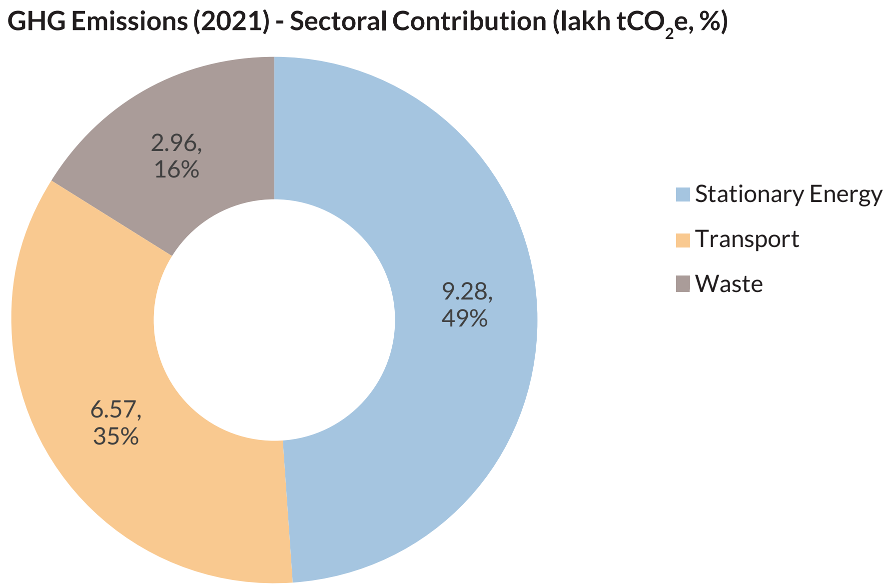
14.2 SUMMARY OF ESTIMATED GHG EMISSIONS IN CHHATRAPATI SAMBHAJINAGAR CITY

In 2021, the estimated GHG emissions in CSMC area were **18.8 lakh** tonnes of CO_2 equivalent (tCO_2e). This is approximately 1.2 tCO_2e per person based on estimated population of 15.95 lakh for the year 2021.

The highest contribution came from stationary energy sector (49%), followed by transportation (35%), and waste and wastewater (16%). Refer to Figure 14-2.

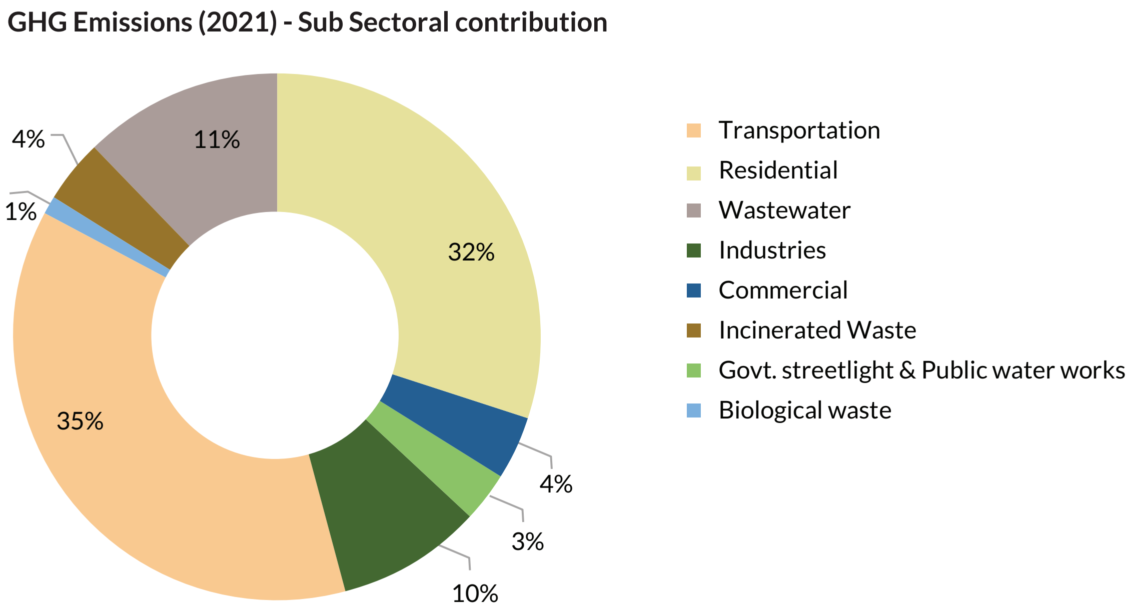
The sub-sector wise break-up is given in Figure 14-3. The three major sub-sectors that contribute substantially to the GHG emissions are on-road transportation (37%), residential sector (30%), and industries (9%).

Figure 14-2: GHG Emissions Inventory- Summary



Source: WRI India analysis

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



Source: WRI India analysis

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 by residential, commercial, and industrial sectors.

- Energy generation is undertaken by the state-run Maharashtra State Power Generation Company Ltd (MAHAGENCO). The electricity supply within Chhatrapati Sambhajinagar city is managed by Maharashtra State Electricity Distribution Company Ltd. (MSEDCL), another state-run company. The energy consumption by different user categories was collected and analysed. The data on electricity consumption was collected for various user categories such as for Group housing (HT), residential (LT), commercial (LT), commercial (HT), industrial (HT), public water works (HT), Public sector (HT), public sector (LT), streetlights (LT), agriculture (LT), non-specified sources (LT and HT) and rooftop solar generation.
- In the case of Maharashtra State, the energy is generated from different sources, such as coal or gas based thermal power plants and hydro power plants. This energy mix has coal-based power plants (60%) as a significant source of electricity generation, followed by renewable energy (23%), gas (8%), hydro (7.5%) and nuclear (1.5%).[28] Therefore, one common GHG emission factor for electricity consumption is considered based on the energy mix and this GHG emissions factor is provided by the Central Electricity Authority of India (CEAI). The GHG emission factor provided by CEAI is 0.79 t/MWh for the year 2021.
- In fuel consumption, data of LPG consumption for residential, commercial, and industrial

subsectors was obtained from fuel companies. Data on coal consumption and fuelwood consumption for the residential sector was obtained from the Draft interim report titled 'Air Quality and Emission Source Apportionment Studies' for Chhatrapati Sambhajinagar prepared by CSIR-National Environmental Engineering Research Institute, Nagpur, India (CSIR-NEERI) and Indian Institute of Technology (IIT) Mumbai in 2020.

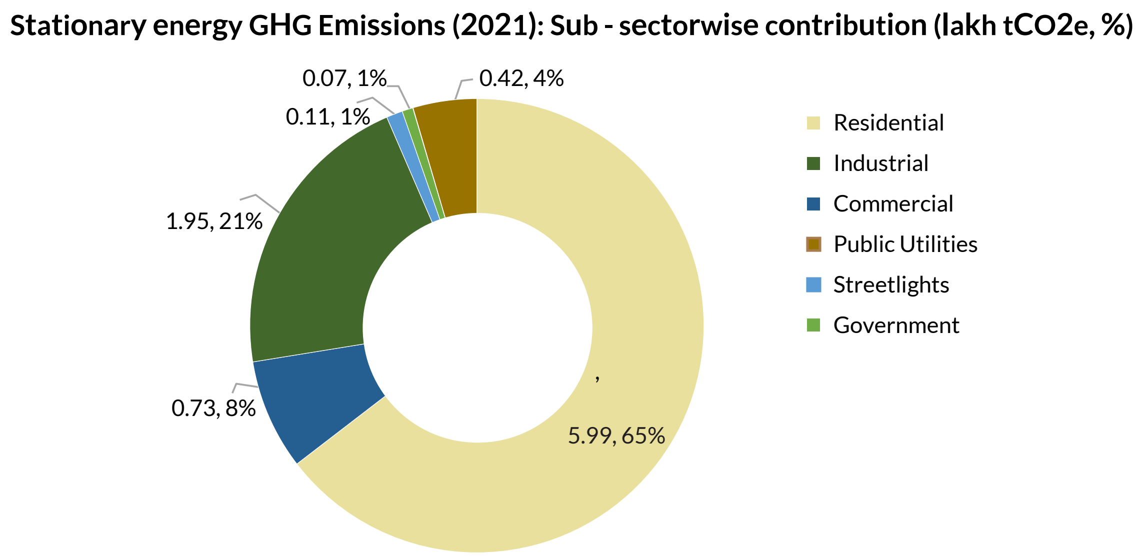
- Chhatrapati Sambhajinagar is identified as a critically polluted industrial cluster by Central Pollution Control Board (CPCB)[29]. Two out of the four clusters, Chikalthana and Railway MIDC areas, are situated within the CSMC boundary and comprise mostly old industries and sick units[30]. These are mainly breweries, pharmaceutical companies, distilleries, etc. Data from the 'proposed action plan for industrial clusters in Chhatrapati Sambhajinagar' of 2010 was used to understand fuel consumption in Chikalthana and Railway MIDC[31]. As there is no updated data available, this data was used. There is no PNG within the city.

2. Sub-sectoral analysis

This stationary energy sector contributes around 49% (9.28 lakh tCO_2e) of the total GHG emissions of Chhatrapati Sambhajinagar city.

- Within the stationary energy sector, the contribution to the total GHG emissions by the electricity consumption for consumer categories — residential, commercial, and industrial — and government utilities is around 62% whereas the contribution of fuel consumption for domestic, commercial, and industrial consumers is around 38%.
- In terms of sub-sectors within stationary energy, residential buildings are responsible for 65% of the total energy related GHG emissions (~ 6 lakh tCO_2e). The commercial, government, and industrial buildings are responsible for the remaining 35% (3.29 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

Chhatrapati Sambhajinagar is identified as a critically polluted industrial cluster by CPCB[32]. Of the four clusters, the clusters Chikalthana and Railway MIDC areas are situated within the CSMC boundary and mostly comprise old industries and sick units[33]. Due to the absence of latest data, fuel consumption in these two clusters was analysed using data from a 2010 action plan that had been proposed for industrial clusters in Chhatrapati Sambhajinagar. . Around 54% of GHG emissions originates from LPG consumption, 27% from coal consumption, and the rest from consumption of bagasse, diesel oil, and fuel oil. This highlights the need for increased energy efficiency measures and use of low carbon fuels in industries.

The estimated GHG emissions from fuel (LPG) usage in residential, commercial, and industrial sectors is 3.54 lakh tCO2e, which amounts to 38% of the stationary energy emissions. The residential sector has a significant share (80%) in LPG consumption, possibly due to a lack of complete data from the commercial sector. Only partial data is available on coal consumption in the residential sector.

14.2.2 Transportation Sector

1. Data availability

While the city has an on-road transportation system, it does not have an intra city railway, metro, or water transport system.

- The transport sector emissions are estimated by applying the fuel sales method and using fuel data received from the fuel companies on the sales of auto LPG, petrol, and diesel from the petrol pumps located within Chhatrapati Sambhajinagar city.
- Currently, there is no sale of Compressed Natural Gas (CNG) for transport within city limits and, hence has not been included in the inventory. However, there are three pumps outside city limits. The city does have some CNG vehicles, with 1% of the total vehicles registered in 2021 comprising CNG vehicles, particularly 3-wheelers and light duty goods vehicles. Sale of CNG vehicles declined by 4% annually between 2010 and 2020 but increased in 2021, with the registration of 156 new CNG LDVs[34]. Furthermore, eight new CNG stations in and around Chhatrapati Sambhajinagar are in the pipeline by the end of 2022[35].
- Data on the number of vehicles registered with the Regional Transport Office (RTO) from 2010-2021 by fuel type 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.

2. Sub sectoral analysis

In 2021, the contribution of the transport sector to the GHG emissions is 6.57 lakh tCO_2e, which is around 35% of the total GHG emissions for the city. Around 53% of GHG emissions were attributed to petrol consumption, followed by 44% from diesel and 3% from auto LPG.

The high vehicle registration rate of 9.18 lakh vehicles, which is fossil-fuel heavy, until February 2022 is another prime factor for the high emissions reported from this sector. Currently, there is also a limited public transit system within the city as there are only 100 buses operational, with a daily average public ridership of 10,000 passengers.

14.2.3 Solid waste management and Wastewater sector

1. Data availability

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

a. Municipal Solid Waste

- In 2021, around 441 tonnes per day of solid waste was generated, out of which around 48% is organic waste and 52% dry waste. In terms of overall waste composition, 48% is food and organic waste, 13% plastic waste, 7% paper waste, textile waste 5%, wood and garden waste 8%, and remaining other materials[36].
- The city treats 95% of its organic waste by composting and 5% by anaerobic digestion. 3 kWH of electricity is generated per day from biogas, which is used internally within the plant and not sent back to the grid. The city does not have any active landfill, although there is an old dumping site at Naregaon with legacy waste. A new landfill site is currently being identified.
- Dry waste that is not recycled is converted to Refuse Derived Fuel (RDF) and is sent to a cement factory for usage as boiler feed. Biomedical waste is incinerated by a private company outside the city. 100% of the energy produced is flared and not used for electricity generation.

b. Wastewater treatment

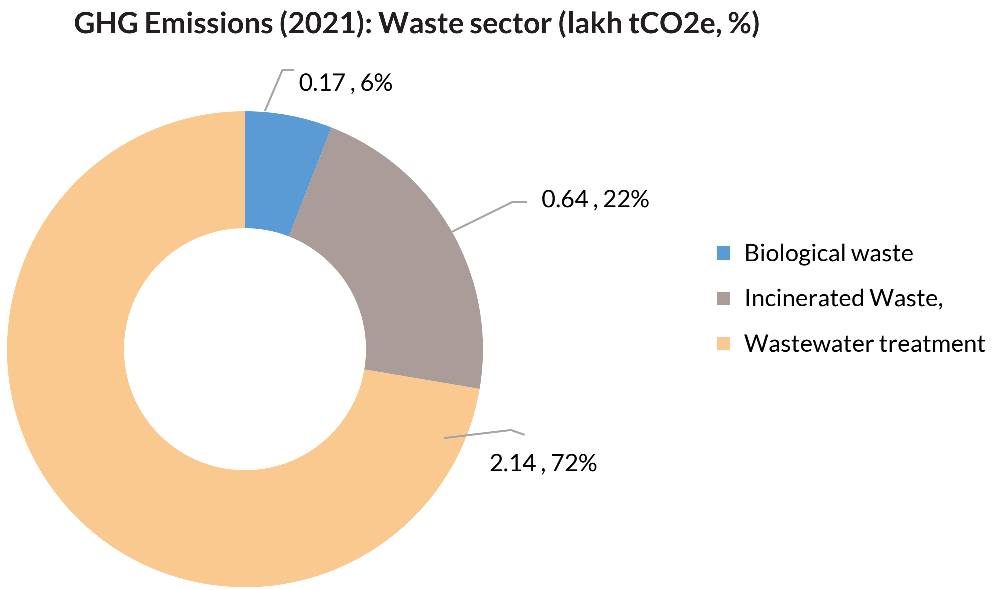
- In 2021, the estimated wastewater generation in CSMC was 120 million litres per day (MLD), and it is treated at four Sewage Treatment Plant (STPs) having a combined capacity of 210 MLD. However, the sewerage network coverage is only 84%, as 16% of wastewater is discharged without treatment, mainly from Satara and Deolai villages, both located within municipal boundaries and not connected to the sewage network.
- The STPs run on sequential batch reactor technology, and methane is not captured.

2. Sub-sectoral analysis

The contribution of solid waste to GHG emissions is around 0.82 lakh tCO_2e, which is 28% of the GHG emissions from waste sector. Of this, biological treatment of waste is responsible for around 0.17 lakh tCO_2e (6%) and incineration of biomedical, paper, plastic, textile, and rubber waste accounts for estimated GHG emissions of 0.64 lakh tCO_2e (22%). The wastewater sector contributes 72% (2.14 lakh tCO_2e) of the overall waste sector related GHG emissions.

The GHG emissions from municipal solid waste are primarily due to methane (CH_4) emissions, nitrous oxide (N_2O) emissions during the biological process, and carbon dioxide (CO_2) emissions due to the incineration process of dry waste. In the case of wastewater treatment processes, the primary emissions are from methane (CH_4).

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



Source: WRI India analysis

15. GHG EMISSIONS - SCENARIO ANALYSIS

15.1 APPROACH AND METHODOLOGY

15.1.1 Objective

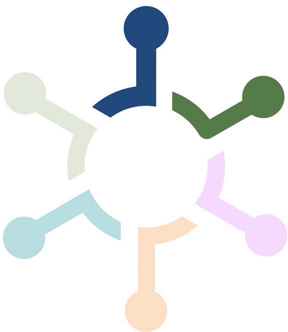
The objective of the scenario modelling exercise is to establish an evidence base for the city to set emissions reduction targets for energy, transport, and waste sectors in line with a fair-share 1.5-degree scenario and identify the strategies to achieve them. These scenarios would be used to structure the climate action planning analysis, document the city's current strategies, identify new strategies that Chhatrapati Sambhajinagar city can plan on implementing in the near and medium terms, and assess the barriers in implementation. 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 Chhatrapati Sambhajinagar city is a part.

15.1.2 Tools, Approach and Methodology

The scenario modelling for Chhatrapati Sambhajinagar city has been developed using the Climate Action for Urban Sustainability (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[37].

CURB allows cities to plan across six sectors in an integrated way: private buildings, municipal buildings and public lighting, electricity generation, solid waste, transportation, and water and wastewater (Figure 15-1). 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 also allows the user to set proxy values[38].

Figure 15-1: CURB sectors and sub-sectors



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

Although forecasting feasible targets until 2050 may not be accurate due to constant changes in technology and costs, setting such long-term targets provide cities with a data-backed timeline for long-term net zero or low carbon targets. Cities can also prioritise the areas with the highest mitigation potential for funding and policy making.

For the modelling study, 2021 has been accounted as the base year. The future interim target years are 2030, 2040, and 2050.

The targets and outputs modelled using the CURB align with the RCP 2.6 scenario and the Paris goal of 1.5-degree reduction. Whereas in a few cases, it also considers RCP 4.5, an intermediate scenario,

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

Business-as-usual scenario:
to represent development as per usual with no actions being taken to become sustainable

Existing and Planned Scenario:
to represent development considering plans and policies that have been envisioned for the city

Ambitious or Achievable scenario:
to represent development where ambitious targets have been set for the city to see sustainable growth

emissions in RCP 4.5 peak around 2040 and then decline. As per 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. Each scenario has a specific set of policy levers that provide relatively high GHG emission mitigation opportunities.

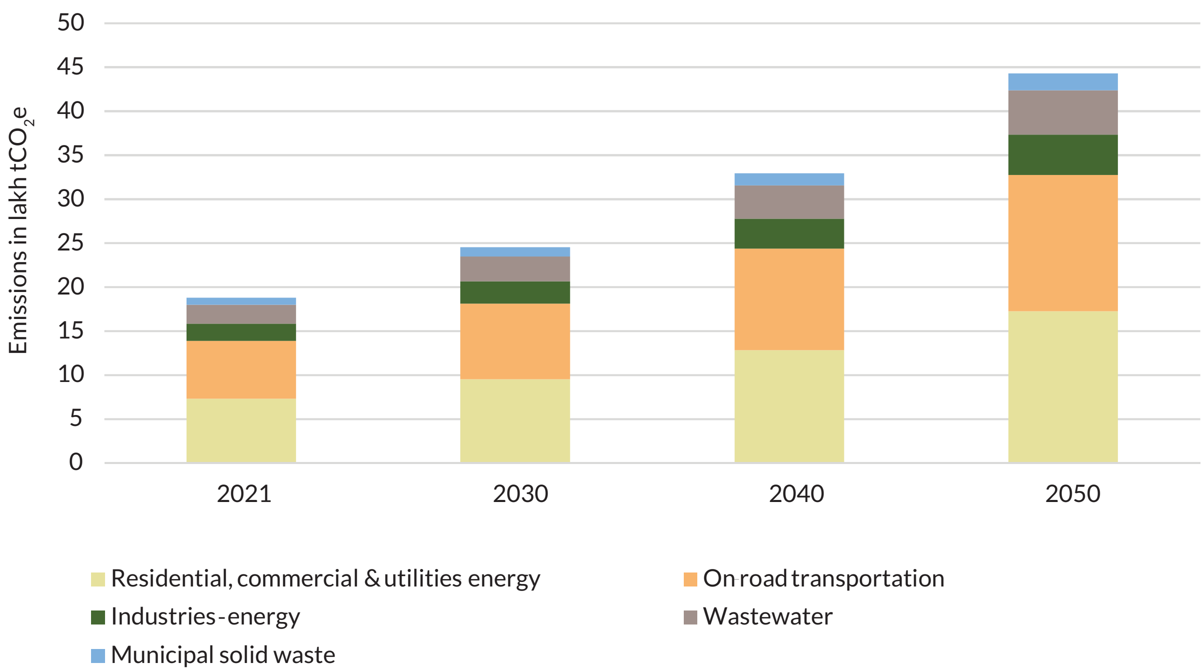
15.2 SCENARIOS ANALYSIS

15.2.1 Scenario 1: Business-as-usual Scenario

The GHG emissions in 2021 account for 18.8 lakh tonnes of CO_2 equivalent (tCO_2e), estimated on the basis of 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 2.4 times times between 2021 and 2050, reaching 44.32 lakh tonnes of CO_2e/year (Figure 15-2)

Figure 15-2: BAU emissions projections for Chhatrapati Sambhajinagar



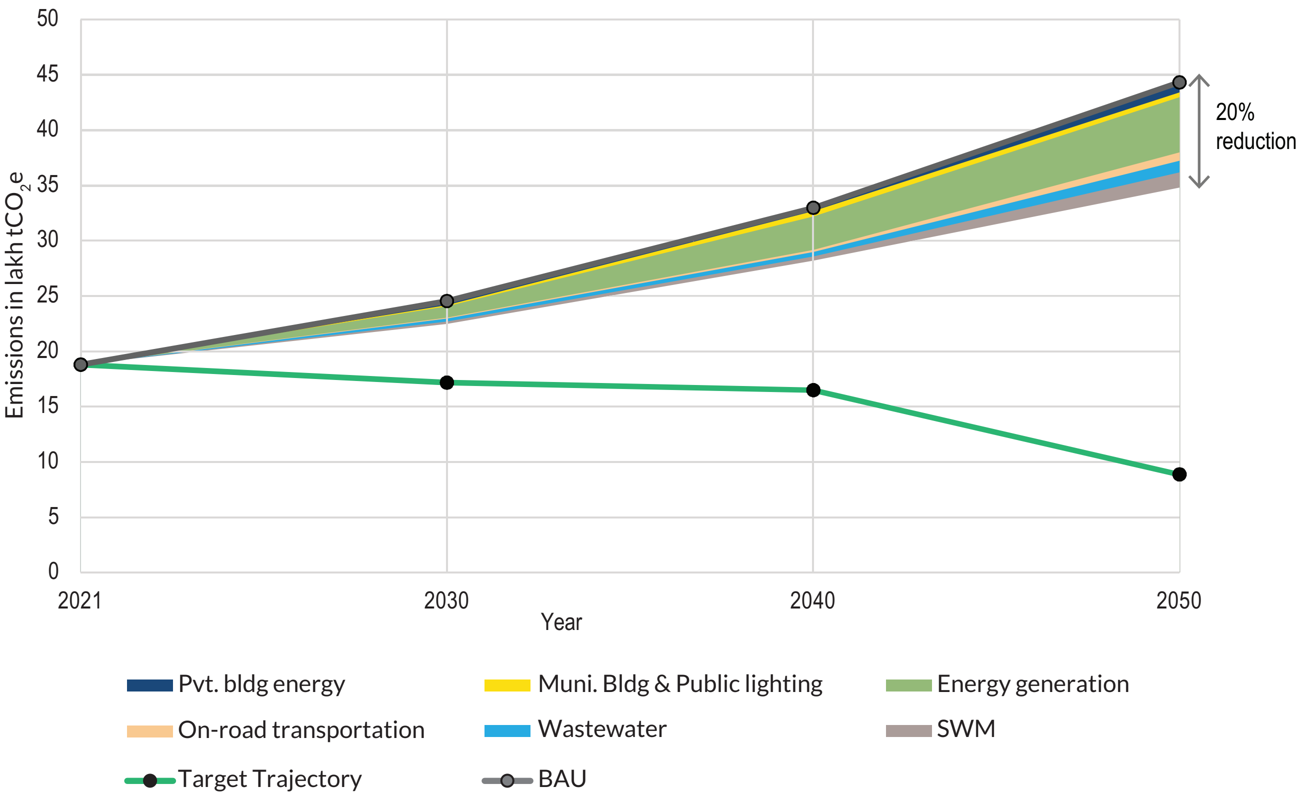
Source: WR India analysis using CURB tool

15.2.2 Scenario 2: Existing and Planned scenario

The E&P scenario uses data from existing and planned city, regional and national actions, policies, and programmes to demonstrate the emissions reduction trajectory for the city regarding the current ambition level. It considers current and planned development strategies with indirect co-benefits of emissions reductions. Examples include nationally determined contributions (NDC), the Maharashtra Power System Master Plan, Net Metering Guidelines, Energy Efficiency and Conservation Policy, National Action Plan for Climate Change (NAPCC), Maharashtra Electric Vehicle Policy 2021, which cover actions to subsidise photovoltaic solar installations, solar rooftops, electric vehicle policy etc. All these were factored as input data in the E&P scenario.

If the city implements the above-described targets by 2050, the consolidated effect results in an emissions reduction of 9% in 2030, 11% in 2040, and 20% in 2050. The planned scenario leaves a significant gap of 60% in meeting the city's 2050 targets and the 1.5°C pathway.

Figure 15-3: Emissions reduction potential of planned scenario



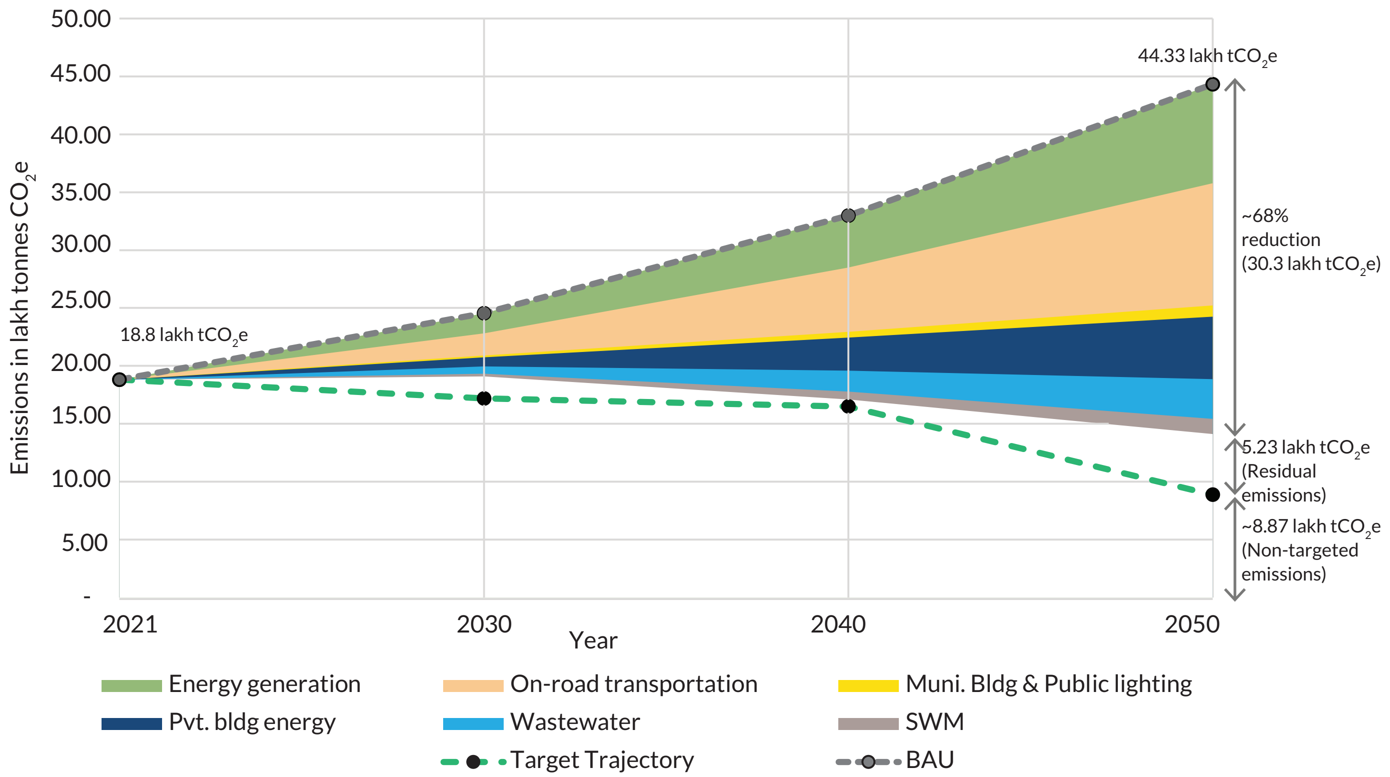
Source: WRI India analysis using CURB tool

15.2.3 Scenario 3: Ambitious scenario

Targets in the ambitious scenario have the potential to achieve approximately 68% emission reduction by 2050 as compared with BAU emissions of 44.33 lakh tCO2e in 2050.

The GHG emissions reduction target for 2050 is 80% of the estimated emissions i.e. 80% of 44.33 lakh tCO2e, which is 35.46 lakh tCO2e. Assuming that the actions proposed as per the Ambitious scenario are implemented by 2050, the GHG emissions will be reduced by 30.3 lakh tCO2e, a reduction of approximately 85% as compared with the target of 35.46 lakh tCO2e by 2050. Thus, there will be residual emissions of 5.23 lakh tCO2e, which is 15% of the emissions reduction target.

Figure 15-4: Emissions reduction potential of ambitious scenario



Source: WRI India analysis using CURB tool

As indicated, in the Ambitious scenario, the GHG emissions amount to 14.1 lakh tCO_2e in 2050 as compared with ~ 44.33 lakh tCO_2e in the BAU scenario.

- In the Ambitious scenario, given further aggressive policy scenario setting, we can expect deeper decarbonisation of the grid beyond 2040 because of India's high rate of renewable energy deployment and global pressure to retire coal power plants.
- Interventions such as fuel efficiency improvements in internal combustion engine (ICE) vehicles, vehicle electrification, increased use of alternative fuels, and

restraints in travel demand could limit or even reverse the growth trend of CO_2 emissions from the transport sector.

- Any significant impact in peaking and subsequent reversal of the emissions trend would only be possible in the case of aggressive vehicle electrification and continued efficiency improvements in ICE vehicles till 2050. Thus, the need for more decisive action to decarbonise the road transport sector is clear as efforts under the High Ambition scenarios fail to achieve carbon neutrality by mid-century.
- The Aggressive Policy scenario could help decrease 45–50% of cumulative CO_2 emissions between 2021 and 2050 using additional decarbonisation efforts, such as mode shift and deeper grid decarbonisation.
- Residual emissions can be further reduced if the city sets a higher renewable energy target. This is a state responsibility, and the city can contribute to a certain extent by adopting rooftop solar, solarising utilities and buildings, and adopting energy efficiency measures. Further research would be required to gauge the reduction of all long-term residual emissions.

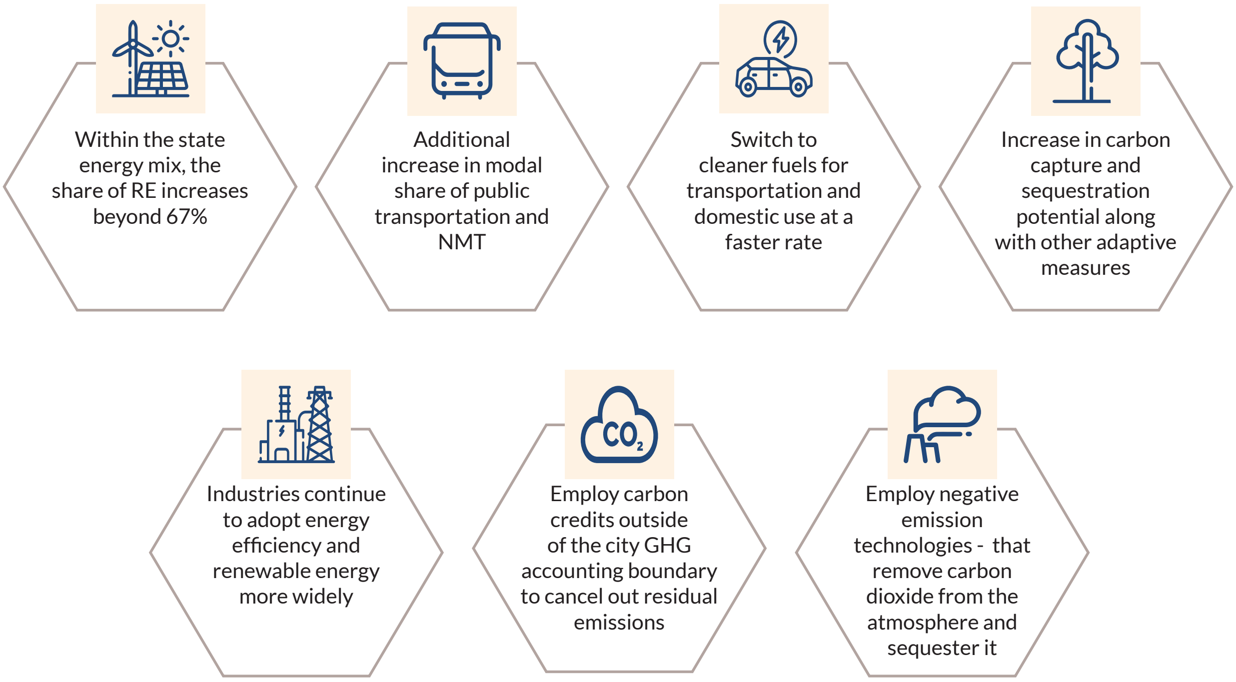
Limitations of the modelling analysis:

- No model is 100% correct 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 capacities, along with the constraints in political will, Chhatrapati Sambhajinagar will continue to have some amount of residual emissions by the year 2050. However, the projected emissions reduction target aligns with the Government of India's 2070 net zero emission reduction target. To reach a net zero by 2050, the Government of Maharashtra and CSMC must take additional vital measures, as presented in Figure 15.-5.

Figure 15-5: Measures to achieve the extended scenario



Source: WRI India analysis 2022

SECTION -V:

Priority Sectors- Assumptions and Targets

Photo Credit: ASCDCL

16. PRIORITY SECTOR IDENTIFICATION

16.1 KEY PRIORITY SECTORS

Based on the VA, the GHG inventory, and stakeholder consultations, six priority areas have been identified for the implementation of strategies for adaptation and mitigation. These include energy and buildings, sustainable mobility, municipal waste management, urban greening and heat mitigation, water resource management, and air quality. In order to develop assumptions and targets under the Ambitious scenario, various stakeholders were consulted and secondary research conducted. The stakeholders included CSMC departments of water supply, public works, environment, solid waste management, and planning, as well as parastatal agencies namely MSEDCL, fuel companies, and civil society organisations.

While developing the Ambitious scenario, the priorities, ongoing projects, and realistic targets for the city are taken into consideration. Still, some reforms and actions are beyond the city's responsibilities.

The energy sector is the most significant contributor to emissions in Chhatrapati Sambhajinagar city. Electricity is supplied to the CSMC area from a state utility (MSEDCL). Therefore, interventions and reforms at the state level are required to improve the energy mix, making it more clean fuel based.

Figure 16-1: Key sectors and strategic pointers

Urban Heat and Greening: focus is on reducing heat impacts, mitigating heat hotspots by greening and water-related interventions and NBS

Air Quality - improving air quality by improving monitoring, actions on hotspots, activity-related actions

Sustainable Mobility: entails improving public transport, expanding non-motorized transport options, transitioning to cleaner fuels and mitigating dust

Sustainable MSW Management: - adoption of decentralised waste processing (recycling, composting and bio-methanation) complimenting with centralised processes, improving source segregation and scientific landfill management

Water Resource Management: flood mitigation, improved access to water supply, groundwater management, 100% wastewater management, wastewater recycling and reuse for non-potable purposes

Energy and Buildings: increasing the share of RE in energy mix, adoption of energy efficiency measures, adoption of rooftop solar at a larger scale and reducing energy consumption

Source: WRI India analysis

16.2 TARGET TABLE

Table 16-1: Summary of sectoral targets for ambitious scenario

Indicators	2030	2040	2050
Residential and commercial buildings sector			
Energy: Private Residential buildings and energy			
Energy-efficient lighting in existing residential buildings	70%	80%	90%
Energy-efficient cooling in existing residential buildings	25%	40%	60%
Energy-efficient water heating in existing residential buildings	30%	40%	60%
Energy-efficient lighting in new residential buildings	30%	50%	100%
Residential PV on-grid connected electricity	25%	50%	75%
Energy: Private Commercial buildings and energy			
Energy-efficient lighting in existing commercial buildings	25%	40%	80%
Energy-efficient cooling in existing commercial buildings	20%	30%	50%
Energy-efficient water heating in existing commercial buildings	15%	30%	70%
Commercial PV on-grid connected electricity	40%	60%	80%
Energy: Municipal Buildings, public street lightning and traffic lights			
Energy-efficient lighting in existing municipal buildings	50%	70%	100%
Energy-efficient cooling in existing municipal buildings	30%	50%	70%
Public streetlight LED retrofits	40%	70%	100%
LED traffic signals	20%	50%	80%
Electricity Decarbonization Sector			
Solar PV	20%	30%	40%
Total by renewables	39%	50%	67%
Coal & others	61%	50%	33%
Sustainable Mobility			
% mode share for public transport	15%	30%	40%
% mode share for walk	18%	20%	22%
% mode share for cycle	3%	4%	5%
Share of auto in modal split	32%	25%	15%
Private - 2w & 4W	32%	21%	18%
Total Modal share	100%	100%	100%
Electrification of passenger automobiles (Three-wheeler auto)	15%	30%	60%
Share of electrification of light duty freight	10%	30%	60%
Share of electrification of buses	15%	30%	50%
Fuel switch of all on-road transport (CNG, electric etc.)			
2W	35%	65%	95%
3W	10%	30%	90%
4W	30%	50%	90%
LDV	15%	40%	75%
HDV	10%	25%	45%
Bus standard	20%	40%	70%

Indicators	2030	2040	2050
Solid Waste Management Sector			
% Paper recycled	55%	80%	95%
% Plastic recycled	55%	80%	95%
Share of organic waste composted	20%	80%	100%
Waste–energy optimisation	25%	50%	80%
Share of CNG SWM transport vehicles	1%	10%	40%
Wastewater and Water Sector			
Improved centralised treatment	50%	100%	100%
Improved decentralised treatment	5%	15%	30%
Wastewater to biogas optimisation	5%	15%	30%
Share of pumps with improved efficiency	10%	20%	50%
Share of NRW	40%	25%	15%

Source: WRI India analysis, 2022

The second most significant contributor to Chhatrapati Sambhajinagar's GHG emissions is the on-road transport sector. The targets for the transport sector prioritise the reduction of private mode share and increase of mass transit usage. However, it is essential to note that despite these efforts, the city will continue to depend on personal vehicles as a mode of transport. This is due to the status of public transportation, citizens' preference for private modes, and the limited reduction of personal vehicle dependency.

Similarly, source segregation of waste and cleaner fuels for waste transportation is critical for sustainable waste management. Various cities have implemented source segregation, which has been challenging due to multiple reasons that include the challenges in changing behaviours change, sustaining awareness, and penalising. The transition to cleaner fuels for waste vehicles also depends on the auto market and technology innovations. The wastewater sector also lists ambitious scenario targets based on investment in the existing processes, which will enhance efficiency and yield better results.

A summary of the Ambitious targets proposed for Chhatrapati Sambhajinagar city using the scenario modelling is presented in Table 16-1.

While these targets align with the sectoral departments of CSMC to ensure the efficient implementation of the Chhatrapati Sambhajinagar CAP, there is immense scope to converge across sectors, catalyse collaborations across Departments, and reap the co-benefits of holistic solutions.

The Chhatrapati Sambhajinagar CAP envisions to encourage the growth of a water-sensitive, low-carbon, green, and inclusive development of the city by embedding climate-resilient solutions for citizens, nature, systems, vulnerable communities, and industries, aligning it with a Net Zero vision for a 'Climate Forward Maharashtra'.

Recognising that steps must be taken on priority across the six identified sectors, the Chhatrapati Sambhajinagar CAP document presents further analysis, target setting, and actions, which are elaborated in the chapters that follow.

16.3 SECTORAL STRATEGIES

a. Recommendations- Energy & Building

- **Strategy E&B-1:** Revise the Solar Master Plan of the city to comprehensively cover the assessment of rooftop solar potential, business models, and incentives for the promotion of adoption of rooftop solar.
- **Strategy E&B-2:** Implement rooftop solar projects on municipal buildings, public open spaces, and municipal utilities on priority.
- **Strategy E&B-3:** Promote energy-efficient demand management in buildings by promoting green building certification, integrating passive design, and using energy-efficient installations and appliances.
- **Strategy E&B-4:** Achieve low carbon transition of commercial and key industrial segments in Chhatrapati Sambhajinagar.

b. Recommendations - Sustainable Mobility

- **Strategy SM-1:** Increase mode share of the public transport (neo-metro and bus) from the current 4% to 15% by 2030, 30% by 2040 and to 40% by 2050 through fleet enhancement, performance improvement measures, switching to cleaner fuels, and awareness building.
- **Strategy SM-2:** Achieve 15% mode share for the proposed Neo-metro by 2050.
- **Strategy SM-3:** Build robust infrastructure and policies for non-motorised transport to increase the mode share of walking to 20 % by 2040 and 22% by 2050, cycle mode share to 4% by 2040 and 5% by 2050.
- **Strategy SM-4:** Adopt various measures for private vehicles and autos to transition to cleaner fuels such as CNG and electric mobility.
- **Strategy SM-5:** Reduce emissions from urban freight through fuel-efficient and low-carbon delivery fleets, thus increasing the share of electric or cleaner fuel-based light-duty goods vehicle fleet to 30% by 2040 and 60% by 2050.

c. Recommendations - Solid Waste Management

- **Strategy SWM-1:** Expedite bioremediation and scientific closure of landfill with landfill gas/leachate management.
- **Strategy SWM-2:** Increase the efficiency of wet and dry waste management.
- **Strategy SWM-3:** Reduce emissions from waste collection and transportation: **Target 2.1:** Increase electric light-duty goods vehicle fleet share to 10% by 2040 and 40% by 2050.
- **Strategy SWM-4:** Implement sustainable construction and demolition waste management in the city.
- **Strategy SWM-5:** Promote efficient waste management through community awareness and engagement.

d. Recommendations - Urban Greening and Heat Mitigation

- **Strategy UG-1:** Increase the green cover from 4.2% to 30% by 2040 to mitigate the urban heat and water logging risk and enhance the carbon sequestration potential.
- **Strategy UG-2:** Increase per capita open spaces to a minimum of 9 sq.m. per person with enhanced accessibility.
- **Strategy UG-3:** Reinforce an enabling environment to enhance the green cover through policy measures, guidelines, a participatory approach, and citizen engagement.

e. Recommendations - Water Resource Management

- **Strategy WS-1:** Provide access to adequate and safe water for all by 2028.
- **Strategy GW-1:** Expand rainwater harvesting to contribute to at least 20% of the water supply by 2030, increase groundwater recharge, and implement innovative solutions for efficient groundwater recharge while managing water quality.
- **Strategy WWM-1:** Enhance sanitation and sewerage systems to ensure 100% coverage of sanitation systems and 100% sewage treatment by 2030, and increase wastewater reuse.
- **Strategy WL-1:** Prioritise water logging hotspots, and integrate these with the river restoration and storm water drainage augmentation plan.
- **Strategy WSCB-1:** Generate awareness, create outreach, and build capacities.

f. Recommendations - Air Quality

- **Strategy AP-1:** Strengthen the air quality monitoring system for better monitoring air quality and providing informed inputs for air pollution mitigation actions.
- **Strategy AP-2:** Reduce particulate matter concentrations by 20%-30% by 2026 and an additional 20% by 2030.
- **Strategy AP-3:** Build community resilience by identifying priority stakeholders and engaging with them via various communication mechanisms.

SECTION VI:
Sectoral Recommendations

Photo Credit: ASCDCL

17. ENERGY & BUILDINGS

The analysis and actions presented in this sector covers the following subsectors:

Figure 17-1: Sub-sectors covered within Energy sector

17.1 SECTORAL OVERVIEW

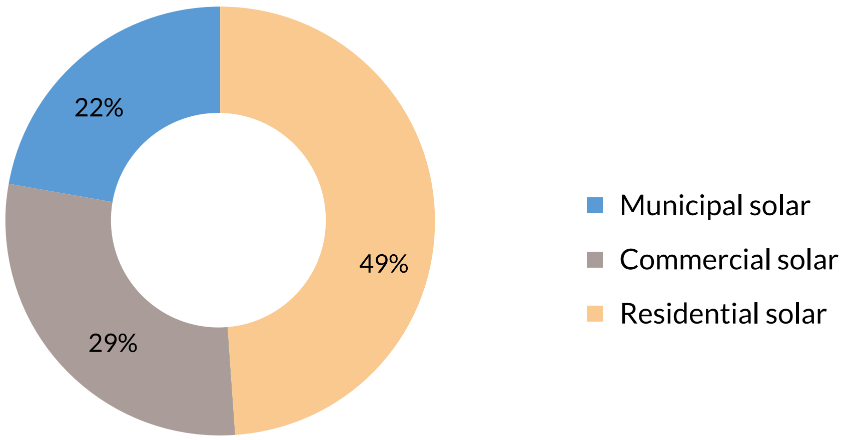
17.1.1 Renewable energy

For the year 2021, renewable energy (RE) in the Chhatrapati Sambhajinagar energy grid was 3% only. The electricity distributor is Maharashtra State Electricity Distribution Company Limited (MSEDCL).

The city boasts of good solar potential, with an average solar radiation of 5.3 KWh/m^2/day[39].

However, as per data from MSEDCL, solar energy generated back to the grid comprised only 2.84% of the total electricity consumption of 41.8 GWh. Majority of solar generation came from residential consumers, followed by commercial consumers. The state's energy mix comprises 23% renewable energy, while the major source of electricity is coal (60%), followed by gas (8%), hydro (7.5%), and nuclear (1.5%)[40].

Figure 17-2: Solar energy distribution to grid by consumer type (2021)



Source: MSEDCL primary data

Residential, commercial, and industrial solar consumers are less than 1%, and the municipal consumers are marginally higher more (Refer Table 17-1).

Table 17-1: Percentage of total consumers with Solar PV as of 2021

Consumer type	Total solar PV consumers	Total consumers	% Consumers with solar PV
Residential	2544	3576439	0.07%
Commercial	367	375188.3	0.10%
Industrial	115	48055.75	0.24%
Municipal	160	12330	1.30%

Source: Primary data (MSEDCL)

The city promotes solarization via initiatives such as 5% property tax rebate for installing solar PV and mandating solar water heaters in new institutional buildings and hotels[41]. 80 KW rooftop PV is operational in the municipal administrative building and 100 KW at the Endo World Hospital[42]. Several educational institutions have set up solar PV, namely Marathwada Institute of Technology College, Chhatrapati Sambhajinagar (100 KW), Babasaheb Ambedkar Marathwada University Chhatrapati Sambhajinagar (10 KW), and JNEC College (40 KW)[43]. The solar rooftop potential for the city, as per the analysis conducted under the draft Solar City Master Plan, 2013, is given in Table 17-2 below[44]:

Table 17-2: Solar rooftop potential in Chhatrapati Sambhajinagar

Area	Solar PV potential (KW)	Emissions reduction (tco2e)
Schools	72	106.5
Hospitals	2685	3969
Banks	962	1423
5 star hotels	400	500
3 star hotels	1250	1563
Municipal buildings	1382	2044
Vegetable market	70	103

Source: Draft Solar City Master Plan, 2013

17.1.2 Fuel consumption and access

38% of energy sector emissions originate from fuel consumption, particularly from the energy and industrial sectors. Within the residential sector, 78% of energy is consumed by LPG, followed by coal and wood[45]. WRI India analysis highlighted that 66.52% of households have access to clean cooking fuel. As per MPCB's Source Apportionment study, within the commercial sector, hotels mostly use LPG while 60% of bakeries use coal, 38% wood, and the rest LPG[46].

17.1.3 Municipal utilities energy consumption

The city's streetlights are mostly LED (75%). The city has 25 LED traffic signals, but there have been no pilots of solar LEDs or signals. Water pumping is also fossil fuel driven, consuming 19,000 MWh in 2021[47].

17.1.4 Energy efficiency in residential, commercial, and municipal buildings

Consultations and data from solar water heater distributors in Chhatrapati Sambhajinagar[48] reveal a 4% annual decline in residential solar water heater adoption. However, commercial sales have increased: yearly 5% in establishments since 2015, 26% in hospitals, and 18% in hotels.

Currently, only 3% of hospitals use solar water heaters. In commercial buildings, 20% have energy-efficient fans and only 30% use CFLs or LED lighting. Heer-Radha is the only green building in the city. It is a residential private property certified by IGBC[49].

17.2 ON-GOING INITIATIVES

The city is undertaking several positive interventions towards promoting decentralised solar energy and improved energy efficiency in buildings.

Table 17-3: Energy – Initiatives taken by CSMC

Renewable energy	Energy efficiency	Green buildings
• Tender stage: 150 KWp(100+50) of grid connected Solar Power Plant (With Net Meter), at operation command centre & ASCDCL HQ[50] • 80 KW solar PV planned in - Usmanpura, Sant Eknath Rang Mandir, 50 KW planned in hospitals, 1 MW planned in zoological park[51] • 1.2 MW planned for Aurangabad airport by Airports Authority of India[52] • MAHAGENCO invites bids for 100 MW projects in 6 areas, including Chhatrapati Sambhajinagar district, with operation and maintenance for 25 years. Out of this, Chhatrapati Sambhajinagar city has potential for 72.5 MW[53] • MSEDCL has submitted a Request for Selection for 50 MW solar power from projects in Chhatrapati Sambhajinagar district. Out of this, the city can implemented 36 MW[54].	The draft solar city master plan prepared in 2013 had targets for increasing energy efficiency in residential, commercial, and municipal buildings, but it has not been implemented.	• The Command & Control Centre, ASCDCL, has also adopted IGBC Green New Building Rating. Its certification is in process, and the Smart City office is expected to be certified with platinum certification. • IGBC also plans to associate at the city level to rate Chhatrapati Sambhajinagar as per IGBC Green Cities Rating. They have signed an MoU with Pune for the same[55], and similar MoUs are planned to be signed with CSMC.

17.3 KEY GAPS

- **Limited proliferation of distributed renewable energy**

Despite a 5% property tax rebate for solar PV, there is limited uptake across all consumer segments. This indicates the need for improved awareness and campaigns to promote distributed solar in the city.

- **Need for increased awareness and data on energy efficiency and demand management in buildings**

Since the 2013 draft solar master plan survey, there is no survey/study on the usage of energy-efficient devices and equipment in commercial and residential buildings. Data on energy efficiency in municipal buildings and utilities is required, with incentives for promoting solar powered devices in municipal buildings.

- **Need for a robust institutional mechanism to promote green buildings**

The gaps highlighted by the representative from the IGBC chapter in Chhatrapati Sambhajinagar included the limited policy support and incentives for green buildings. The slow approval process and the lack of awareness amongst developers were also cited as barriers to green building uptake.

- **Limited usage of renewable energy and energy conservation practices in industries**

Consultations with industries highlighted a few challenges, such as the procedural issues in getting solar PV connections from MSEDCL and the lack of incentives targeted at promoting solar, etc. in industries.

17.4 SECTORAL ASPIRATION

Decarbonising Chhatrapati Sambhajinagar's energy grid and shifting towards energy efficient and low carbon development. This should be driven by increasing consumer awareness and energy-efficient demand management while ensuring equitable access to clean energy across all income groups.

Overall target: 25% GHG emissions reduction by 2030, 51% by 2040, and 60% by 2050, as per BAU emissions of the respective years.

17.4.1 Sectoral strategies

The following are the key sectoral strategies to meet the above-mentioned aspirations:

Strategy E&B-1: Revise the Solar City Master Plan of the city to comprehensively cover the assessment of rooftop solar potential, business models, and incentives for the promotion of the adoption of rooftop solar

Strategy E&B-2: Take up rooftop solar projects on municipal buildings, public open spaces, and municipal utilities on priority

Strategy E&B-3: Promote energy-efficient demand management in buildings by promoting green building certification, integrating passive design, and using energy-efficient installations and appliances.

Strategy E&B-4: Promote low carbon transition of commercial and key industrial segments in Chhatrapati Sambhajinagar

17.2.2 Sectoral actions

Key sectoral strategies and actions are given below:

Table 17-4: Strategy E&B-1: Revise the Solar Master Plan of the city to comprehensively cover the assessment of rooftop solar potential, business models, and incentives for the promotion of the adoption of rooftop solar.

Action description	Stakeholders & Financing	Indicators
Revise the Solar Master Plan 2013 by conducting surveys and assessing the following - • Revise energy baseline for 2023-24, assess consumption patterns • Capture information on energy-efficient equipment and consumer preference and barriers (policy, pricing) for uptake • Update goals and strategies • Develop a roadmap for retrofitting low-income and informal housing with energy-efficient equipment by 2050 • Introduce various ways of incentivisation for those who install solar PV, such as tax rebates, reduction in other utility bills like water or waste, increase in FAR, etc., **Timeframe: 2025-26**	Lead: CSMC, Consultancies with expertise in RE and EE infrastructure and financial management Supporting: MSEDCL; Finance: Central financial assistance from MNRE, private institutions, Municipal Budget	Output: Revised Solar Master Plan, survey for 2023 Outcome: % solar in energy mix, %increase in consumers with energy-efficient equipment, reduction in GHG emissions from stationary energy

Table 17-5: Strategy E&B-2: Take up rooftop solar projects on municipal buildings, public open spaces, and municipal utilities on priority.

Action description	Stakeholders & Financing	Indicators
Demonstrate a pilot and then implement full-scale rooftop solar projects and, wherever feasible, solar PV projects in the following: • Public spaces: crematoria, playgrounds, stadiums, bus stops, and other open spaces such as the Siddharth Garden and Mukti Sangram area (50000 sq. m area potential). • Institutional buildings – municipal buildings, universities, hospitals, railway stations, etc. • Solar PV at WTPs and STPs and all waste management and processing facilities (such as MRFs) • Ensure a 100% transition to RE-powered streetlights, lights in public spaces, and traffic signals. **Timeframe: 2025- 2030**	Lead: CSMC SWM department Supporting: ASCDCL, MSEDCL Financing: Jawaharlal Nehru National Solar Mission Phase II (JNNSM PHASE-II) - Viability Gap Funding based on the bid, upper limit of INR 1.0 crore/MW for the open category and INR 1.25 crore/MW for projects in the Domestic Content Requirement (DCR) category[56], Viability gap funding under Central Public Sector Undertaking Scheme phase II through participation in bids by SECI	Output: # of MRFs, public spaces, municipal buildings, WTPs, STPs with solar power Outcome: % solar in energy mix, reduction in GHG emissions from stationary energy and waste
Explore innovative funding models in RE • Revenue sharing: Delhi Municipal Corporation had opened up a tender for solar PV in all municipal buildings where revenue is shared between the agency and DMC over a minimum period of 25 years[57] • Green bonds: Introduce bonds issued outside India but in Indian rupee. The investor bears the risk rather than the borrower. Indore plans to issue green masala bonds for funding a floating solar project[58]. **Timeframe: 2025- 2027**	Lead: CSMC Supporting: ASCDCL, Investors, International Development organisations (World Bank, Asian Development Bank, etc.) Financing: International Development Organisations (IDO) (World Bank, Asian Development Bank, etc)	Output: Increase in solar PV in municipal buildings Outcome: Reduced emissions from stationary energy and wastewater, % solar in electricity grid

Table 17-6: Strategy E&B-3: Promote energy-efficient demand management in buildings by promoting green building certification, integrating passive design, and using energy-efficient installations and appliances.

Action description	Stakeholders & Financing	Indicators
Set up Energy Efficiency and Green Building Cell in CSMC for RE and EE implementation, coordination, and monitoring. • The cell should include multiple relevant stakeholders from CSMC, ASCDCL, MSEDCL, and supporting agencies (IGBC). • The cell shall update building bylaws to incorporate ECBC provisions related to energy efficiency and solar rooftops. • Mandate heat-resistant/ insulated roof and wall materials in all new building structures, including housing schemes for economically weaker sections, government offices and commercial buildings. • Introduce energy-efficient equipment drives with private distributors. Encourage innovative financing through on bill payment and attractive EMI schemes. • Provide low-cost, energy-efficient appliances for residential consumers (In Andhra Pradesh, the Andhra Pradesh Electricity Regulatory Commission (APERC) offers products at discounted rates as compared with market rates. Reduced GST can also be given on such products[59]. • Issue a mandate for all existing commercial buildings to retrofit lighting and other appliances, for new residential buildings to have LEDs and, for all energy appliances installed to be of atleast 4 star rating. • Mandate the procurement of only energy-efficient appliances with BEE 5-star rating in all municipal building facilities. • Conduct periodic auditing of all municipal buildings and utilities. **Timeframe: 2030**	Lead: CSMC Supporting: NGOs or universities, RWAs, MSEDCL, distributors, IGBC Chhatrapati Sambhajinagar Chapter, builders associations Financing: CSMC budget, organizations like Alliance for Energy Efficient Economy, State Energy Conservation Fund (SECF) for Maharashtra, Energy Efficiency Financing Platform (EEFP): M/s, PTC India ltd, M/s. SIDBI, HSBC Bank, Tata Capital and IFCI ltd have been signed by BEE to promote energy efficiency projects[60]	**Output:** Energy Efficiency and Green Building Cell **Outcome:** Number of incentives for energy efficiency in residential and commercial buildings, % of households and commercial buildings with energy efficient heating, cooling and cooking appliances, reduced emissions from stationary energy

Action description	Stakeholders & Financing	Indicators
Promote the integration of passive design strategies to ensure well-being and thermal comfort. Integrating passive design strategies, such as building orientation, shading, ventilation, and low-energy cooling solutions, can significantly reduce the demand for electricity in buildings used for lighting, cooling, and applications. CSMC must explore incorporating some of these passive strategies in building laws for broader adoption. **Timeframe: 2025**	Lead: CSMC Supporting: IGBC, NGOs, distributors	**Output:** % reduction in the use of cooling appliances, % increase in energy savings, number of buildings with passive design strategies **Outcome:** % of energy demand reduced in new buildings
Conduct awareness training workshops for: • Resident Welfare Associations and large-scale distributors on the uptake of energy-efficient appliances and energy conservation measures. • Developers and Town Planning Department by IGBC on green buildings • Municipal officers and citizens on energy-saving measures and behavioural change. This can be accompanied by energy-efficient equipment drives/ sales in municipal buildings with private distributors. **Timeframe: Start in 2025**	Lead: CSMC Supporting: IGBC, NGOs, distributors	**Output:** Mandate, number of trainings and equipment drives **Outcome:** % of municipal buildings with energy-efficient equipment, % reduction in GHG emissions from the stationary energy sector

Table 17-7: Strategy E&B-4: Low carbon transition of commercial and key industrial segments in Chhatrapati Sambhajinagar.

Action description	Stakeholders & Financing	Indicators
Facilitate and promote the adoption of RE and improve energy efficiency by: • Promoting captive uses of RE by MSMEs • Providing low-cost, energy-efficient equipment for industries or providing subsidies on capital costs. • Promoting the installation of Smart Meters by collaborating with MSEDCL • Organising routine consultations among all stakeholders to address issues related to adoption of RE and energy efficiency measures • Exploring the feasibility of piloting green hydrogen for steel manufacturing • Pharmaceutical companies can explore the feasibility of electric cold chain shipping: Omega Seiki Mobility, a Delhi-based company, unveiled Rage+ Frost, an electric three- wheeler with a refrigerated carriage, purposely designed for pharmaceuticals • Replacing coal-fired boilers with biomass for all breweries and associated industries: Case example: Malabar Breweries in Kerala witnessed a 47% reduction in its energy cost despite the increase in manufacturing (Kerala)[61] **Timeframe: 2035**	Lead: MSEDCL, Industrial associations Support: CSMC, MASSIA, CMIA, CII Financing: Venture Capital Fund for Energy Efficiency (VCFEE) by Ministry of Power, Industry associations	Output: # of RE captive power plants, # of MSMEs that have adopted RE measures Outcome: Increased % of RE in the grid, decrease in GHG emissions

Photo Credit: ASCDCL

18. SUSTAINABLE MOBILITY

18.1 SECTORAL OVERVIEW

The only transport system in the city of Chhatrapati Sambhajinagar is an on-road one. The analysis and actions presented for this sector cover the following subsectors:

As per the draft comprehensive mobility plan prepared by Urban Mass Transit Company Limited and Maha-Metro, the current modal split for 2022 is as follows: automobiles 4%, non-motorised transport (pedestrian and cycle) 18%, 2-wheelers 38%, 3-wheelers 36%, and bus 4%, as depicted in Figure 18-2.

Figure 18-1: Urban Transport - Key sub-sectors covered

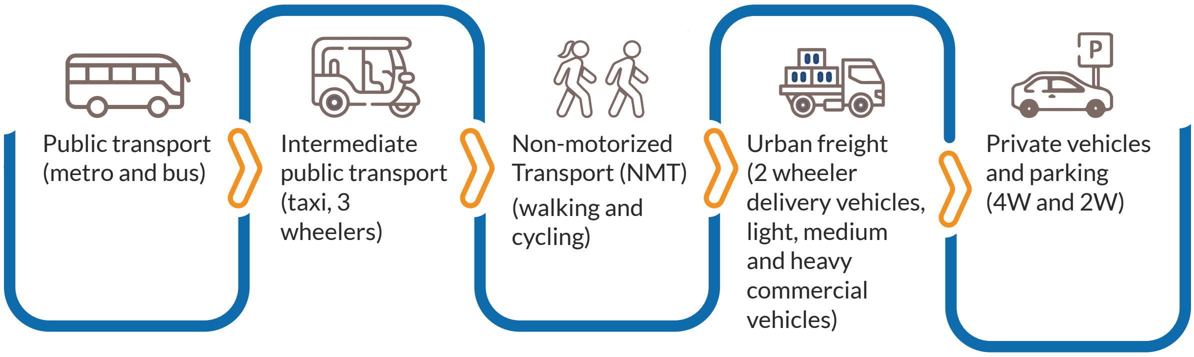
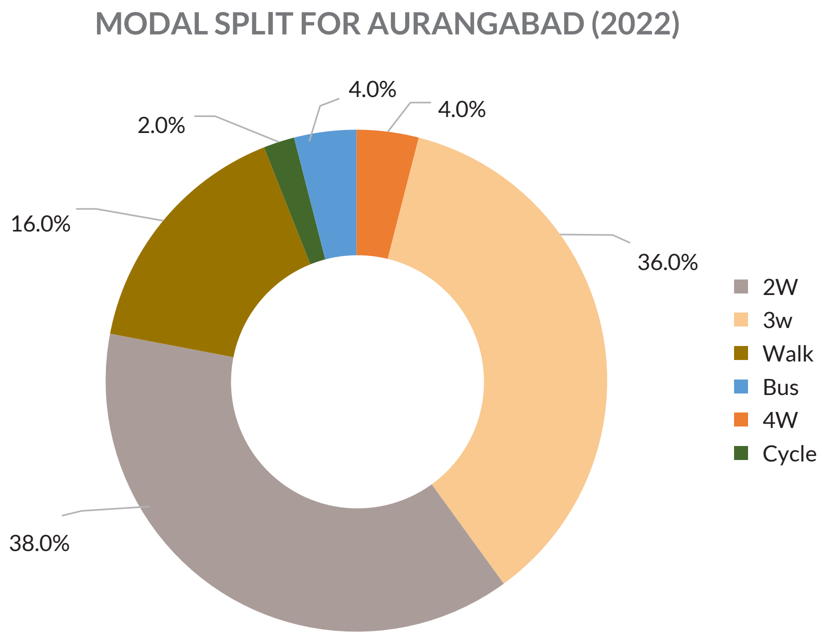


Figure 18-2: Modal split for Chhatrapati Sambhajinagar



Source: Draft Comprehensive Mobility Plan- 2022 and WRI India analysis

18.2 PUBLIC TRANSPORTATION SYSTEM

Chhatrapati Sambhajinagar has a fleet of 100 midi buses (9 meters, UBS II specification, all diesel BS-IV) run by ASCDCL on 31 routes, with minimum and maximum route lengths of 6.6 km and 22.6 km, respectively[62]. It is a joint public service venture between ASCDCL and MSRTC with a current ridership of 10,000 daily passengers[63]. Currently, the buses are running on a GCC model.

Currently, Chhatrapati Sambhajinagar city has six buses per lakh population. The city needs to increase its fleet to at least 380 buses by the year 2026 to meet the lowest service-level benchmark of 20 buses for 1 lakh people (MoHUA). It should aim for 775 buses (40 buses per 1 lakh people) by the year 2030.

Table 18-1: Bus demand estimation

WRI India estimates	Estimated Population	Norm buses/ lakh pop.	Buses, No.
2026	16,90,000	31	524
2030	19,34,680#	40*	774#
2032	20,70,000	48	994
2040	24,76,475#	48*	1,189#
2042	25,90,000	48	1,243
2050	30,13,668#	60*	1,808#
2052	31,30,000	84	2,629

*Source: Draft Comprehensive Mobility Plan- 2022 and WRI India analysis; *Assumed, #Estimated*

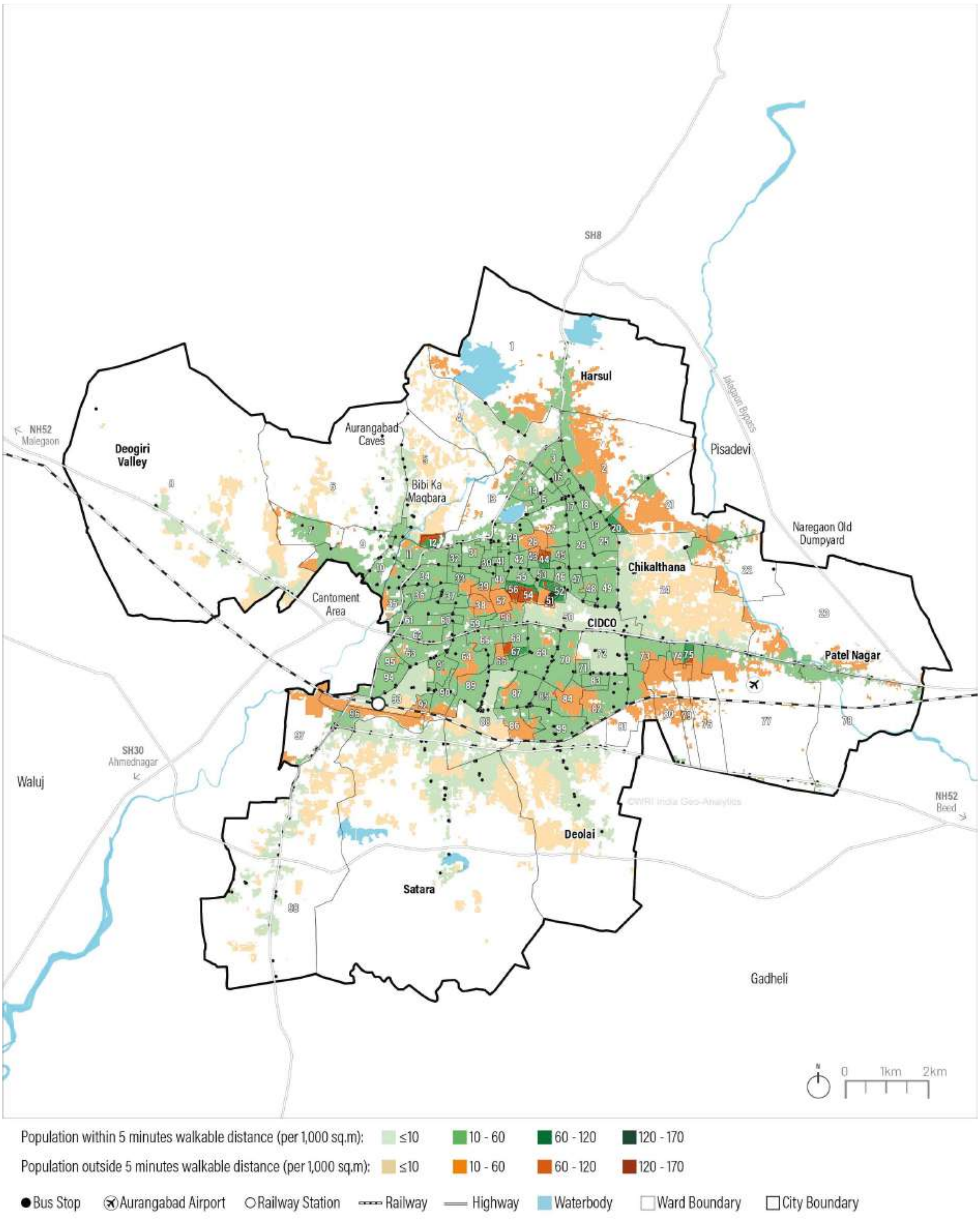
The city has implemented digital payment in its buses and has an app named Mazi Bus and a web-based portal named Chhatrapati Sambhajinagar Smart City Bus Portal, which provide real-time information on bus arrivals and cancellations.

18.2.1 Public transport accessibility

The city has 584 bus stops and 90 bus shelters[64]. As per WRI India's access analysis,

- 68% population of the city has access to bus stops within the required limit of 500 m.
- Areas such as Deolai, and Chikalthana MIDC have limited access, while Sanjay Nagar and New Baijipura in the core of the city are the higher density areas that are outside ease of access (Figure 18-3). This calls for a priority action to increase the access in the higher density areas.

Figure 18-3: Percentage of population living within 500 m of bus stops (2022)



Source: WRI India analysis 2022

18.2.2 Intermediate public transport

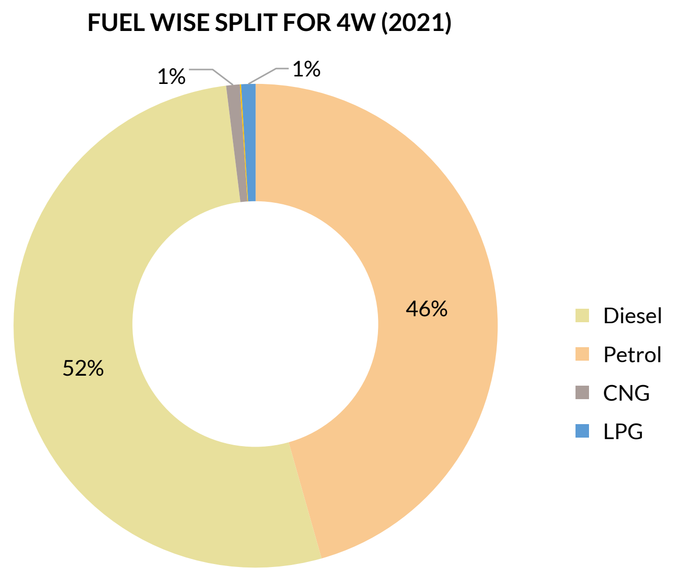
City has 37,000 registered intermediate public transport (IPT) vehicles as of March 2021 (3,639 cabs and 35,954 autorickshaws). On average, IPT covers 10-15 trips per day within the city[65]. While 96% of cabs run on diesel, 3% run on petrol. There are no electric cabs. 92% of auto rickshaws run on petrol, 4% on diesel, 1% on CNG, 1% on electricity and 2% on auto LPG[66].

18.2.3 Private vehicles and parking

The city has a 42% mode share for private vehicles (2-wheelers and 4-wheelers). Between 2011 and 2021, the registration of 4-wheelers and 2-wheelers grew at a CAGR of 3% and 13%, respectively[67]. Most 4-wheelers run on diesel and petrol (Figure 18-4). With respect to 2-wheelers, 100% of the fleet runs on petrol, as per RTO data. Exhaust from private vehicles also contributes significantly to $PM_{2.5}$ and PM_{10} emissions (4-wheelers contribute 15% of $PM_{2.5}$ load and 12% of PM_{10} load; 2-wheelers contribute 8% of $PM_{2.5}$ load and 10% of PM_{10} load) [68]

The city also has 24 main traffic junctions. The vehicle density (number of vehicles/km road length) is 542 per km of road length, which is higher than Delhi (245) and Kolkata (355)[69]. Parking demand in the city grew at an average of 30% per year, and a parking policy was adopted to manage the demand in 2022[70].

Figure 18-4: Break-up of fuel usage by 4-wheelers in 2022 (RTO data)

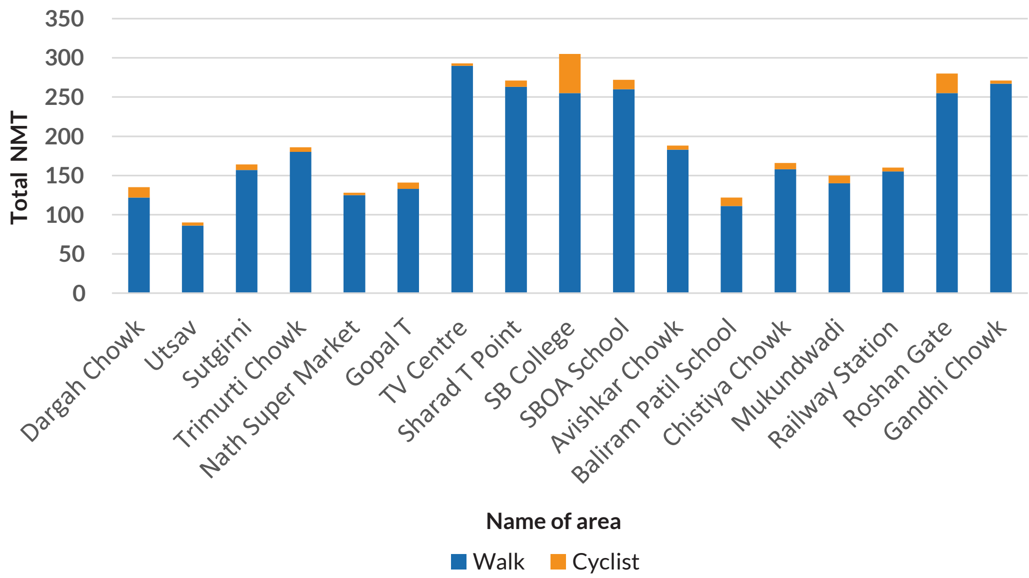


Source: WRI India analysis 2022

18.2.4 Non-motorised transport

Walking and cycling have a combined mode share of 18%. However, only 4.7% of the city's roads have footpaths[71]. The city has a 5km cycle track between Kranti Chowk and Railway Station, piloted under the Streets4People challenge[72]. The city has also developed a Healthy Streets Policy in 2022[73]. As per the inception report of the NMT Policy[74], the areas with the highest walking footfall include the TV Centre, SB College, SBOA School, Roshan Gate, and Gandhi Chowk while those with the highest *cyclists' footfall* are SB College, Roshan Gate, SBOA School, Dargah Chowk (Figure 18-5). 5% of total NMT users are cyclists.

Figure 18-5: Pedestrian and cyclists' footfall in Chhatrapati Sambhajinagar



Source: Healthy streets policy 2022[75]

18.2.5 Urban freight

Heavy commercial vehicles (HCV) contribute to 50% of PM_{10} emissions in the city[76]. HCVs contribute to the highest percentage of PM_{10} (25%) and $PM_{2.5}$ (31%) load in the city. As per RTO registration data, 99% of LCVs run on diesel while 100% of HCVs run on diesel. Both HCVs and LCVs in the city grew at 2% each year, as per RTO registration data.

Chhatrapati Sambhajinagar has also been shortlisted to be developed as a 'freight Smart city'[77]. As a part of this, a "*City-Level Logistics Committee for Planning and Development of Freight Smart Cities for Aurangabad City*" was formed in March 2022 with the aim to improve *freight performance and logistics planning* in the city.

18.3 ONGOING AND PLANNED INITIATIVES

In Chhatrapati Sambhajinagar, initiatives are ongoing to improve public transport infrastructure, promote the uptake of electric vehicles by municipal officers, manage parking, and improve non-motorized transport infrastructure in the city. The ongoing and planned initiatives are listed in Table 18-2:

Table 18-2: Urban Transport – ongoing initiatives

Public transport and IPT	Non-motorized transport	Private vehicles and parking
• 38.2 km of the MRTS bus-based system by 2026 and an additional 11.1kms by 2042 being planned [78] • Plan to expand bus fleet to 521 by 2026, 1001 by 2032, and 2615 by 2052 including city bus, feeder and MRTS[79] • 20% of the conventional auto-rickshaws are to be converted to electric auto-rickshaws in the next five years (from 2023)[80] • 35 e-buses planned by 2024. 15 chargers with a charging point each are planned in the city by the end of 2022 mainly under flyovers and in government buildings (as per Maharashtra EV Policy, 2021)[81]. • Neo-metro proposed by 2033 • Upcoming CNG filling stations as Bharat Petroleum to invest Rs. 3,972 Crore for Development of City Gas Distribution Network in Chhatrapati Sambhajinagar over next 5 years[82]	• 13 km NMT priority corridors, 25 km cycle lanes planned[83] • Healthy Streets Policy: 5- and 10-year targets (10km footpaths per 1L population, 5km cycle paths/1 L population by 2030) • Streets4people challenge: Pedestrianization pilots in Kranti Chowk to Osmanpura Chowk, Paithan gate, Connaught street[84].	• Proposed business corridor connecting Shendra, Waluj and Chhatrapati Sambhajinagar will promote vehicular growth and density as per draft CMP. • Roads: 111 new smart roads at Rs. 317 crore[85] • Parking policy 2022: 5 pilot sites-area parking plans[86] • Plan to mandate in new DP : 1 EV charger in every residential complex with 25 or more flats; 35% EV parking space in new constructions; 10 acre land in APMC market: 5 acre planned for buses, remaining for public parking for freight[87]

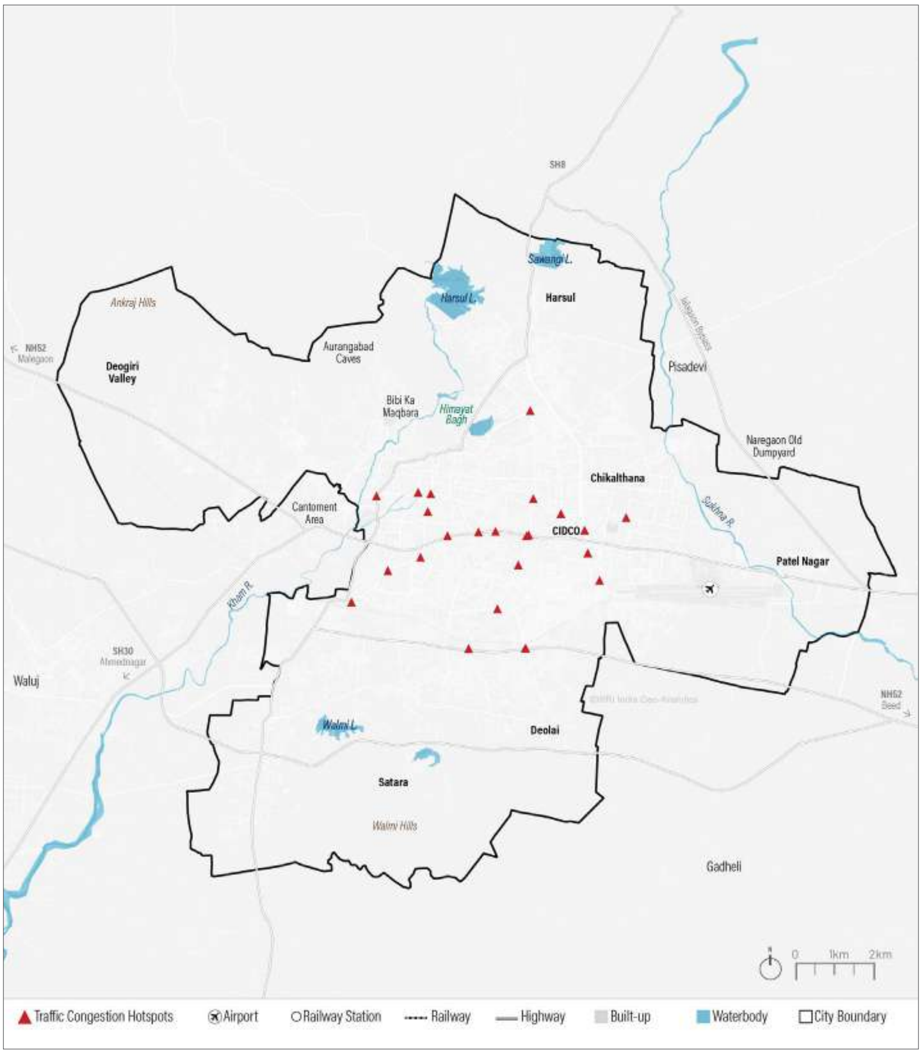
18.4 KEY GAPS AND CHALLENGES

1. Limited public transport infrastructure, access, and ridership and increased congestion

The city has only 6 buses per 1 lakh population. It needs at least 20 buses per lakh population to meet the minimum level of service designated by MOHUA[88]. Moreover, all buses are BSIV and there is a need to improve fleet fuel efficiency.

The city has also begun witnessing an increase in congestion in major corridors, such as Jalna Road, owing to an increase in the number of private vehicles. Under the NCAP, a Micro Action plan is prepared, which identifies the major traffic junctions in the city as air pollution hotspots. There are 24 such junctions all over the city, as mapped in Figure 18-6. Most of these traffic congestion hotspots lie on the Jalna Road highway.

Figure 18-6: Traffic congestion hotspots in Chhatrapati Sambhajinagar city



Source: WRI India analysis 2022

2. Fossil fuel-driven fleets (IPT, private vehicles, and urban freight) with <1% electric vehicles
As per RTO data:

- Diesel cabs increased by 14% and petrol by 33% each year between 2010 and 2021. There are no electric cabs in the city.
- Private vehicles: Between 2015 and 2021, petrol cars increased by CAGR 4% and diesel 2-wheeler by CAGR increased by 8%.
- EV auto registrations increased five times in one year between 2020 and 2021
- Freight: Between 2015 and 2021, light goods vehicles diesel and petrol increased by 11% and 77% respectively.

The city needs a baseline assessment of freight emissions with clear incentives to promote clean fuel freight. As per RTO data, 17 CNG HCVs are registered in 2021. This shows a willingness amongst consumers to expand into low-carbon fleets, but the CNG refuelling infrastructure needs improvement.

3. Insufficient infrastructure and poor safety for pedestrians and cyclists
Less than 5% of the city's roads have accessible footpaths, as per the Healthy Streets Policy 2022 survey[89]. Many footpaths are discontinuous, encroached, and not disabled-friendly, along with having other issues such as absence of maintenance of footpaths, dust on streets, smokers on footpaths, temperatures too high to walk on footpaths, indicated by pedestrians. The city also has poorly designed junctions, such as the Jalna Road junction, Akashvani, Amarpreet Hotel, and High Court junctions,[90] with more than 20% of fatalities involving pedestrians[91].

18.5 RECOMMENDATIONS

18.5.1 Sectoral aspiration

Decarbonizing Chhatrapati Sambhajinagar's transport sector by shifting the travel demand towards non-motorised and public transport, along with an equitable clean fuel transition across passenger and freight segments.

Overall target: 17% GHG emissions reduction by 2030, 40% by 2040, and 70% by 2050, as per respective years BAU emissions

18.5.2 Approach

Below are the key sectoral strategies for the Sustainable Mobility sector:

- **Strategy SM-1:** Increase mode share of the public transport from the current 4% to 15% by 2030, 30% by 2040, and 40% by 2050 through fleet enhancement, performance improvement measures, switching to cleaner fuels, and creating awareness

- **Strategy SM-2:** Achieve 15% mode share for the proposed Neo-metro by 2050

- **Strategy SM-3:** Build robust infrastructure and policies for non-motorised transport to increase the mode share of walking to 20 % by 2040 and 22% by 2050 and cycle mode share to 4% by 2040 and 5% by 2050

- **Strategy SM-4:** Adopt various measures for private vehicles and autos to transition to cleaner fuels, such as CNG, and electric mobility
- **Strategy SM-5:** Reduce emissions from urban freight through fuel-efficient and low-carbon delivery fleets, thus increasing the share of electric or cleaner fuel-based light-duty goods vehicle fleet to 30% by 2040 and 60% by 2050

18.5.3 Sectoral Strategies and actions

Table 18-3 :Strategy SM-1: Increase mode share of the public transport from the current 4% to 15% by 2030, 30% by 2040, and 40% by 2050 through fleet enhancement, performance improvement measures, switching to cleaner fuels, and creating awareness

Action description	Stakeholders & financing	Indicators
Increase bus fleet as per the MoHUA norm, with 100% BSVI fleet Presently, the fleet (6 buses per lakh population) should be increased to 380 buses by 2026 to meet the lowest SLB by MoHUA. It should aim for 775 buses (40 buses per 1 lakh people) by 2030. Currently, buses are run on the GCC model. A hybrid GCC[92] model can be explored for new buses. **Timeframe: 2024-2030**	**Stakeholder lead:** ASCDCL Smart bus division, CSMC **Stakeholder support:** CSMC (roads, DP), traffic police **Financing:** CSMC budget, ASCDCL, CSMC; FAME, State and central schemes, PPP etc	**Output:** No. of buses, bus network length, increase in revenue from public transport, service coverage of public transport in the city (length of bus network/ total road network) **Outcome:** % mode share for the bus (disaggregated by gender), % decrease in emissions from transport
Procure E-buses through GCC/Hybrid GCC model, with a target share of EV buses in the total fleet as 30% by 2040 and 50% by 2050. **Develop charging infrastructure for buses at depots.** **Timeframe: 2024**	**Stakeholder lead:** CSMC Smart Bus Division, Bus operators **Financing:** Maharashtra EV Policy, PPP model, loans from multilateral development banks	**Output:** No. of EV buses operated with inclusive access; no. of charging stations in a 3x3km grid, or per million population, no. of bus stops with chargers **Outcome**: % mode share for bus, ridership, revenue increase from E-buses, % decrease in emissions from transport, shorter charging time for e-buses

Action description	Stakeholders & financing	Indicators
Improve the bus stops infrastructure, adding passenger information systems (PIS) for at least 50% of bus stops by 2030 and making it more accessible to the public. **Increase the number of bus stops with shelters** (only 15% of bus stops have shelters). Larger bus stops should be provided with commuter amenities such as toilets, drinking water, and benches. Green roofs can also be adopted, as has been done in Mumbai[93]. **Timeframe: 2025-2030**	**Stakeholder lead:** ASCDCL Smart bus division **Stakeholder support:** CSMC (roads, DP, mechanical, gardens, SWM), private agencies, local start-ups, food agencies and shops to collaborate for coupons **Financing:** CSMC budget	**Output:** No. of bus stops with shelters, No. of bus stops with drinking water, toilets, vending machines etc, no. of bus stops with green roofs, no. of bus stops with PIS (% of total bus stops) **Outcome:** Increase in bus ridership and mode share, level of passenger comfort, increase in bus revenue, % decrease in emissions from transport, increased recycling rates for plastic, reduced littering
Route rationalization for Majhi buses to increase service coverage to 0.8[94], especially in wards 57, 79, and 80. **Timeframe: 2024-2025**	**Stakeholder lead:** ASCDCL Smart bus division **Stakeholder support:** CSMC (roads, DP) traffic police **Financing:** CSMC budget	**Output:** % increase in number of bus stops, bus network length, service coverage of public transport in the city, increase in revenue from public transport **Outcome:** Increase in bus ridership, % mode share for the bus, % decrease in emissions from transport
Increase last-mile access by identifying bus stops that lack last-mile access to footpaths and cycle paths; increase footpath network close to bus stops by removing encroachment, planting trees, and increasing ROW. **Timeframe: 2024-2026**	**Stakeholder lead:** ASCDCL Smart bus division, NMT cell **Stakeholder support:** CSMC (roads, DP) traffic police, citizen forums **Financing**: CSMC budget, AMRUT 2.0: will provide 1/3rd of the project cost as a government grant for NMT projects, PPPs	**Output:** % of bus stops with access to footpaths, increase in % coverage of footpaths, % increase in bus ridership **Outcome:** % mode share for the bus (disaggregated by gender), % decrease in emissions from transport

Action description	Stakeholders & financing	Indicators
Introduce schemes and policies that will increase uptake of public transport: • Increase women's ridership by adopting measures such as concessional fare, separate buses for women, dedicated seats, improved safety by installing panic buttons, redressal helplines, and employment of women drivers. • Encourage all companies to provide public transport allowance/incentives for employees. Incentives such as property tax rebates, etc. can be provided to such companies. **Timeframe: 2024 - 2028**	**Stakeholder lead:** ASCDCL Smart bus division **Stakeholder support:** CSMC (roads, DP) traffic police, women self-help groups, big MNCs, cyclists' foundations in the city **Financing**: CSMC budget, CSR, Nirbhaya fund: a corpus fund set up by the Department of Economic Affairs, Ministry of Finance for initiatives to improve women's safety[95]	**Output**: No. of buses with panic buttons & reserved seats, no. of women drivers trained and hired, % increase in daily bus ridership for women, reduction in no. of complaints No. of companies with public transport incentives, % employees shifting to public transport **Outcome**: % decrease in emissions from transport, % mode share of public transport, ridership (disaggregated by gender and income level)
Build staff capacity through trainings on E-bus procurement and charging infrastructure business models, specialized trainings for e-bus drivers etc. **Timeframe: 2024-25**	**Stakeholder lead:** ASCDCL, CSMC **Stakeholder support:** Bus operators, staff, drives, etc. **Financing**: CSMC budget, NCAP funds	**Output**: No. of staff and drivers trained particularly from low-income groups **Outcome**: No. of EV buses operational, no. of drivers employed, % decrease in emissions from transport

Table 18-4: Strategy SM-2: Achieve 15% mode share for the future proposed Neo-metro by 2050

Action description	Stakeholders and financing	Indicators
Achieve 15% mode share for the proposed Neo-metro by 2050 by adopting the following measures: • Prepare a detailed Transit Oriented Study as per the Maharashtra TOD Policy, and integrate this as a part of the revised Development Plan • Plan for last-mile access for the proposed metro corridor from Waluj to Shendra by linking metro routes with -Mazi bus stations, micro-mobility electric scooters, electric bicycles, and cab services outside the metro (for example, Ahmedabad metro[96]), providing autorickshaw depots close to starting and ending of the metro route, feeder bus services (for example, Delhi[97]), space for private vehicle parking • Develop integrated ticketing and pass options with clear pricing systems and finance distribution. Day passes/multi-day passes for metro and bus can be piloted. Concessions can be given to women, group travellers, children, etc. For example, Kochi has a Metro1 card. Ahmedabad has a Janmitra card for buses and plans to integrate with metro, IPT, NMT, etc. The financial institution is ICICI Bank.[98] **Timeframe: 2025, integrate into metro planning and DPR before it is launched**	**Stakeholder lead:** Maha-Metro, CSMC **Stakeholder support:** ASCDCL, Auto rickshaw unions, Healthy streets committee, private agencies for funding **Financing:** CSMC budget, Maha-Metro budget	**Output:** No. of metro stations with feeder buses, autorickshaw stands, private vehicle parking, etc, increase in metro ridership No. of integrated passes, no. of passes for low-income groups, women, and elderly **Outcome:** Mode share for metro, reduction in GHG emissions from transport % mode share of public transport, ridership (disaggregated by gender, income level), waiting time, % of monthly income spent on transport, reduced emissions

Table 18-5: Strategy SM-3: ; Build robust infrastructure and policies for non-motorized transport to increase the mode share of walking to 20 % by 2040 and 22% by 2050, cycle mode share to 4% by 2040 and 5% by 2050

Action description	Stakeholders & financing	Indicators
Create an NMT roadmap to implement the healthy streets policy targets with short-, medium- and long-term interventions[99]. • The proposed NMT committee will lead the visioning workshops on how to integrate NMT into all development planning policies, in new road development, in revised DP report, and public outreach processes as part of master planning activities. • Conduct a study for assessment of existing NMT infrastructure, assess, ridership, demand. • Design a network connecting high-cyclist areas identified in the NMT survey. Map the informal cycling network and bike rental shops, and integrate cycle tracks with tourist areas, using branding. • Pilot a public bicycle sharing scheme. **Timeframe: 2024-2028** • Ensure that a minimum of 70% of footpaths are obstacle-free and permeable by 2030, with footpaths on 25% of the total road network by 2040 (10 km footpaths and 5 km cycle paths per lakh population envisioned[100]) **Timeframe: 2026**	**Stakeholder lead:** CSMC, ASCDCL **Stakeholder support:** traffic police, DP and road department, public forums NGOs, universities, activist groups, urban planners, cycling groups (Cyclists Foundation Chhatrapati Sambhajinagar) **Financing**: CSMC budget, CSR, NCAP, XV FC funds, Healthy streets budget, AMRUT 2.0, National clean air action programme funds	**Output**: Road map for NMT and its integration with DP, assessment of existing NMT infrastructure, access, ridership, % of permeable footpaths, % of roads with cycle tracks, no. of cycles and cycle stands under the PBS, reduced fatality rate for cyclists. **Outcome**: % increase in NMT users disaggregated by gender, decrease in transport emissions, reduced water logging on footpaths during rains, reduced NMT user fatality rates % increase in cycle mode share disaggregated by gender, improved AQI due to lower private vehicle usage

Action description	Stakeholders & financing	Indicators
Ensure bicycle parking lots in at least 50% of interchanges (bus stops, terminals, and railway stations) as per LoS 3 under MOHUA's transport service benchmarks.[101] **Timeframe: 2024 – 2027**	**Stakeholder lead:** CSMC, Healthy Streets cell **Stakeholder support:** traffic police, DP, roads department, public forums, cycling groups (Cyclists Foundation Chhatrapati Sambhajinagar) Financing: CSMC budget, Healthy Streets budget, AMRUT 2.0, NCAP funds	**Output**: % of roads with cycle tracks, no. of cycles under the PBS, reduced fatality rate for cyclists, % of interchanges with cycle parking lots **Outcome**: % increase in cycle mode share disaggregated by gender, % decrease in emissions from transport, % improvement in AQI
Implement safe junction redesign projects on priority for major junctions of Jalna road junctions, Akashvani junction, Amarpreet junction, and High court junctions, as listed in Figure 18-7: Identify black spots, use safer street-design elements, including protected pedestrian crossings, ramps for wheelchair users, and unobstructed footpaths. Short-term pilots can be implemented and refined. The city has a target for redesigning all junctions by 2027 as per the healthy streets policy. **Timeframe: 2024 - 2030**	**Stakeholder lead:** CSMC, Healthy Streets cell **Stakeholder support:** traffic police, DP, roads department, public forums **Financing**: CSMC budget, XV FC Healthy Streets budget	**Output**: % of junctions redesigned **Outcome**: Decrease in % of NMT user fatalities annually, % decrease in congestion

Table 18-6: Strategy SM-4: Adopt various measures for private vehicles and autos to transition to cleaner fuels like CNG and electric mobility

Action description	Stakeholders & financing	Indicators
Increase uptake of EV to reduce emissions from private transportation by: • Setting up an EV cell within CSMC with representation from relevant departments to allow for dedicated planning and implementation of EV policies and initiatives. • On priority basis, the EV cell can undertake a spatial analysis for site selection based on space availability and charging demand for EV charging stations. For example, CSMC can plan EV charging stations close to all major tourist hubs. • Encourage micro-mobility solutions, such as shared e-bikes/e-scooters for last-mile connectivity • Provide incentives for EV vehicles through interventions such as: • For the public for electric 2W and 4W: parking fee waivers, road tax exemption, registration fee reduction, and subsidies for 2-wheelers for students and working professionals. • For CSMC employees: Incentives to purchase EVs (low interest rates, allowance, etc.), parking fee exemptions or dedicated parking spaces for EVs • Through Partnerships with Marathwada Auto Cluster, MIDCs, and other organizations to boost EV adoption among employees and the private sector. **Timeframe: 2024 to 2030**	**Stakeholder lead:** CSMC **Stakeholder support:** ASCDCL, MAC, MIDC, MASSIA, Micro-mobility operators[102] **Financing:** CSMC budget, State Bank of India's green car loans: 20 basis points lower interest rate than a regular car loan, FAME Phase II for 2W and 3W, CSMC budget, NCAP funds, PPP models	**Outcome:** Formation of functional EV cell, no. of departments and organizations represented in the cell, baseline survey of EV uptake and challenges, % of the population surveyed, no. of incentives across groups, % of parking spaces reserved for EVs, No. of consultations or meetings with the organizations such as MAC, MIDC, MASSIA, increase in the number of clean fuel cars **Output:** Increase in EV uptake and awareness, no. of initiatives to address the challenges,% of CSMC employees owning EVs, % of the population with EVs, improved AQI, % decrease in emissions from transport

Action description	Stakeholders & financing	Indicators
Provide initiatives to promote electric charging infrastructure: • Charging infrastructure incentives, such as increased FSI, tax rebates, for housing complexes, malls or other buildings having EV charging. • Distribute WRI guidelines for EV charging in shopping malls and all commercial establishments as a guiding document[103] • Pilot solar powered charging stations in bus stops, autorickshaw stands, parking lots, etc. • Retrofit all existing municipal buildings with charging infrastructure. • Include charging stations within all off-street parking lots proposed under Parking Policy, 2022. **Timeframe: 2025-2030**	**Stakeholder lead:** CSMC, ASCDCL **Stakeholder support:** MSEDCL, Charging providers, shopping malls, bus stop operators, private shops, resident welfare associations **Financing:** Maharashtra EV policy, FAME Phase II, CSMC budget, PPP, concessional loans from multilateral development banks, green bonds, municipal bonds[104], National clean air action plan (NCAP) funds	**Output:** No. of chargers in a 3x3km grid or per 1000 population, # of incentives provided for charging, % of malls/ housing complexes,% bus stops, etc. having chargers, % of parking lots, municipal infrastructure with chargers **Outcome:** % Increase in uptake of EV, reduced range anxiety, reduced fuel consumption for transport sector, improved AQI, % decrease in emissions from transport
Promote the transition of autos to electric or CNG through • Retrofitting CNG autos through one-time incentives. • Organising awareness programs for E-autos, and building capacity on models and incentives **Timeframe: 2025, long-term implementation**	**Stakeholder lead:** **CSMC** **Stakeholder support:** ASCDCL, NGOs like Chhatrapati Sambhajinagar First (formerly known as Aurangabad first), autorickshaw and cab unions, drivers **Financing:** CSMC budget, NCAP funds, Fifteenth Finance Commission funds	**Output:** % increase in Electric autos/CNG autos registrations in the city **Outcome:** % decrease in emissions from transport % decrease in emissions from transport

Table 18-7: Strategy SM-5: **Reduce emissions from urban freight through fuel-efficient and low-carbon delivery fleets thus increasing the share of electric or cleaner fuel-based light-duty goods vehicle fleet to 30% by 2040 and 60% by 2050**

Action description	Stakeholders & financing	Indicators
Reduce emissions from urban freight through a series of actions: • Develop a dedicated freight policy for the city as it is uniquely positioned on the DMIC corridor with MIDCS in and around it. • Identify freight hotspots and total GHG emissions through roadside remote sensing. MORTH has also provided product specifications for the same[105]. • Mandate only EV/CNG LDVs in the city limits. Develop truck terminals at city periphery as transfer hubs with dedicated parking with charging stations. • Incentivise EV/CNG LDVs through parking fee waivers/ dedicated parking lots, road tax exemptions, flexible timings, and dedicated loading/unloading zones . • Provide scrappage incentives/ take-back schemes for converting diesel/petrol vehicles to EVs/ CNGs. • Conduct awareness workshops for freight owners and operators on fuel efficiency and route rationalisation. **Timeframe: 2025 to 2030**	**Stakeholder lead:** ASDCL's freight coordination committee **Stakeholder support:** CSMC (roads, DP), healthy streets committee, freight operators, Goods transport associations **Financing:** International development banks (ADB, WB)	**Output:** No. and locations of freight hotspots in the city, no. of high-density routes, GHG inventory for freight emissions, no. of roads with remote sensing (% of total), # of incentives for LDVs and HDVs, % of parking spaces reserved for E-freight, # warehouses with EV charging, no. transfer stations with EV charging, no. of awareness programmes, no. of operators who participated **Outcome:** % decrease in emissions from transport, a roadmap for freight decarbonisation developed based on findings, % increase in uptake of EV/CNG LDVs and HDVs, improved AQI

Photo credit: WRI India

19. SUSTAINABLE WASTE MANAGEMENT

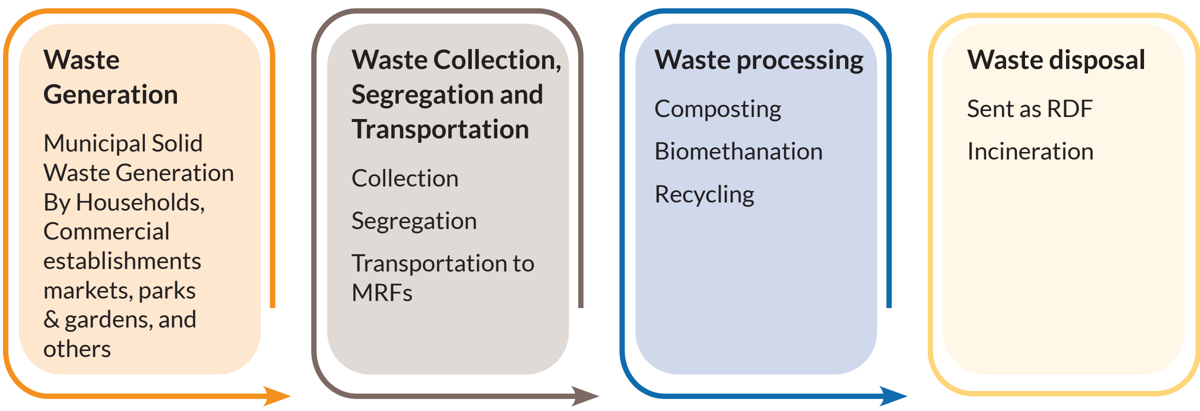
The analysis and actions presented in this sector cover the following subsectors:

Figure 19-1: Waste Management – sub-sectors covered

19.1 SECTORAL OVERVIEW

The process of waste management in Chhatrapati Sambhajinagar is explained in detail in the sections that follow:

Figure 19-2: Process of waste management in Chhatrapati Sambhajinagar



Source: WRI India analysis

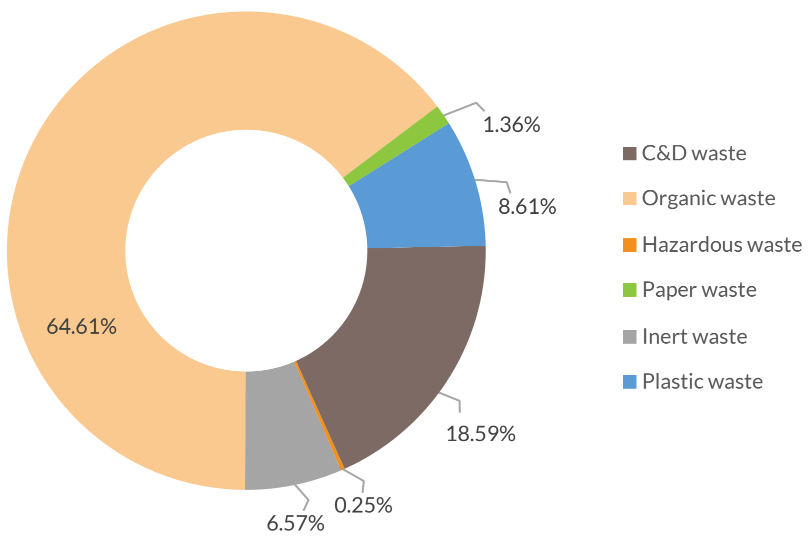
19.1.1 Waste generation

The city generated a total of 441 TPD waste in 2021. This comprised 64.6% organic waste, 18.6% construction and demolition (C&D) waste, 8.6% plastic waste, 6.6% inert waste, 1.4% paper waste, and 0.2% hazardous waste. This amounted to 0.27 kg per capita per day and 100kg per capita per annum, which is less than India's average of 0.4kg per capita per day. The total waste generated grew by 2% each year, while organic waste grew by 2%, paper waste at 6%, plastic by 3%, C&D waste by 2%, and hazardous waste by 5% between 2015 and 2021[106]. 75% of waste is generated from residential sources, while commercial establishments generate 10% of the waste, hotels generate 5%, institutions generate 3% and the remaining is generated in vegetable markets and slaughterhouses. In terms of waste composition: 10% of waste is generated by High-income groups, 50% by Middle-Income Groups, and 25% by Low-income groups/Economically Weaker sections.

19.1.2 Collection and transportation

Waste Collection, Segregation, and Transport: The city currently has 100% door-to-door collection outsourced privately[107]. Waste transportation is outsourced to a private agency till 2026. 312 auto tippers are used for primary collection. 21 are run by CSMC and the rest are privately owned. 13 tippers and 9 compactors are used for secondary collection. All are diesel-driven. A waste truck travels 22,000 km on average per year, with a fuel efficiency of 11km/liter. The city does not have

Figure 19-3: Waste composition (2021)



Source: Primary data from CSMC, WRI India analysis any transfer stations[108]. However, the city has only a 50% average source segregation rate, varying across wards. Wards 24, 25, 26, 27, 41, 42, 43, 44, 45, 57, 58, 60, 61 and zones 1,2,3,5 and 8 have poor segregation[109].

19.1.3 Waste Processing

The city has 2 solid waste treatment plants in Padegaon and Chikalthana, 4 material recovery facilities (Harsul, Central Naka, Kanchanwadi, Ramnagar) and 1 bio-methanation plant in Kanchanwadi (Tables 16-1 and 16-2) Out of the 285 TPD of organic waste, 30 TPD is sent to the bio-methanation plant in Kanchanwadi. The remaining 255 TPD organic waste mixed with 44 TPD paper and plastic waste is first sent to 2 solid waste treatment plants in Padegaon and Chikalthana (Table 16-1). 20 TPD paper and plastic recycled waste is sent to 4 Material Recovery Facilities (MRFs) for further segregation, out of which 16 TPD is recycled and sold to private agents and 4 TPD of plastic and paper waste is sent as Refuse Derived Fuel (RDF) for cement plants. The remaining 24 TPD dry waste is recycled in the solid waste treatment plants and sold to informal dealers. 25 TPD of wet waste is converted to compost in Padegaon and Chikalthana and sold by private agencies. The 29 TPD of inert is currently stored at the MRF facilities until a new landfill site is identified and developed.

The capacity and efficiencies of all waste utilities in the city are listed in the Table19-1 and 19-2:

Table 19-1: List of solid waste treatment utilities and their capacities (2021)

Type of facility	Location	Type of input waste	Capacity (TPD)	Input (TPD)	Output (TPD)	Type of output waste	Efficiency (%)
Solid waste processing plants	Padegaon	Mixed waste (dry and wet)	150	150	18	Compost (100% sold by private agency: windrow composting) & energy Dry waste segregated and sent to MRF	12%
	Chikalthana		150	150	19		13%
Material Recovery Facility	Harsul	Mixed dry waste	10	10	8.5	Segregated waste: glass, plastic, paper, textiles, etc. either sold to private recyclers or sent for RDF	85%
	Central Naka		5	3	2.5		83%
	Kanchanwadi		5	3	2.5		83%
	Ramnagar		5	3	2.5		83%

Source: SWM department, CSMC

Table 19-2: Bio methanation plant and its efficiency (2021)

Type of facility	Input type	Capacity	Input (TPD)	Output (TPD)	Efficiency (%)	Biogas (m^3)	Electricity (KW/day)
Kanchanwadi bio methanation	Mixed waste	30	26	5	19%	250	3

Source: SWM department, CSMC

1. Wet waste processing

Organic waste generation grows by 2% each year on average. 285 TPD was generated in 2021, out of which 95% was treated by composting in solid waste processing plants and 5% by anaerobic digestion in bio-methanation plants. 250 m^3 of biogas and 3KW of electricity was generated per day, which are not connected to the grid and used within the facility. All the compost is sold by a private agency[110]. As per the SWM Rules 2016, CSMC has notified all RWAs, market associations, gated communities, and institutions with more than 5000 sq.m. area to treat wet waste by composting or bio-methanation. The fine would be imposed for noncompliance, as stated in the SWM Rules 2016.[111]

2. Dry waste processing

Only 30% of paper and plastic waste is recycled while the rest is incinerated. 100% of wood, metal and 80% of glass is recycled. 100% of textile waste is incinerated while 50% of rubber waste is recycled and the rest is incinerated. 6TPD biomedical waste and domestic hazardous waste (sanitary waste, etc) is incinerated by Watergrace Pvt. Ltd outside the city limits[112].

3. Construction and demolition waste management

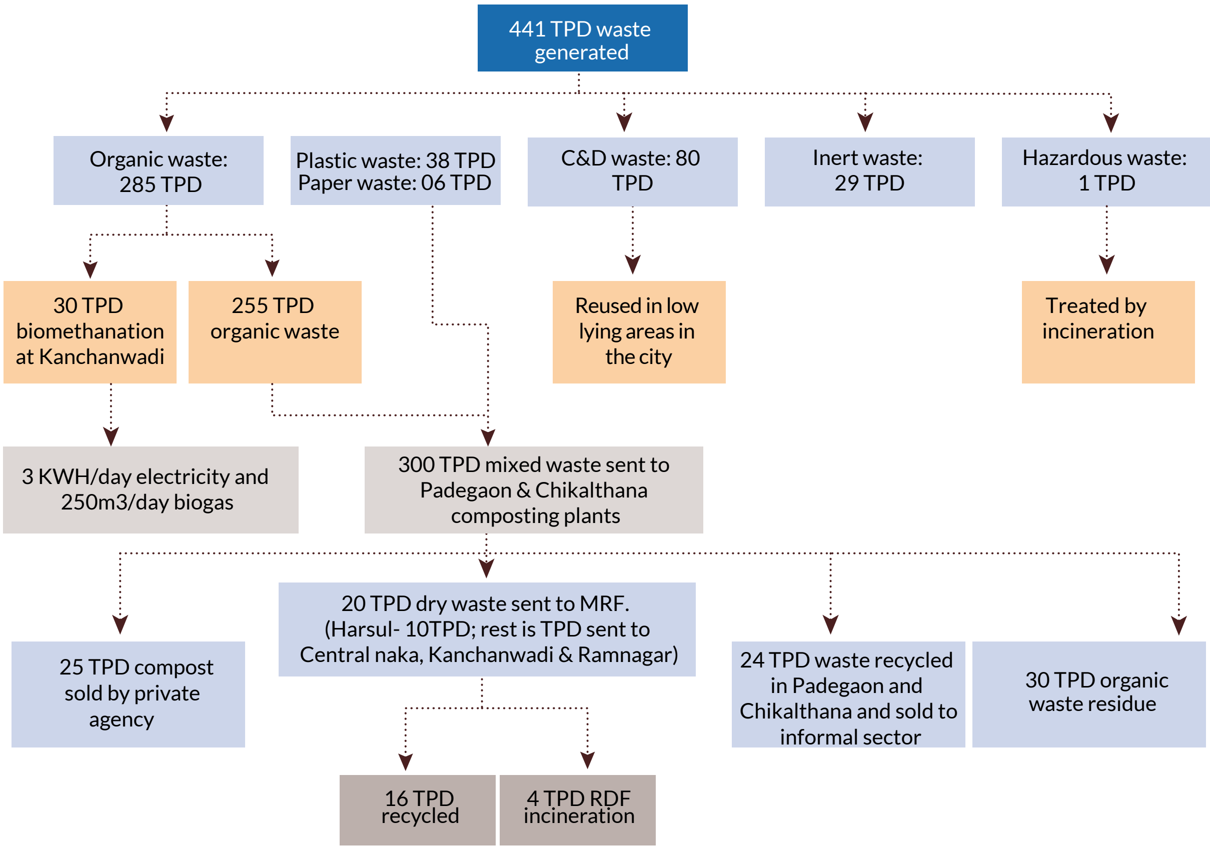
Around 80 TPD C&D waste is produced in the city, which is used to fill low-lying areas.[113]. C&D waste generated increases by 3% each year. The city does not have a dedicated recycling facility, only a collection centre in Kanchanwadi.

4. Legacy Waste at Landfill Site

The legacy waste in the landfill at Naregaon is spread over 44 acres of land, containing 12,35,294 tonnes of waste. Biomining of the waste is proposed. About 32 acres of land to be recovered and the remediated site would be converted into a garden.

A complete flowchart of CSMC's waste management system is presented in Figure 19-4.

Figure 19-4: CSMC's waste management system



Source: SWM department, CSMC

19.2 ONGOING AND PROPOSED INITIATIVES

Table 19-3: Waste management – ongoing initiatives

Waste collection, segregation, and transport	Wet waste management	Dry waste management
• Out of 21 hoppers owned by CSMC, 9 are planned to be converted to electric vehicles. INR 2 crore are outlaid for electrifying 10% of SWM transport fleet [114]. • Transfer stations are planned at Ramnagar, Shivaji Nagar and Salim ali parking, under construction, to be commissioned under NCAP.	• 4 decentralized composting units with the capacity of 16 TPD each proposed in SWM DPR to process 10% of total waste • CSMC is planning to start selling compost under their name [115.] • Decentralized composting units are planned in all 586 gardens. • Proposed bio methanation plants Kabitkhedi. Choitram Mandi and near star square. • Proposed organic waste converters in the zoo, Nehru park, Khajrana Ganesh Mandir, Ranjit Hanuman Mandir.	• Biomining of of legacy dumpsite in Naregaon is planned to be done by 2024. It will be capped, and plantation will be done over the capped dump site. Work order is yet to be issued. Estimated budget of 67 Cr [116]. • Sanitary landfill planned, plan to treat 16% of municipal waste (inert from composting plants and MRFs). • 197 TPD proposed MRF plant to be commissioned by Dec. 2023 under NCAP • Leachate treatment plants of 30 KLD at Padegaon, 40 KLD at Chikalthana and Harsul being constructed. • Proposed brick/block manufacturing plant of capacity 200-250 bricks/blocks per hour to process 100 TPD of C&D waste[117].

19.3 KEY GAPS

- Need for greater efficiency of dry waste recovery with scientific landfill management
- Limited awareness on segregation at source
- Inadequate wet waste management
- Inadequate revenue generation from processed wet waste
- Absence of a C&D waste management system
- Fossil fuel-intensive waste transportation fleet

19.4 RECOMMENDATIONS

19.4.1 Sectoral aspiration

Creating a zero-waste city, focussing on reducing waste to landfill by improving recycling and reuse while also decarbonising the entire waste value chain from generation, collection, transport, and recovery.

Overall target: 25% GHG emissions reduction by 2030, 58% by 2040 and 90% by 2050, as per respective years' BAU emissions.

19.4.2 Approach

To address the key gaps and overcome the challenges faced by the solid waste management department, the city must adopt actions that focus on:

- Expediting the scientific closure of the landfill and increasing the efficiency of the wet waste processing as 65% of the city's waste generated is organic in nature. This also calls for improved segregation of waste.
- Reducing waste to landfill by improving recycling and reuse while also decarbonising the entire waste value chain from generation, collection, transport, and recovery.

19.4.3 Sectoral strategies and actions

The key strategies proposed are as follows:

- **Strategy SWM-1:** Expedite bioremediation and scientific closure of landfill with landfill gas/leachate management.
- **Strategy SWM-2:** Increase the efficiency of wet and dry waste management.
- **Strategy SWM-3:** Reduce emissions from waste collection and transportation
  - Target 2.1: Increase electric light-duty goods vehicle fleet share to 10% by 2040 and 40% by 2050
- **Strategy SWM-4:** Implement sustainable construction & demolition waste management in the city
- **Strategy SWM-5:** Promote efficient waste management through community awareness and engagement

Table 19-4: Strategy SWM-1: **Expedite bioremediation and scientific closure of landfill with landfill gas/leachate management.**

Action	Stakeholder & financing	Monitoring Indicator
Mandate the bioremediation of the Naregaon landfill site with maximum gas recovery and recovery of land to create green space. **Example:** Nashik Waste Management Pvt Ltd. (NWMPL) has completed the biomining of 1.90 lakh tonnes of legacy waste and capping of legacy waste for the scientific closure of old dumping sites, as per a provision laid under MSW Rules 2016 and CPCB Guidelines.[118] **Timeframe: 2024-25**	**Stakeholder lead:** CSMC SWM department **Stakeholder support:** Gardens department, MPCB **Financing:** SBM 2.0, MVA, Green bonds	**Output:** % of waste recovered, % of land recovered **Outcome:** % decrease in groundwater contamination, % of landfill area converted into green space, Increase in the quality of air, groundwater, surface water and soil post bioremediation

Table 19-5: Strategy SWM-2: **Increasing efficiency of wet and dry waste management.**

Action	Stakeholder & financing	Monitoring indicators
Ensure 100% segregation of waste into at least 3 categories: biodegradable, non-biodegradable, and sanitary waste. **Timeframe: 2024-35**	**Stakeholder lead:** SWM department **Stakeholder support:** Ward officers, sanitation workers, resident welfare associations (RWAs), NGOs. **Financing:** SWM budget, MVA, revenue from waste collection	**Output:** % of recycling rates at ward level **Outcome:** Reduction in per capita waste, reduced emissions from waste management

Action	Stakeholder & financing	Monitoring indicators
Increase the efficiency of the centralized wet waste processing plants to 50% by 2030. This can be achieved by ensuring 100% segregation of waste. **Increase efficiency of bio-methanation plant by co-digestion of wet waste and septage.** Case example: In Nashik, the waste-to-energy plant has a capacity of 250 KW (kilowatt). It uses 20 metric tons of bio waste and 10-kilo litres of septage daily from public toilets. 500 kwh of electricity is generated per day and used for the working of the adjoining compost plant. **Timeframe: Starting 2024-25; continuous and ongoing process.**	**Stakeholder lead:** SWM department, Waste processing facility operators **Financing:** SWM budget, SBM 2.0, MVA	**Output:** % increase in segregation of waste, Levy by waste type (INR/kg), revenue collected annually, % increase in wet waste processing efficiency **Outcome:** % increase in efficiency of wet waste processing, % of monthly income spent on solid waste collection, % of segregation ward wise, reduction in per capita waste, reduced emissions from waste sector
Ensuring compliance by Bulk Waste Generators (BWG) **Timeframe: Starting 2024; continuous and ongoing process.**	**Stakeholder lead:** SWM department, Waste processing facility operators **Financing:** SWM budget, SBM 2.0, MVA	**Output:** % of bulk waste generators with composting, reduction in wet waste generated for community composting and bio methanation **Outcome:** % increase in efficiency of wet waste processing, % of monthly income spent on solid waste collection, reduction in per capita waste, reduced emissions from waste sector
Expedite the proposal of 4 decentralized composting units, based on land availability. **Timeframe: 2024**	**Stakeholder lead:** SWM department **Financing:** SBM 2.0	**Output:** No. of decentralized composting units developed **Outcome:** Increased efficiency of wet waste management

Action	Stakeholder & financing	Monitoring indicators
Establish a grievance portal within CSMC website, and set up a 24X7 toll-free number This would assist citizens to report open dumping and illegal disposal of waste such as C&D waste. **Timeframe: 2024; continuous process.**	**Stakeholder lead:** CSMC, PR department to spread outreach about this function. **Financing:** SWM budget, SBM 2.0	**Output:** No. of complaints in the portal, reduction in open dumping, illegal dumping of C&D waste **Outcome:** No. of complaints addressed, increase in recycling of C&D waste in the city, Reduced emissions from waste sector
Geotagging of all waste management vehicles. Use ICCT to monitor over speeding, delay, change in routes, and vehicle issues. **Timeframe: 2024**	**Stakeholder lead:** SWM department, waste fleet operator, technology partner **Financing:** SWM budget	**Output:** No. of vehicles geotagged, reduction in fuel waste and delays from vehicles **Outcome:** Reduced emissions from waste transport sector
Introduce buyback schemes in each zone/ward: Plastic and paper collection centres where citizens can get money/ coupons/ etc. This can be done with tie-up with PROs for plastic recycling. Initiating tie-ups with producer responsibility organizations (PRO) companies for sustainable e-waste management. **Timeframe: 2024-25; continuous process**	**Stakeholder lead:** CSMC SWM department, PR department **Stakeholder support:** PROs, NGOs, CSOs, citizens, tourists, RWS, ward officers . **Financing:** CSR, SWM budget	**Output:** No. of RVMs installed in the city, % plastic recycled, # coupons provided per day, tie up with PROs, no. of drives conducted, kg e-waste collected **Outcome:** Reduction in waste generated per capita, increase in recycling, reduced emissions from waste management, % waste recycled
Medium and long term priority actions		
Waste management in tourist areas: **Timeframe: 2030**	**Stakeholder lead:** CSMC SWM department **Stakeholder support:** NGOs, CSOs, resident welfare associations (RWAs), ward officers **Financing:** CSMC budget, revenue from waste collection, C&D waste, and other revenues	**Output:** No. of tourist places with colour-coded dustbins **Outcome:** % increase in recycling, reduction in per capita waste, reduced emissions from waste management

Action	Stakeholder & financing	Monitoring indicators
Utilizing waste for sustainable construction. This involves two key actions: 1. Using plastic waste in new road development. 2. Making eco bricks from plastic, paper and inert waste which can be used in construction, hence reducing the emissions from incineration. **Timeframe: 2024-2030**	**Stakeholder lead:** Roads department and SWM department **Stakeholder support:** MRF facility operators, private company for plastic shredding if needed, schools, NGOs **Financing:** SWM budget, SBM 2.0, NCAP funding	**Output:** % of roads with plastic, km of roads with plastic mixed, # of eco-bricks produced, no. of schools involved **Outcome:** % recycling of plastic waste, reduced emissions from landfilling and incineration
Bio-CNG models from vegetable waste can be piloted in markets such as Shahgunj, APMC, Rajkumar vegetable market, Kothari vegetable market. **Case examples:** **Pune**: Trial project for bio-CNG for 100 buses by Pune-based Noble Exchange (NEX). Segregated waste is brought by PMC to the facility. Bio-CNG is filled in cylinders and sold to fuel companies such as IOCL, BPCL[119] **Timeframe: 2026 to test pilots, can be implemented as a long-term action.**	**Stakeholder lead:** CSMC SWM department **Stakeholder support:** ASCDCL, vegetable mandi vendors, bus operator, fuel companies **Financing:** CSMC budget, PPP	**Output:** # of bio-CNG plants set up, no. of bio-CNG buses, kg bio-CNG produced per day **Outcome:** kg wet waste converted to bio-CNG, reduced emissions from waste composting

Table 19-6: Strategy SWM-3: Reducing emissions from waste collection and transportation.

Action	Stakeholder & financing	Monitoring indicators
Target 2.1: Increasing electric light-duty goods vehicle fleet share to 1% by 2030, 10% by 2040 and 40% by 2050		
Introduce electric waste collection hoppers: CSMC currently have a third-party contract with the waste collection agency till 2026. CSMC should explore the flexibility of the current contract to shift a certain proportion of the fleet to electric vehicles or mandate a % of the electric fleet in new tenders. Incentives such as higher tipping fees, dedicated parking spaces, dedicated loading and unloading areas in vegetable mandis, etc. can be provided for converting to e-fleets. Case example: Tamil Nadu has 1700+ battery-operated waste pickup vehicles with 3 bins for segregated waste. The vehicles have a range of 50km and can run for 6 hours on a single charge[120]. **Timeframe: 2026, 2030 for complete fleet electrification**	**Stakeholder lead:** CSMC, private operator running SWM fleet, private organizations **Financing:** PPP, SBM 2.0, NCAP	**Output:** % of SWM fleet electrified, no. of incentives **Outcome:** Reduced emissions from waste transport sector

Table 19-7: Strategy SWM-4: Implement sustainable construction and demolition waste management in the city

Priority Actions	Stakeholder & financing	Monitoring Indicators
Mandating the setup of a dedicated C&D waste processing facility on a PPP model 100 TPD C&D waste recycling facility is planned currently. **Timeframe: 2023-24**	**Stakeholder lead:** SWM department **Financing:** SBM 2.0, PPP	**Output:** No. of C&D waste recycling units in the city with capacity, no. of vehicles for C&D collection and transport **Outcome:** Improved C&D recycling rates in medium-long term

Priority Actions	Stakeholder & financing	Monitoring Indicators
Reuse C&D waste: Mandate usage of at least 20% C&D waste in construction and infrastructure development works (roads, new colonies, govt. buildings) in all municipal and government contracts. Explore the feasibility of using C&D waste in the heritage restoration of Chhatrapati Sambhajinagar's gates and other architecture that is ongoing. **Timeframe: 2023-24; continuous and regular process**	**Stakeholder lead:** CSMC SWM department **Stakeholder support:** Private agency, Builders, Credai Chhatrapati Sambhajinagar CIDCO, Maharashtra Housing Development Corporation Limited **Financing: NA**	**Output:** No. of bricks manufactured from C&D waste, % of new housing in the city with recycled C&D waste, km of roads developed mixed with C&D waste, no. of heritage buildings restored with % of C&D waste **Outcome:** Reduced emissions from landfills/ construction waste, increased recycling rates for C&D waste.
Medium and long-term actions		
Conduct a ward wise comprehensive study of C&D waste management in the city. Identify areas for new recycling facilities based on demand and land availability. **Timeframe: 2028**	**Stakeholder lead:** SWM department **Stakeholder support:** Universities, students, NGOs with local waste management expertise **Financing: NA**	**Output:** Comprehensive study and data on C&D waste generation and reuse **Outcome:** Development of recycling facilities, improved reuse of C&D waste, and improved C&D recycling rates in medium-long term

Table 19-8: Strategy SWM-5: Promote efficient waste management through community awareness and engagement

Priority Actions	Stakeholder & financing	Monitoring Indicators
Education and awareness drive with ICE activities for efficient waste management with 100% at-source segregation. Engage with students from Municipal schools and government colleges on priority. **Timeframe: 2024; a continuous and ongoing process**	**Stakeholder lead:** SWM department, PR department **Stakeholder support:** NGOs, CSOs, citizens, students, industrial associations **Financing:** SWM budget, NCAP funds, Swachh Bharat Mission, Majhi Vasundhara Abhiyan	**Output:** No. of campaigns conducted, no. of brochures distributed, no. of vehicles with messaging, % of households covered, % of schools where campaigns were conducted **Outcome:** increase in % of wards with segregation at source, reduction in waste dumping

Priority Actions	Stakeholder & financing	Monitoring Indicators
Conduct training of sanitary inspectors, safai karmacharis, and local network of dry waste buyers, ploggers on good practices and inefficient waste management. Additionally, conduct a programme for waste pickers involving existing ragpickers' associations. **Timeframe: 2024**	**Stakeholder lead:** CSMC SWM department **Stakeholder support:** NGOs, CSOs, ragpickers' associations **Financing:** SWM budget, SBM 2.0, Majhi Vasundhara Abhiyan, CSR, NGO collaborations	**Output:** No. of trainings conducted **Outcome:** % increase in segregation, recycling of waste, % emission reductions from solid waste management
Introduce electric waste collection hoppers: CSMC currently have a third-party contract with the waste collection agency till 2026. CSMC should explore the flexibility of the current contract to shift a certain proportion of the fleet to electric vehicles or mandate a % of the electric fleet in new tenders. Incentives such as higher tipping fees, dedicated parking spaces, dedicated loading and unloading areas in vegetable mandis, etc. can be provided for converting to e-fleets. Case example: Tamil Nadu has 1700+ battery-operated waste pickup vehicles with 3 bins for segregated waste. The vehicles have a range of 50km and can run for 6 hours on a single charge[121] **Timeframe: 2027**	**Stakeholder lead:** CSMC SWM department, SHGs, NGOs **Stakeholder support:** Citizen groups **Financing:** SWM budget, CSR	**Output:** No. of cloth banks (ward wise), no. of cloth bags sold and plastic bags collected **Outcome:** Reduction in plastic waste


MAKAI GATE

20. URBAN GREENING AND HEAT MITIGATION

20.1 SECTORAL OVERVIEW

Chhatrapati Sambhajinagar is a part of the hot semi-arid region in Maharashtra, receiving mean annual rainfall of ~788 mm. The city is at an elevation of 568 m above sea level, along the divide of the Upper and Middle Godavari sub-basins. The two rivers Kham and Sukhna pass through the city. The topography of the city is mostly plain. There are three major lakes in the city, namely Salim Ali Lake, Harsul lake, and Sawangi lake (Refer Figure 20-1).

The forests are a part of the Aurangabad Forest Division, entirely dry and deciduous in nature. They belong to the formation 'dry, tropical forests' of Champion and Seths and fall under the sub-group '5A Southern Tropical Dry Deciduous Forest'[122]. The city has 161 parks and gardens and 176 playgrounds123. Some other open and green spaces in Chhatrapati Sambhajinagar city are listed in Table 20-1.

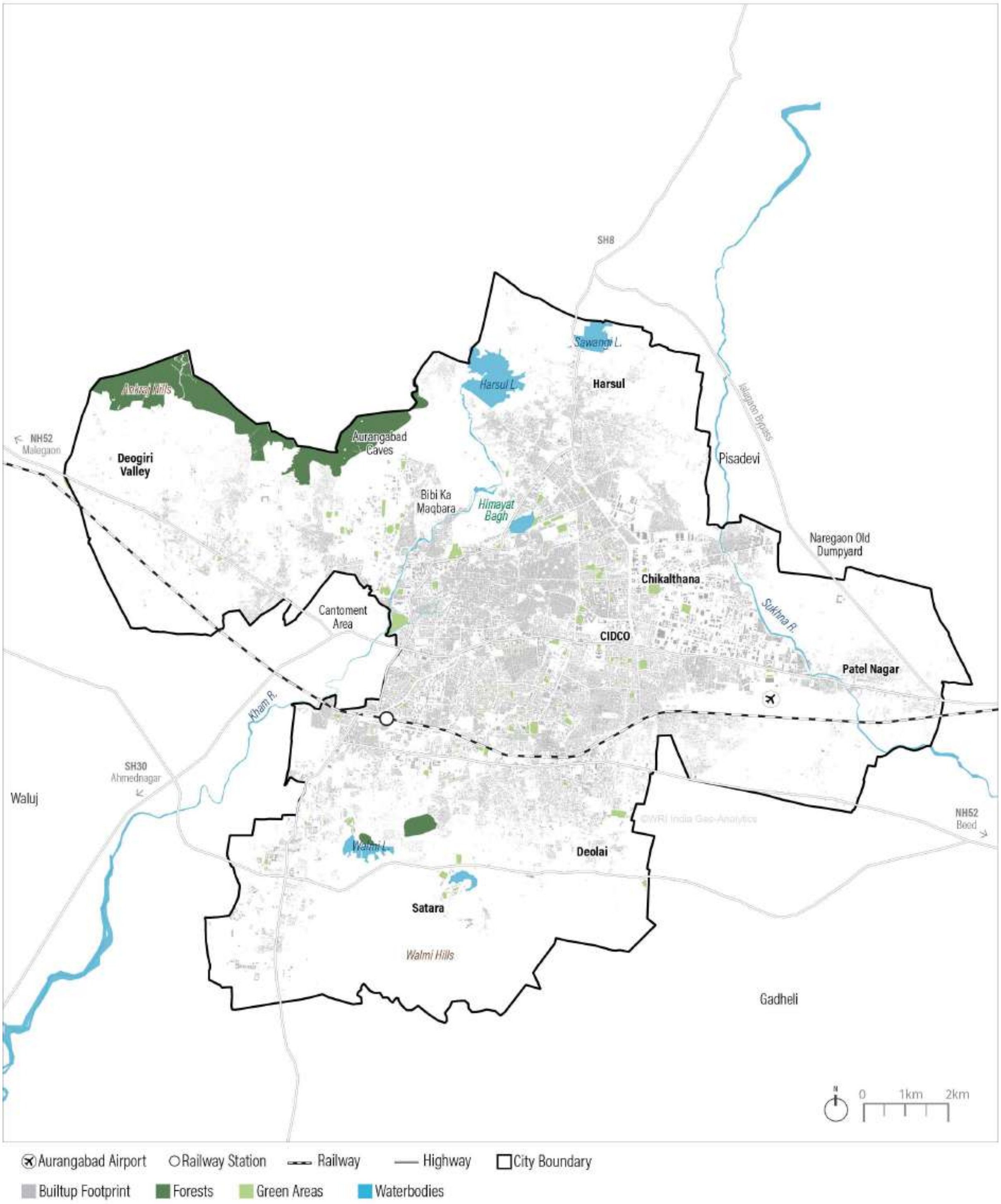
Chhatrapati Sambhajinagar was ruled by the Mughals in the early 1600s, and gardens were an integral part of the Mughal architecture (Bibi ka Maqbara: The Unknown Glory of Dakkhani Taj, 2022). There are various gardens developed along the historic sites in the city by the Mughals. The gardens at Bibi Ka Muqbara, spread over 23 acres, are an integral part of open green spaces in the city. Similarly, the Himayat Bagh, spread over 300 acres, was developed in the 17th century as a summer palace by the Mughal Emperor Aurangzeb[124]. Today, these gardens are considered important ecological assets by the CSMC and the citizens.

Table 20-1: Open and green spaces in the city

Type	Area (in sq.km)	% (against total area)
Forest	4.9	2.72
Parks and gardens	0.6	0.34
Plantation	1.99	1.11
Playgrounds	0.96	0.54
Total	8.45 sq.km	4.71%

Source: Existing Land Use (2021) from CSMC

Figure 20-1: Ecological features of Chhatrapati Sambhajinagar



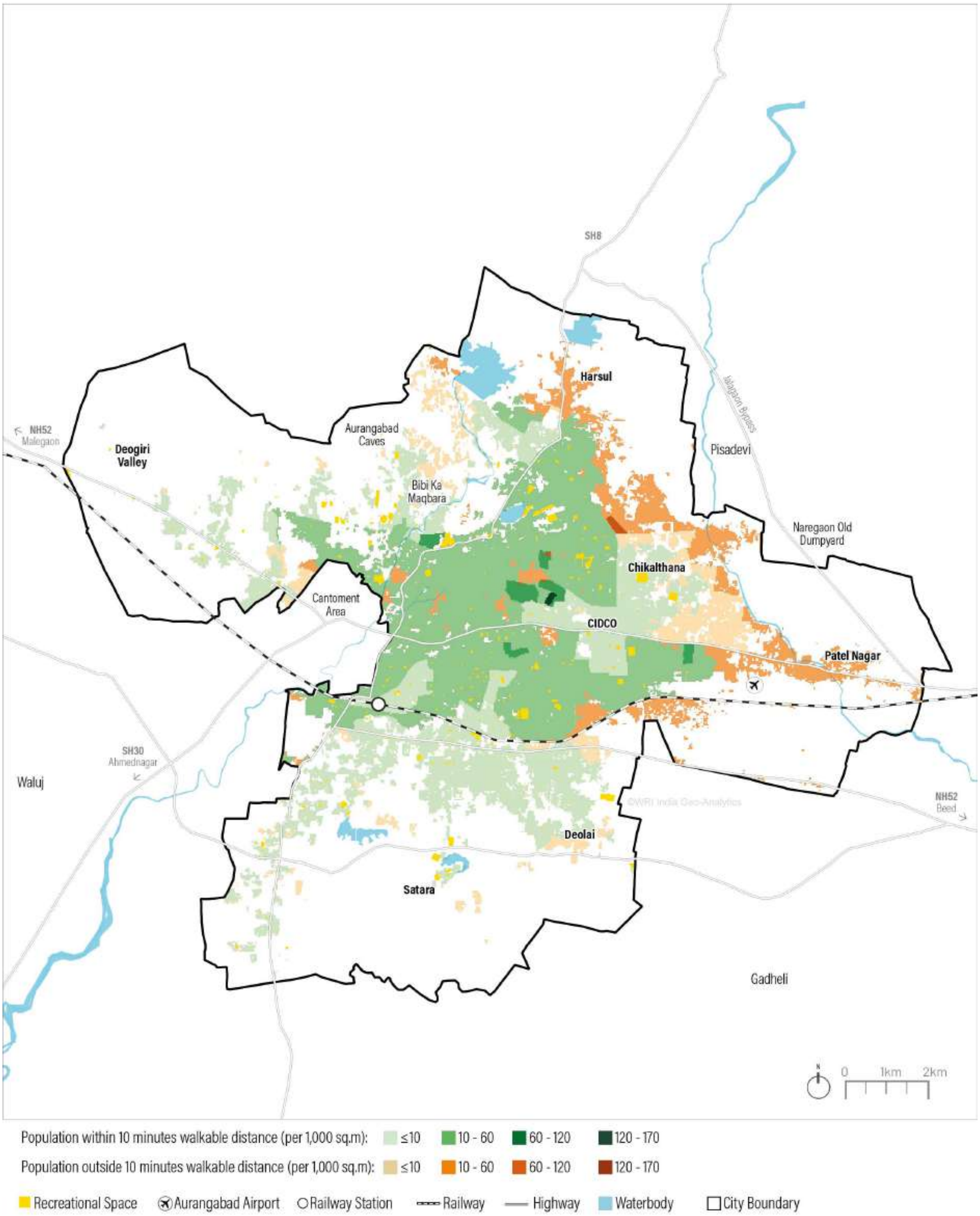
Source: WRI India analysis (2022)

As per Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines, open spaces can include three categories, namely recreational space, organised green, and other common open spaces (such as vacant lands/ open spaces including flood plains, forest cover, etc. in plain areas). So, as per the URDPFI guidelines, the norm for open spaces, including all the above mentioned categories, is 10-12 sq. m per person.

The analysis of the existing land use (2021) was done to estimate open spaces within the CSMC area (Refer Figure: 2-5). There are four sub-categories of open spaces as per ELU: forests, parks and gardens, plantations and playgrounds. There are three more categories Open Land, Open Land - Residential Unoccupied, and Open Land (in Residential), which cover 89.9 sq. km area or 49.9% of the total land area of the city. The percentage of green cover in the city in the form of parks, gardens, plantations, and forest area is 4.2% only (refer Table 20-1). The city has 36 sq. km of agricultural land, covering 20% of the total city area, which is mostly situated on the periphery of the city. The total open spaces in Chhatrapati Sambhajinagar form four sub-categories: forests, parks and gardens, plantations and playgrounds, which total around 8.45 sq.km. i.e. 7.1 sq. m per person. This is lower than the URDPFI norm of 10-12 sq. m per person. Although the per capita open space availability is low, the accessibility to public recreational spaces is comparatively higher in the city, at 82.5%.[125]

WRI's accessibility analysis (Figure 20-3) reveals that 17.5% of the population does not have access to any parks, gardens, playgrounds, or maidans within 1 km. There is a lack of such ease of access, especially in high-density areas in the northwest of Chikalthana and in the vicinity of Kiradpura. This ease of accessibility is further reduced in the event of water logging, from 82.5% to 2.79%.

Figure 20-2: Access to parks and grounds

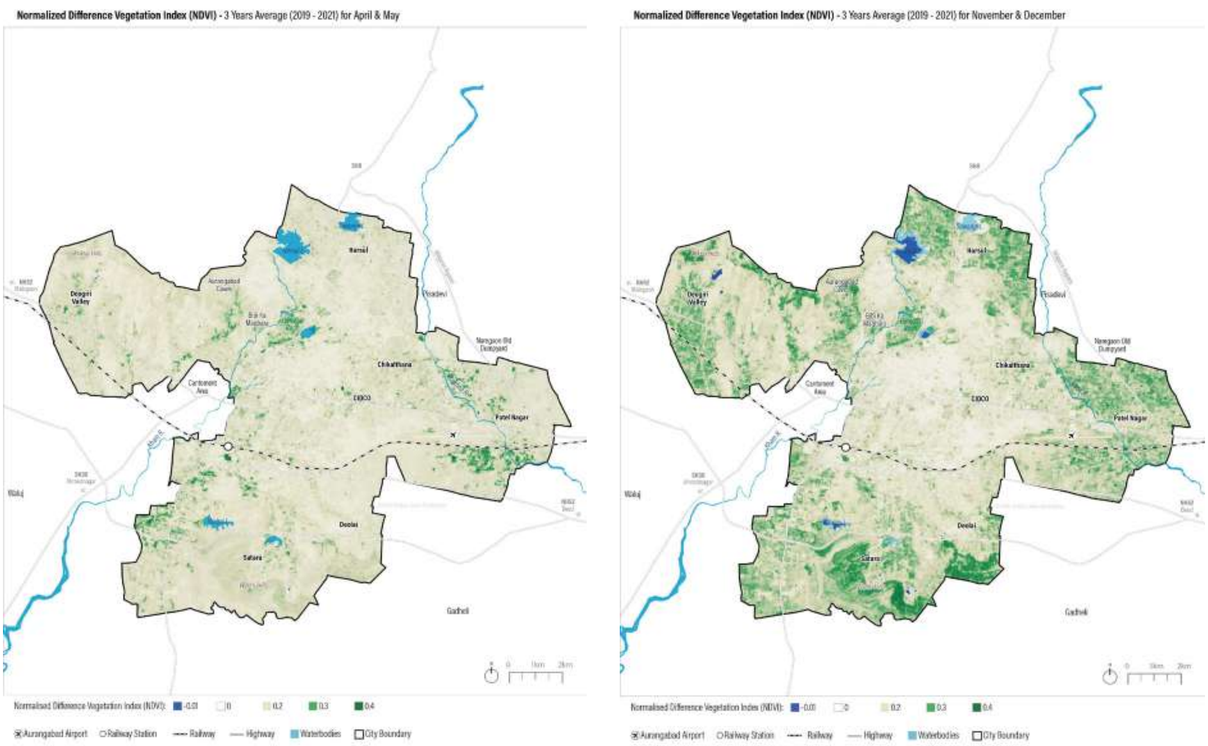


Source: WRI India analysis 2022, CSMC

20.1.1 Urban heat and green cover

The risk of urban heat is a prominent one in the city, as seen from the VA analysis. The UHI effect was studied via LST and NDVI to understand the effect of vegetation on the micro-climate. The annual average LST within the city ranges between 27°C and 38°C. In the summers, LST can reach 48°C during the daytime. The annual air temperature deviations have been on the rise since 2007, indicating the warming effect in the urban region. The NDVI analysis of the city for both timeframes (pre-monsoon and post-monsoon) show major lack of green spaces in the core of the city. On the ward level, there is no correlation observed between LST and vegetation cover. The correlation coefficient between summer LST- vegetation cover and post-monsoon – vegetation, considering all the wards, is observed to be 0.05, and 0.35, respectively. The main reasons for these are cropping patterns observed in post-monsoon season.

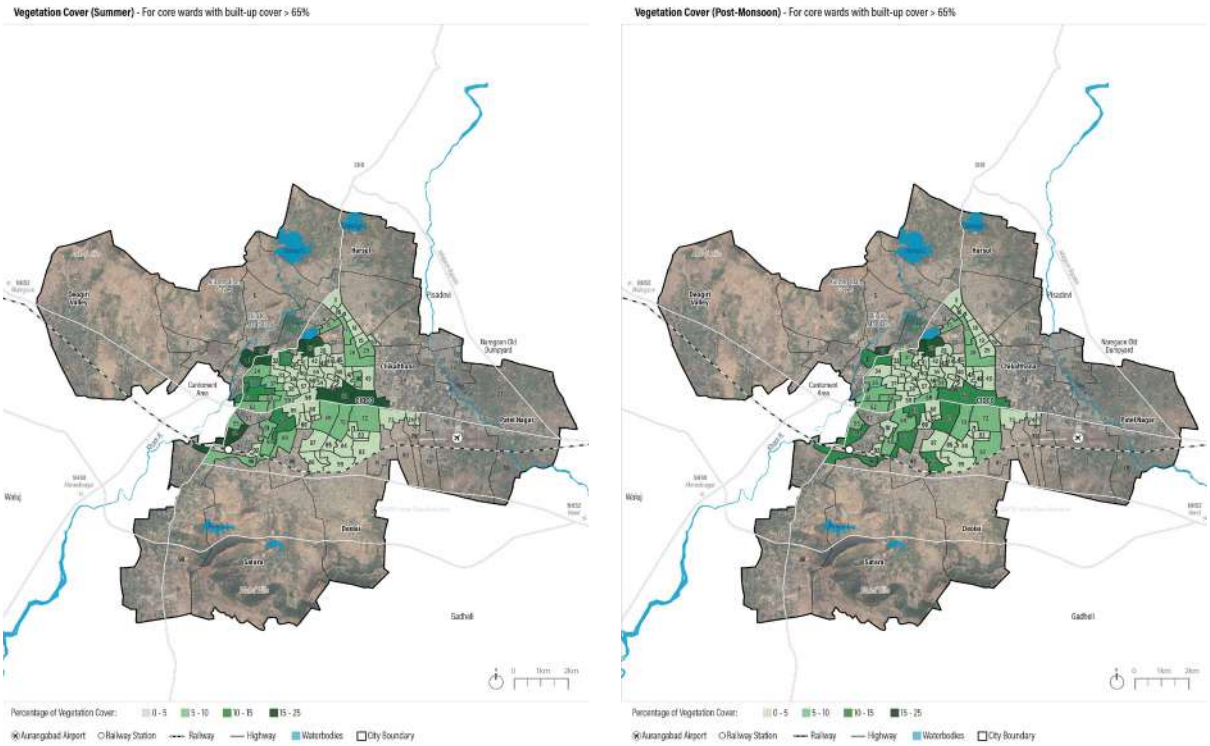
Figure 20-3: **Seasonal NDVI Variations**



Source: WRI India analysis 2022, Landsat 8, CSMC

Chhatrapati Sambhajinagar has been facing increase in heat events such as heat waves. The year 2022 witnessed 24 days as extreme heatwave. LST analysis shows higher impact of heat in areas with high population density, such as Shahganj, where the percentage area under vegetation is anywhere between 0% and 5% (Figure 20-5).

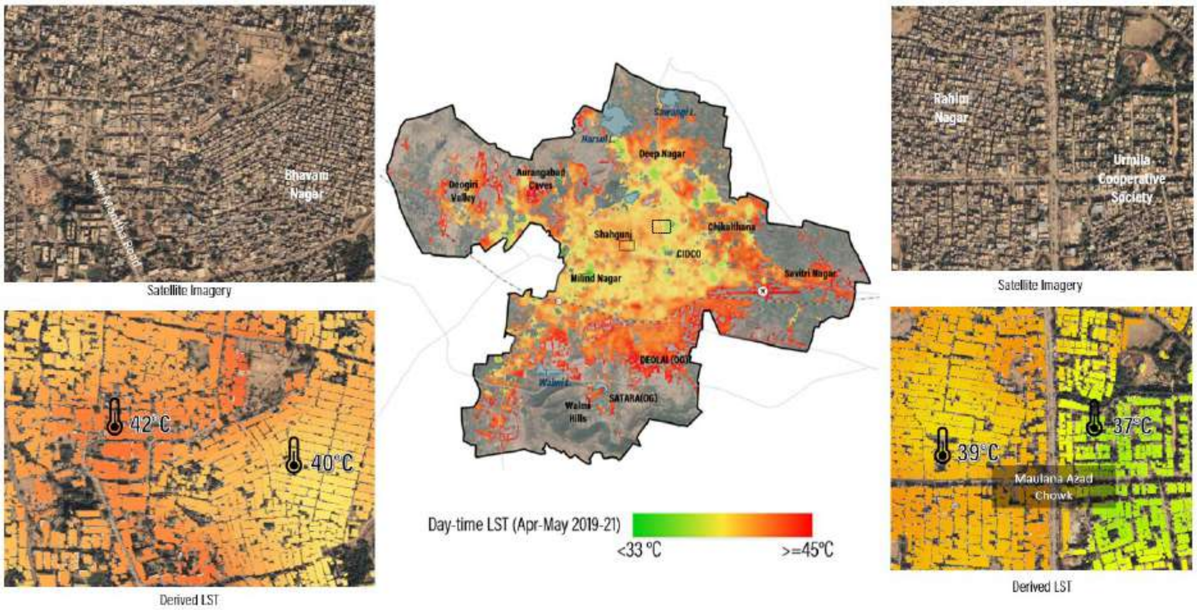
Figure 20-4: Seasonal variations in vegetation cover in wards with built-up>65%



Source: WRI India analysis 2022, Landsat 8, CSMC

Figure 20-5 shows drastically different LST in two neighborhoods divided by TV Centre Road. A vast difference of about 2°C is observed here, with Rahim Nagar reporting 39°C LST and Urmila Cooperative Society reporting about 37°C of LST. While Rahim Nagar is a densely spaced urban form with hardly any green cover, Urmila Cooperative Society seems to show considerable green cover in the form of trees and the presence of a neighbourhood-level park named Nehru Udyan. Additionally, the spacing between the buildings contributes to ventilation between spaces, which could be contributing to the local regulation of LST.

Figure 20-5: Example of LST hotspots near Maulana Azad Chowk (R) corresponding to differences in urban form



Source: WRI India analysis 2022, Landsat 8, Microsoft Building Footprint 2021, CSMC

This clearly indicates the need to understand the impact of heat and UHI dynamics in the city through ancillary data, such as quality and health of vegetation, soil, and other LST dependant factors such as roofing material, urban form.

Urban heat risk also has an impact on services such as emergency healthcare facilities, which affect the population of the city, thereby creating serious health hazards. From the VA analysis, it is found that out of 35.93% of the overall city's population impacted by heat, 25.82% of the population falls beyond the serviceable radius of 8-10 minutes drive time distance of hospitals. Even when it comes to fire services, since excessive heat can cause fire hazards, especially in closely packed neighbourhoods such as Sanjay Nagar Wasti which is located at the heart of the city and near the railway station, the city lacks behind. 26.28% of the population lives beyond the serviceable radius of 5-7 minutes and are also at heat risk, making them more vulnerable due to potential fire hazards.

20.1.2 Carbon sequestration potential

Carbon sinks are areas such as forests ecosystems (soil, tree cover) and oceans, which absorb more carbon from the atmosphere than they release. The carbon sequestration potential from these natural carbon sink for Chhatrapati Sambhajinagar was calculated for the 'Forests in the city' and 'Trees outside Forests (ToF)'[126].

- Carbon sequestration potential from Forests in the city: According to the city's Land Use Land Cover, there is 4.9 sq. km of forest area. This forest area has a carbon sequestration potential of 986.37 tonnes of CO_2/year (estimated)[127].

- Carbon sequestration potential from Trees outside Forests: Green cover in the form of parks, gardens and plantations are considered for ToF in Chhatrapati Sambhajinagar. As per the city's Land Use Land Cover, 2.61 sq. km of green cover is available in the form of parks, gardens, and plantations in Chhatrapati Sambhajinagar, according to the LULC. The 2.61 sq. km of green cover has a carbon sequestration potential of 2,675 tonnes of CO_2/year (estimated).[128]

20.2 ONGOING INITIATIVES

The Garden Department of CSMC has started planting trees of Indian species under the AMRUT scheme for green space development. In 2017-18, a total of 4,638 trees were planted. The Garden Dept. also planted a total of 24, 478 trees as part of the State Government's target of planting 50 crore trees within various CSMC premises including schools, primary health centres, gardens, and open spaces in colonies. A few other initiatives undertaken by CSMC in the urban greening sector are listed below:

1. Tree census

The Tree Census exercise is being carried out by CSMC, ASCDCL, with support from Chhatrapati Sambhajinagar First (formerly known as Aurangabad First), Prayas Youth Foundation, and students volunteering from MGM College. This would include geotagging trees according to the tree's height, botanical name and local name, the size of the bark, the tree's ownership type, and tree health. The tree census commenced in September, and within a span of six months, the students were able to volunteer their time and tag 31,042 (as of January 2023) trees in a ward-wise manner. All the collected data is uploaded on the Tree Census app and would be verified and presented to the city officials.

2. Tree Plantations and green space developments

- Under AMRUT: 9 new gardens developed; 1,78,582 sq.m. of the green area developed from 2015 to 2018
- CSMC has set a target of 50,000 tree plantations for the year 2023-24, out of which 12,000 trees were planted on World Environment Day. Plantations were also taken near the CIDCO bus stand, Kalagram auditorium, Beed bypass, Salim Ali Lake
- Upcoming vertical gardens at S B College Road, CIDCO Bus Stand, Mondha Naka and Daily Market Aurangpura developed via NCAP and XVFC funds.
- Safari Park proposed: A new Safari Park is proposed at Mitmita for 167 crores, spread over 100 acres, to house 500 animals over 60 species. The expected annual visitors are around 10 lakhs.

3. Kham Ecological Restoration

Kham river had been reduced to a *nullah* due to the rapid disposal of solid waste, untreated sewage, and industrial wastewater, and the reduction in vegetation in the river. The drone survey identified 249 points where untreated sewage emptied into the riverbed. In January 20221, CSMC, ASCDCL along with Ecosattva and Varroc Industries started working together on the Kham River to restore and rejuvenate the water body. The project led to waterfront development and an increase in open green-blue space in the city, which is accessed by citizens of all age groups.

Key features of the Kham river restoration project are:

- 7 km stretch of the river has been cleaned with stone pitching, deepening, and widening.
- 500 tons of plastic has been removed with the assistance of over 11,000 citizens (as of July 2022)
- 14,000 sq. m area covered in greening; 20.000 plantations planted (as of July 2022)
- About 86 species of flowers, herbs, and exotic weeds were identified
- 100 sanitation workers trained, 5 km pitched, 15 km stretch cleaned
- Behavioral changes, increased awareness amongst the citizens witnessed, hence higher engagement levels
- Amphitheater, butterfly garden and children's garden are a few of the recreational spaces developed at the river restoration site
- The Kham River Rejuvenation and Sewage Management project received Special Jury Award under 'FICCI Water Award 2022'.

20.3 KEY GAPS IN THE SECTOR

1. **Gap in the demand and availability of green spaces in the city:** As per the recommended URDPFI guidelines, 10-12 sq. m. per capita open spaces should be available. Chhatrapati Sambhajinagar lacks open spaces as the current total open area available (parks, gardens, playgrounds) is 8.45 sq.km i.e. 7.1 sq. m per capita, while the guidelines require a minimum 11.8 sq. km.

2. **Poor adoption of data-centric and scientific methods**: A tree census was already carried out in the past, which recorded 2.27 lakh trees in the city, but quantitative data was lacking, such as canopy density, age of tree, and species. As there is no baseline data on the green cover, it is difficult to interpret the green cover loss or gain in the city. Agriculture is practised in the periphery of the city, although there is no depository of data related to the cropping patterns, water consumption.

3. **Lack of landscape restoration approach:** A few gardens are in a poor state and not well maintained. Some of the old gardens and parks require upliftment to make them more accessible to kids and the elderly. The relationship between vegetation and UHI at the ward level seems weaker from the urban heat analysis. There is a need to dive deeper into these and understand the effect of the type of vegetation on the microclimate and develop new green spaces in areas of heat hotspot. Although a biodiversity register exists at the city level, there is a need to develop it at the ward level and understand the correlation between LST and vegetation. This allows planning for adopting scientific plantation techniques integrated with cooling mechanisms.

20.4 RECOMMENDATIONS

20.4.1 Sectoral aspiration

The goal is to develop and restore the city's blue- green infrastructure, conserve native biodiversity, and promote localised solutions to tackle the heat impact, thus bringing together the citizens of Chhatrapati Sambhajinagar closer to nature.

20.4.2 Approach

Based on the insights from the vulnerability assessment, the approach focuses on three aspects:

1. Green cover protection, restoration, and increasing the percentage of year-round vegetation to tackle the heat risk, water logging risk and increase per capita organized green spaces
2. Ease of access to open spaces in the periphery of the city.
3. Biodiversity enhancement and ecosystems restoration

20.4.3 Key strategies and actions

- **Strategy UG-1:** Increase the green cover from 4.2% to 30% by 2040 to mitigate the urban heat and water logging risk, and enhance the carbon sequestration potential.

- **Strategy UG-2:** Increase per capita open spaces to a minimum of 9 sq. m per person with enhanced accessibility.

- **Strategy UG-3:** Reinforce an enabling environment to enhance the green cover through policy measures, guidelines, a participatory approach, and citizen engagement.

- **Strategy UG4:** Prepare a comprehensive Urban Heat Action Plan for Chhatrapati Sambhajinagar City

Table 20-2: Strategy UG1: Increase the green cover from 4.2% to 30% by 2040 to mitigate the urban heat and water logging risk, and enhance the carbon sequestration potential

Action Description	Stakeholder & financing	Monitoring Indicators
Expedite the ongoing tree census exercise, collate, and analyse the data from the tree census and prepare a comprehensive plan for (a) identification and conversion of barren and public open land to green spaces to increase vegetation cover, especially in and around MIDC areas; (b) utilization of the space available on dividers, traffic islands and parking lots for plantations and carry out plantations in schools, colleges, and water catchment areas of Kham and Sukhna Rivers; (c) estimation of the carbon sequestration potential in Chhatrapati Sambhajinagar city; (d) use of only native tree species in greening initiatives and (e) achieve at least 30% of green cover in the city. Case example: Freetown in Sierra Leone initiated #FreetowntheTreeTown, a community, urban greening initiatives for scientific tree planting that is tracked on its TreeTracker app. This innovative effort harnesses digital technology to establish long-term climate resilience for the community. The campaign has led to ecosystem benefits, including reducing heat stress, improving air and water quality, and reducing flooding and landslide risks[129]. **Timeframe: 2025-26, a few strategies to be on-going and continuous**	**Stakeholder lead:** CSMC - Gardens department, DP unit, ASCDCL - MSI Department. Various industrial associations, NGOs, CSOs. **Stakeholder support:** NGOs and local biodiversity/tree experts to assist in the tagging exercise. **Financing:** CSMC budget, XV Finance Commission, Amrut budget, CSR	**Output:** No. of new areas developed as green covers with the use of native tree species **Outcome:** % of the area increased under green cover, total % of reduction in the heat island effect

Action Description	Stakeholder & financing	Monitoring Indicators
Take policy decisions, and prepare guidelines on increasing green cover by focusing on- • Upgrading the People's Biodiversity Register (PBR) every 5 years and creating a Local Biodiversity Strategy and Action Plan (LBSAP) demarcating the biodiversity hotspots • Developing guidelines to preserve and manage ecosystems at heritage sites, such as Delhi Gate, Bhadkal Gate, Bibi ka Muqbara, Aurangabad Caves, and Sunheri Mahal, which are seen as heat hotspots • Introducing rain gardens in flooding areas that have high groundwater recharge potential as well. Some locations that are identified through WRI's analysis are water logging spots in the central city, especially in CIDCO and Harsul. • Incorporating innovative greening solutions, such as green roofs, on government buildings, educational, and other institutions. • Certain mandates can be in place to have 7-10% of area under green cover for development of new plots with built-up area of greater than 5000 sq. m and for buildings under renovations and repair[130]. • Develop guidelines for the street-side landscape to create permeable surfaces and green avenues, and integrate them as nature-based solutions (NBS). **Timeframe: 2026**	**Stakeholder lead:** CSMC - Gardens Department, Biodiversity Committee, Roads department, Drainage department. ASCDCL - Heritage Department Archaeological Survey of India (ASI) Aurangabad Circle **Stakeholder support:** NGOs, local biodiversity/ tree experts **Financing:** Amrut budget, CSR	**Output:** Development of policy documents and guidelines, new areas developed as rain gardens, area of land restored as green cover at the heritage sites **Outcomes:** % reduction in water logging and the urban heat island effect

Table 20-3: Strategy UG-2: Increase per capita open spaces to a minimum of 9 sq.m./person with enhanced accessibility by 2030

Action Description	Stakeholder	Monitoring Indicators
Conduct a ward-wise gap analysis for per capita open spaces. Develop ward level open space plans to create new open spaces and enhance the existing ones. This can be tracked via an application and shared on a dashboard accessible to the citizens. **Timeframe: 2024-25**	**Stakeholder lead: CSMC -** Gardens Department, DP unit, Slum department ASCDCL - MSI Department. **Stakeholder support:** Zonal officers, NGOs, CSOs, students with planning background can support in carrying out the gap analysis. **Financing:** CSMC budget, XV Finance Commission, Amrut budget, CSR	**Output:** Number of new open spaces developed in the vulnerable areas, dashboard developed to track temperatures and cool spots during high temperature days. **Outcome:** % increase in per capita open space in the areas vulnerable to heat and waterlogging risk

Table 20-4: Strategy UG-3: Reinforce an enabling environment to enhance the green cover through policy measures, guidelines, a participatory approach, and citizen engagement

Action Description	Stakeholder & financing	Monitoring Indicators
Create the enabling environment for increasing green cover and accessible open spaces in Chhatrapati Sambhajinagar city through a series of interventions including: • Create nurseries/treebanks for community tree plantations • Incorporate permeable NMT tracks and trails to increase access to open green spaces in the city (for example higher density areas in the north-west of Chikalthana and the vicinity of Kiradpura) • Ensure strict enforcement of reservations for hills and forests, protecting them from illegal deforestation. • Create an interactive GIS-based biodiversity map, hence increasing community awareness about species protection and conservation. • Develop a ward-wise dashboard to check temperatures during heat waves and disburse information about cool spots, such as gardens, parks, and fountains. **Timeframe:** 2025-26, few strategies to be on-going and continuous	**Stakeholder lead:** Government of Maharashtra - Forest department, CSMC - Gardens department, Roads department, **Stakeholder support:** Environment department, NGOs, local biodiversity/tree experts **Financing:** CSMC budget, XV Finance Commission, Amrut budget, CSR	**Output:** % of new green covers developed, development of ward-level dashboard. **Outcome:** % increased access to open and green spaces, % of reduction in the urban heat island effect.

Table 20-5: Strategy UG4: Prepare a comprehensive Urban Heat Action Plan for Chhatrapati Sambhajinagar City

Action Description	Stakeholder & financing	Monitoring
Priority Action: Develop an Urban Heat Action Plan for the city as per the Guidelines for Preparation of Action Plan – Prevention and Management of Heat-Wave, Government of India covering the following aspects- • Capture data and analyse the data on cases of health impact and mortalities due to heat impact • Establish Early Warning System and Inter-Agency Coordination - Early Warning and Indicators of heatwave, forecast and issuance of heat alerts or heat warnings and identification of colour signals for heat alert • Capacity building/training programme for health care professionals at a local level to recognise and respond to heat-related illnesses, particularly during extreme heat events. Awareness messages can be circulated on how to protect against the extreme heatwave through print, electronic, and social media and IEC materials, collaborating with NGOs to expand outreach and communication with the city's most vulnerable communities, and developing heat emergency response plan. • Reduce heat exposure, and promote adaptive measures through the identification of high-risk areas of the city, based on the LST and urban heat hotspots, develop a 'Paint streets white' / Cool roofs programme campaign with public participation to paint the streets, roads and roofs with white reflective paints, to reflect back the sun's rays and reduce temperatures in the immediate area, especially in vulnerable areas. Develop adaptation strategies in the pre-heat period to combat the UHI effect such as scientific greening of streetside landscapes, maintenance of green cover, raise awareness and conduct tree plantation events. • Building bylaws should include components for passive ventilation and cool-roof technologies to increase thermal comfort • Appoint a 'Chief Heat Officer' within CSMC to take care of provisions during the period of extreme temperatures **Timeframe: 2024-25**	**Stakeholder lead:** CSMC - Health department, PR/Media department, DP unit Indian Meteorological Department (IMD) **Stakeholder support:** Government and Private hospitals, medical professionals, Environment department, Garden department, Education department, NGOs, CSOs, ALMs, **Financing:** CSMC budget	**Output:** Development of the Heat Action Plan, no. of health cases impacted due to heat captured, number of training programs conducted, % of early warning advisories sent out, number of streets/roads covered under the Cool roofs program. **Outcomes:** % of citizens reached through the early warning advisories, % of reduction in the urban heat island effect and increase in thermal comfort.


Photo credit: Ecosattva

21. WATER RESOURCES MANAGEMENT

21.1 BACKGROUND

Being in a semi-arid region with an average annual rainfall of around 700 mm, Chhatrapati Sambhajinagar city and the region has historically been striving to augment water resources. Owing to these reasons and lack of the surface reservoirs, since the 17th century, Mughal emperors constructed a series of underground aqueduct systems known as '*Nahar*'. Historically, the city received most of its water from these subterranean sources located in the northern and southern highlands. Out of the 50 n*ahar* that were originally constructed, only two remain functional in the present day and provide around 2- 5 MLD water[131]. As these systems are now inadequate to cater to the demands of the growing population of CSMC, the city administration has developed various surface and groundwater sources over the last five to six decades. Surface reservoirs, such as the Harsul and Jayakwadi dams, have been major sources supplying water to the city, apart from the numerous underground wells. As per WRI's Aqueduct Water Risk Atlas[132], Chhatrapati Sambhajinagar district has a high baseline water stress, defined as a measure of the ratio of total water withdrawals to available renewable surface and groundwater supplies. Chhatrapati Sambhajinagar city has a high (40-80%) to extremely high (>80%) level of water stress. This 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.

21.2 WATER SUPPLY

21.2.1 Sectoral overview

The major source of water for Chhatrapati Sambhajinagar city is Jayakwadi Dam, located at a distance of 45 km.

- The capacity reserved for Chhatrapati Sambhajinagar city, through two distribution systems, is around 156 MLD.
- The 56-MLD scheme was developed in 1985 and the 100-MLD scheme in 1992, providing water to the city centre area, which is characterised by a network of distribution pipelines and service reservoirs.

In addition to the Jayakwadi Dam, the city relies on small-scale water bodies within the city limits, such as the Harsul Dam and Rosabaug tank.

- The Harsul dam was commissioned in 1954 to cater to a population of less than a million. It has a capacity of 10 MLD. Harsul dam is also the origin of the Kham River. The latter is currently closed for maintenance and repair work[133].
- Rosabaug tank has a capacity of 1.5 MLD.

Around 60 service reservoirs provide water from these schemes to a population of around 1.5 million, with a frequency of once in four days for 1 hour[134]. Whereas the newly added areas, such as Satara-Deolai, do not have access to water distribution pipelines.

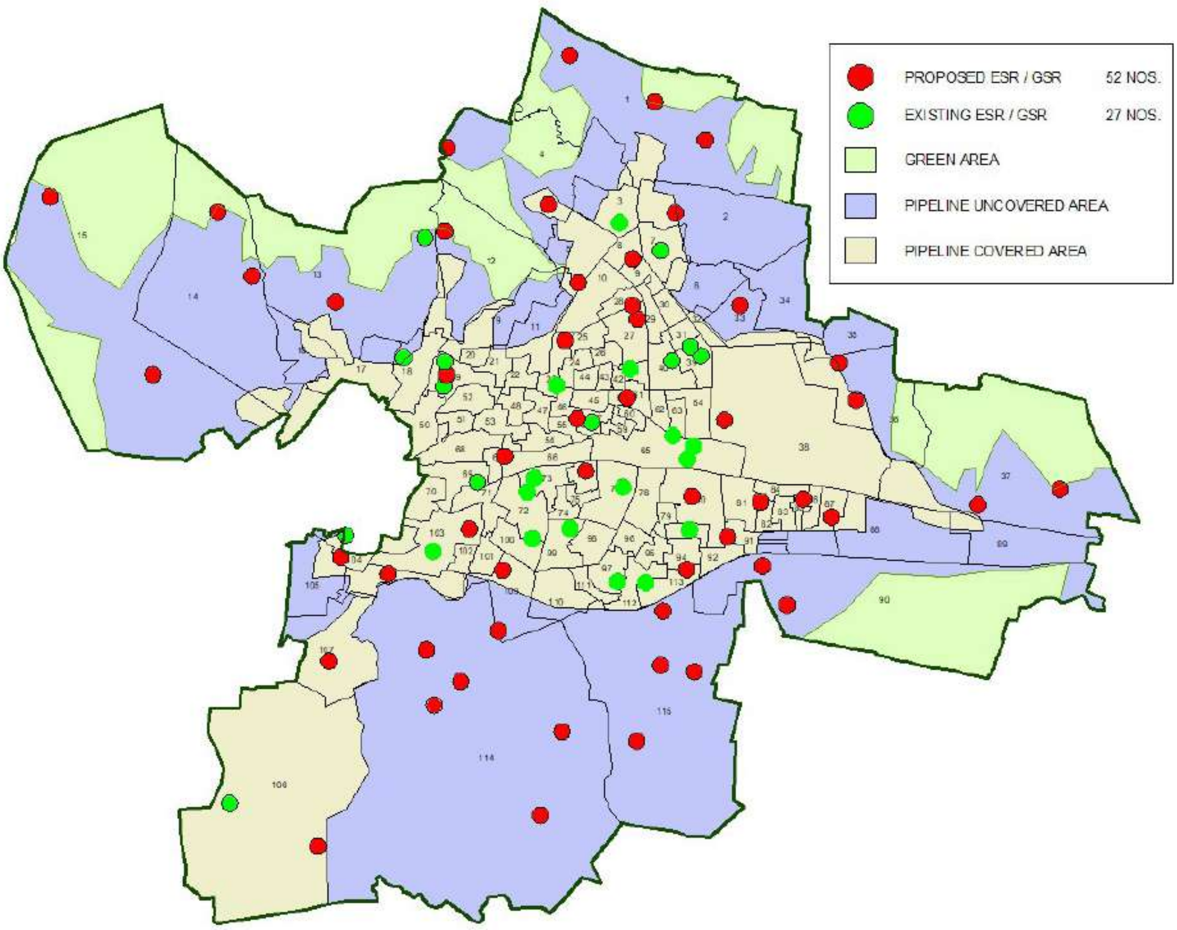
According to WRI's VA analysis of access to drinking water and source of drinking water, it was found that parts of Misarwadi (ward no. 21), Satara, and Deolai are the most vulnerable since more than 75% of households do not have treated water facilities.

The city administration has plans to expand supply to such areasby extending the distribution network and planning service reservoirs as shown in Figure 21-1.[135]

21.2.2 Water Demand and Supply

This section describes the assessment of water quality for both drinking water and treated wastewater. Water treatment plants are installed on both the supply schemes of 100 MLD and 56 MLD of Jayakwadi Dam, where the water quality is tested for both raw water and treated water. Details of the water supply sources, treatment capacity, quantity supplied, total loss, etc. are presented in Table 21-1.

Figure 21-1: Existing and proposed water supply network area of Chhatrapati Sambhajinagar city



Source: Presentation shared by Water Department, Chhatrapati Sambhajinagar Municipal Corporation

Table 21-1: Details of water supply schemes of Chhatrapati Sambhajinagar city in MLD

	Jayakwadi Dam	Jayakwadi Dam	Harsul Tank	Total Quantity
Source capacity	56	100	10	166
Water Treatment Plant	Pharola	Pharola	Harsul	
Treatment capacity	56	100	10	166
Actual quantity treated	37 - 40	90 – 94	5 – 6	132-140
Quantity supplied after treatment	31 – 33	88 – 90	4 – 5	123 – 128
Total water loss	8-9 (10-12%)	10 - 16 (10-16%)	5 – 6 (50-60%)	23-31

Source: Chhatrapati Sambhajinagar City Water Supply Final Copy Report

CSMC had treated around 143.5.MLD water in 2019-20, which includes 1.5 MLD water treated at Rosabaug Treatment Plant. The total water losses indicated above include the transmission losses in the distribution system and the losses from water treatment plants. The estimated water supply was 122 MLD in 2021[136]. As per the Performance Assessment System (PAS) Report shared by CSMC, Non-Revenue Water (NRW), which is the difference between water supplied in the distribution system and the amount of water billed, is more than 30% on average. In the current situation, CSMC supplies water at a frequency of 1 hour in a span of 4-5 days.

As per the CSMC's ESR 2021-22, the estimated water demand of the city is around 317.17 MLD in 2021, while the projected demand is 450.79 MLD for 2037 and 604.86 MLD for the year 2052. Maharashtra Jeevan Pradhikaran (MJP) is the agency responsible for the proposed water augmentation project, and a DPR has been prepared thereof. A snapshot of the demand and supply is presented in Table 21-2.

Table 21-2: Water demand and supply of Chhatrapati Sambhajinagar city

Indicator / Year	2021	2037	2052
Population (projected)	16,96,263	24,47,790	33,27,342
Daily water demand (MLD)	317.17	450.79	604.86
Water supply (MLD)	122	450.79*	604.86*
Gap, MLD (estimated)	195.17	-	-

*Source: MJP presentation 'Augmentation to Chhatrapati Sambhajinagar Water Supply Project' dated 19.07.2019; *It is assumed that the proposed WS scheme will be implemented to fulfil the demand.*

As evident, the data for water demand and supply is sourced from different documents. Hence, to understand the exact scenario, there is a need to consolidate the available data. A household survey carried out by a private entity indicates that there are 279,423 domestic households in the city[137] while the ESR 2021-22 indicates that there are 1,38,000 connections[138], which accounts for 49% of households of the city connected through the water distribution network. Similarly, in the commercial sector, the water supply coverage is around 16%, based on the data presented in the ESR and the household survey.

The average per capita water supply in the city is around 72 lpcd [139] (litres per capita per day) based on the data shared by CSMC. Another study conducted by World Bank in 2014 cites the per capita supply as around 110 lpcd[140]. However, both these figures highlight that per capita water supplied in the city is below the service level benchmarks of 135 lpcd[141] prescribed by the Ministry of Urban Development, Government of India. Also, there is a huge gap in the provision of water for drinking and domestic purpose from surface water sources, which has led to the rampant development of groundwater resources in the city.

21.2.3 Ongoing initiatives

Some of the key initiatives taken by CSMC are as follow:

- A water supply scheme is proposed to extend from Jayakwadi Dam to provide water to unserved areas such as Satara-Deolai. MJP will execute the project, and a DPR is awaiting approval. The initiative aims to be part of the AMRUT 2.0 scheme. The DPR outlines plans for the intermediate stage (2037) and ultimate stage (2052), estimating demands of approximately 451 MLD and 605 MLD, respectively. The scheme includes key components, such as Jayakwadi headworks, raw water pumping system, rising mains, water treatment plant, storage reservoirs, and a distribution system.
- 'Jal Bell App' has been developed by CSMC and ASCDCL to inform the citizens about the water supply schedule and to address grievances.
- Urban River Management Plan: NIUA, with CSMC and ASCDCL has prepared a river management plan for the rejuvenation of the Kham and Sukhna rivers in Chhatrapati Sambhajinagar.

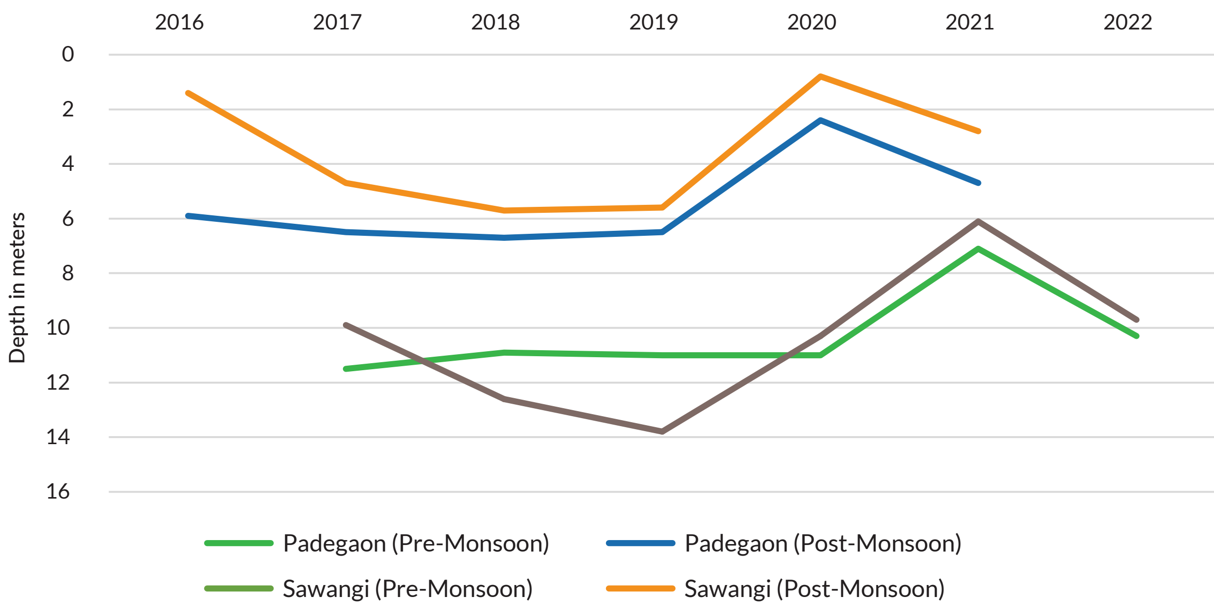
21.3 GROUNDWATER MANAGEMENT

The Central Groundwater Board (CGWB) monitors groundwater levels at the district and taluka levels in all states. In Maharashtra, Groundwater Survey and Development Agency (GSDA) is the nodal agency to monitor aquifer and ground water levels and develop resources through various schemes.

There are 57 borewells as of 2020 and 1392 handpumps as of 2021, based on the data provided by the CSMC. All the 57 borewells are functional and metered while 50% of them are used for gardening purpose. Barring two, all contain water, as per the survey carried out 2020. Currently, the survey does not indicate the depth at which water is available in these wells. There is an ongoing initiative by CSMC of mapping of borewells in the city limits with location coordinates and photographs of location. All the borewells also have electric pumps installed, which could potentially lead to over-extraction. Primary data shared by GSDA, reveals depleting water levels in and around the city since 1990.

To understand the seasonal changes, GSDA has installed two monitoring wells, one in Padegaon and one in Sawangi, and the water level trends pre- and post-monsoon seasons over the past six years are depicted in Figure 21-2.

Figure 21-2: Groundwater level trend in Chhatrapati Sambhajinagar city



Source: GSDA primary data, WRI India analysis

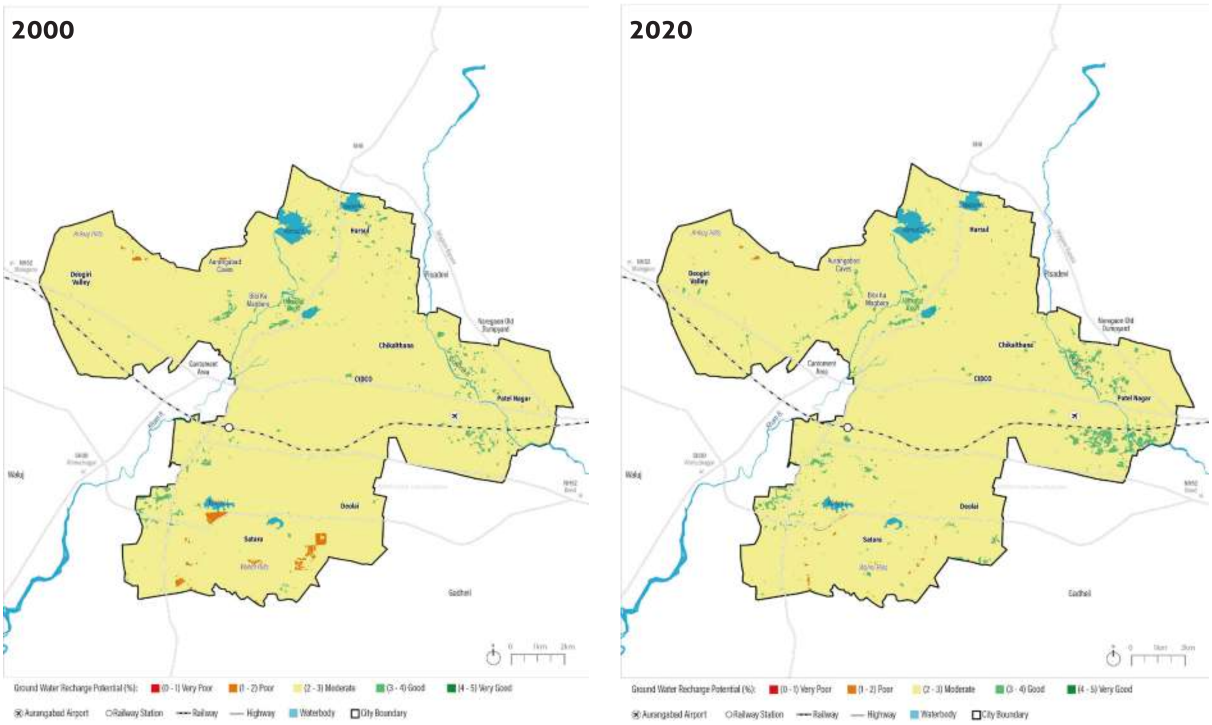
The changing water levels in 2020 and 2021 reflect patterns expected during the COVID-19 lockdown period and usage patterns. The year 2020 witnessed more than eight events of Rather Heavy Rain and two of Heavy Rain[142], which could be a contributing factor to the increase in water levels. Besides this, to address the water requirement in no-network area, the CSMC supplies water sourced from designated wells in five locations (by 2022)[143] within the city limits using tankers[144]. During summer months, tankers supply, on an average, 2.2 MLD water and for the rest of the year around 0.32 MLD[145]. Each tanker, with an average capacity of 5000 litres, costs anything between INR658 and INR879, resulting in a unit cost of INR0.13 –INR0.17 per litre.

Given the increasing reliance on groundwater resources, it is crucial to understand its recharge potential for replenishing and sustainable use in future. Groundwater recharge potential (GWRP) within the city limits 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). The GWRP for the city was obtained for two years – 2000 and 2020 – which were compared to find the percentage change in the recharge potential at each grid (resolution of 30m).

The city exhibits a 'moderate' groundwater recharge potential while the recharge potential is 'good' around the waterbodies as well as towards to east of the city along the Sukhna river. The region to the south of the city has seen an increase (poor to moderate) in groundwater recharge potential in 2020 as with to the year 2000. The region to the east of the city has also seen an increase in GWRP in the period 2019-2000 as compared with 1999-2000 as seen in Figure 21-3. This could be due to the increase in green cover in the area or any other form of land use change that could contribute to increase in groundwater recharge.

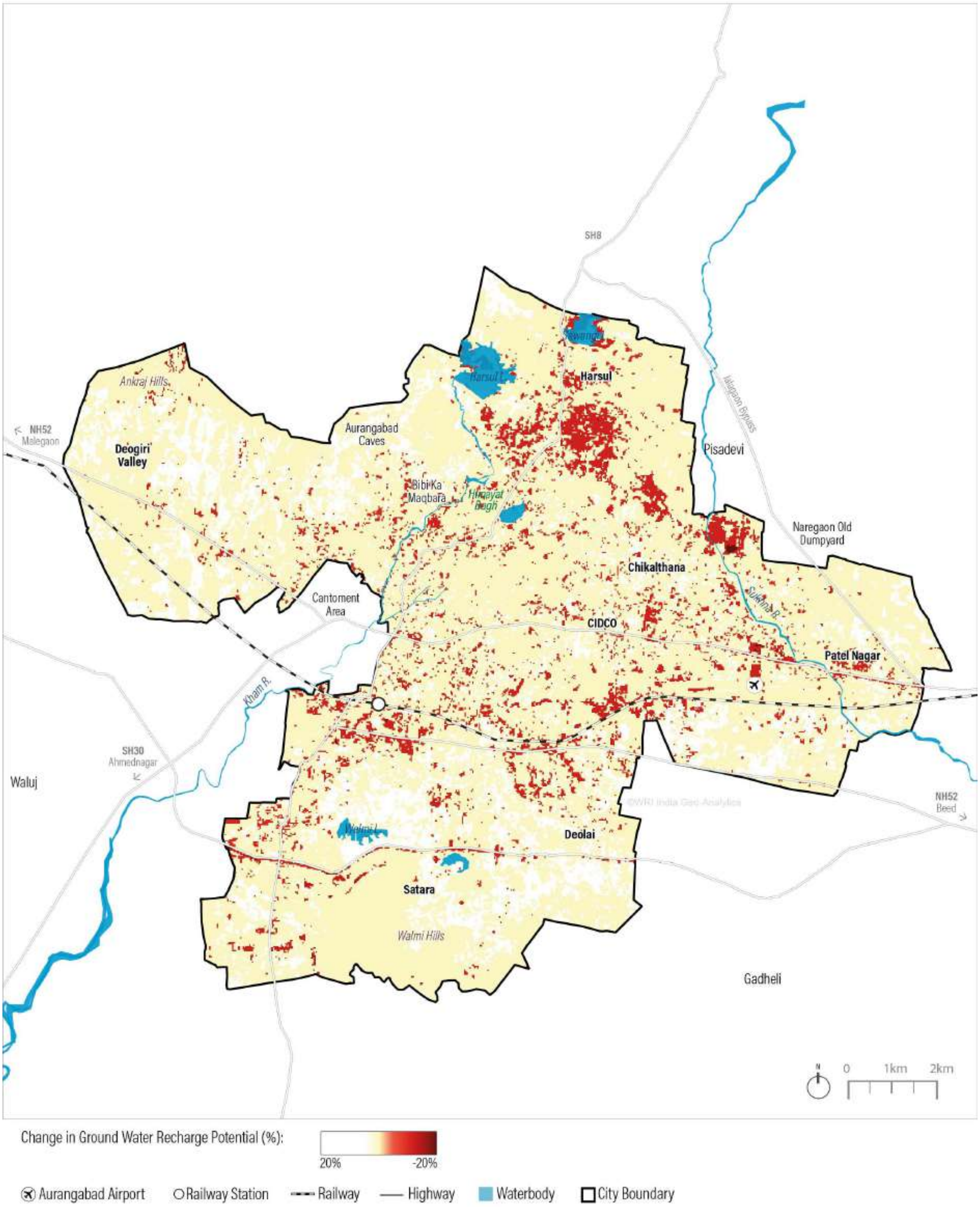
On calculating the change in GWRP between 2000 and 2020, it is observed that the north-east regions on the city have seen decrease in the GWRP due to increased real-estate development as seen in Figure 21-4.

Figure 21-3: GWRP within CSMC area for two timestamps, two decades apart



Source: WRI India analysis, 2022

Figure 21-4: Areas showing Decrease in GWRP (in percentage)



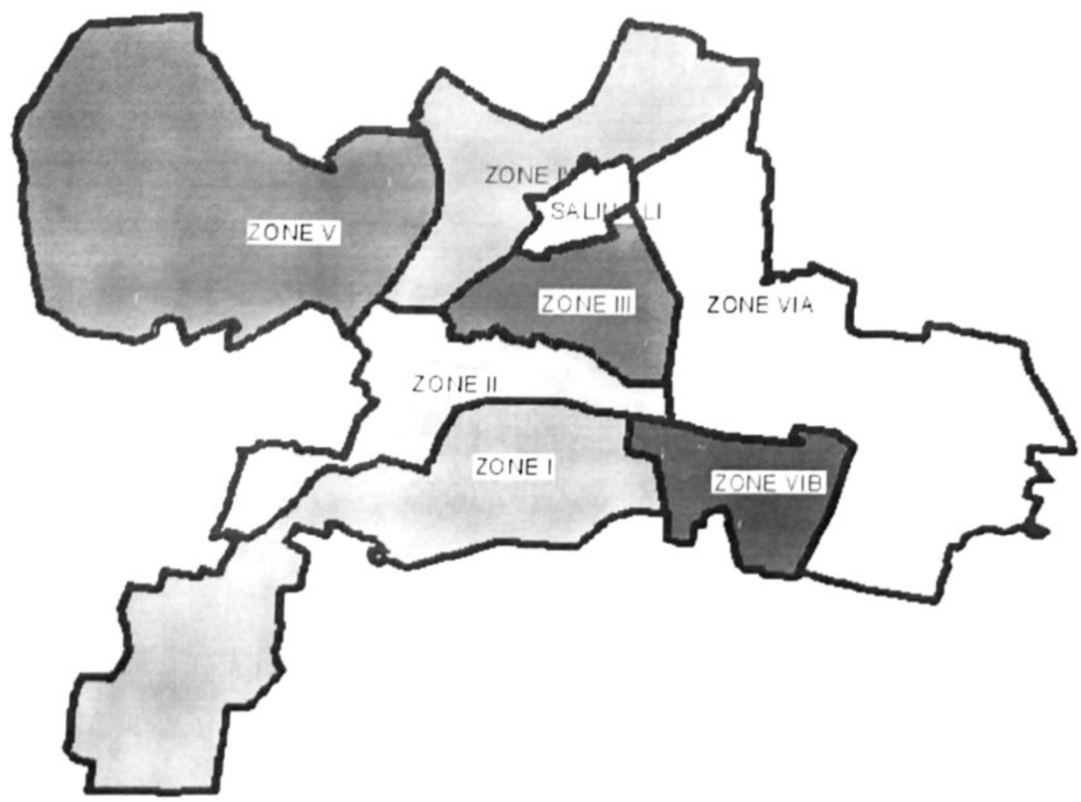
Source: WRI India analysis, 2022

21.4 WASTEWATER MANAGEMENT

21.4.1 Wastewater generation and treatment

The city generates 103 MLD of sewage, of which around 80-85 MLD is being treated using four STPs and six sewage pumping stations located across eight zones (Refer Figure 21-5 and Table 21-3). All the four STPs undertake secondary wastewater treatment using Sequential Batch Reactor (SBR) technology, which treats 80-90% of the sewage. Only 4% of the sewage is recycled and reused. The sewage network in the city covers about 90% of the area with an efficiency of 73%. In terms of sanitation services, around 94% of the city area is provided with toilets (ESR 2021-22).

Figure 21-5: Sewerage Zones in Chhatrapati Sambhajinagar city



Source: Map shared by CSMC

Table 21-3: **Details of Sewage Treatment Plants and Pumping Stations in Chhatrapati Sambhajinagar City.**

Sr. No	Sewage Treatment Plant	Capacity (in MLD)	Sewage Pumping Station	Capacity (in MLD)
1	Kachanwadi	161	Golwadi	211
2	Zalta	35	Zalta	60
3	Padegaon	10	Padegaon	14
4	Dr. Salim Ali	5	Dr. Salim Ali	5
5			Ward No. 98	12
6			Banewadi	14

Source: Environmental Status Report of Chhatrapati Sambhajinagar Municipal Corporation 2021-22

Data on the actual amount of wastewater treated in these STPs is limited. As per the ESR 2021-22, the current 211 MLD capacity is adequate to process sewage until 2030. A DPR prepared for the rejuvenation of Kham River (August 2021) mentions around 38.3 MLD of raw, untreated sewage being released into the Kham River. This highlights the urgency to enhance the sanitation and sewerage systems in the city. Currently, there are plans to develop a separate storm water drainage network in the city by 2023, but these need to be aligned with future rainfall and run-off patterns in the city. The ESR 2021-22 does outline the CSMC's plans for sewage and treatment plants, as detailed in Table 21-4.

In terms of common effluent treatment plants, there is only one in MICD Waluj, which also lies outside of the city boundaries, with a capacity of 10 MLD with primary, secondary, and tertiary treatment units[146].

Table 21-4: **Wastewater generation and treatment in Chhatrapati Sambhajinagar city**

Indicator / Year	2021	2037	2041
Population (projected) in lakh	15,95,346	24,47,790	33,27,342
Water supply, MLD (estimated)	122	450.79)	604.86
Estimated sewage generation MLD	103 MLD	360 MLD	483.8 MLD
STP capacity, MLD	211 MLD	211 MLD	211 MLD
STP capacity, gap, MLD (estimated)	-	149 MLD	272.8 MLD

Source: ESR 2021-22 and WRI India analysis

21.4.2 Ongoing initiatives

- Sewage Upgradation and Development Programme under the Central Government's Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) is ongoing, including extension of sewage network by additional 30%, separation of stormwater drains by laying out parallel sewer lines to be disposed in the main sewer lines.
- The coverage of toilets is being extended through Swaccha Maharashtra Abhiyan.
- Around 4% of treated wastewater is re-used for industrial and road construction activities.
- Kham River restoration project is being jointly undertaken by CSMC, ASCDCL, and local NGOs. It includes works such as cleaning of the river basin, clearing waste disposed on riverbank, desilting, deepening, erecting steel barricades along the bridges on river to trap plastic and other types of solid waste, etc. The river has 249 sewage points which will be connected to sewage pipelines and a network.

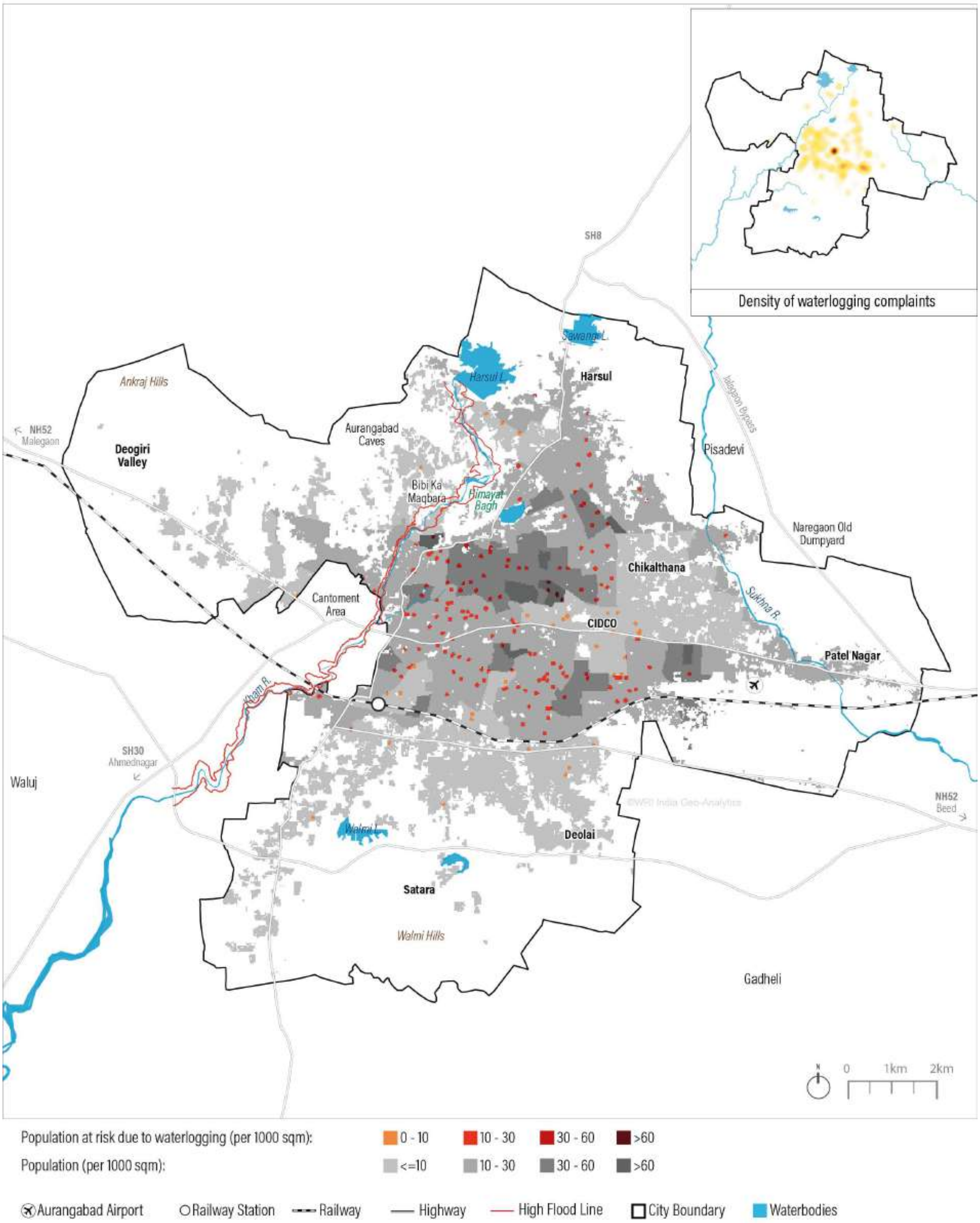
21.5 WATERLOGGING

Waterlogging in the city is majorly observed as an infrastructural issue. Due to the lack of a drainage system for stormwater, the low-lying areas of the city get flooded during heavy rainfall (Taji & Regularwar, 2017). Apart from this, the Kham and Sukhna rivers have low-lying areas astride their courses. Each year, some of the slums near the edge of Kham River have to be evacuated to safe places as the flood waters enter these areas (Fire Hazards Response and Mitigation Plan, 2011). In recent years, many incidents of low lying areas getting waterlogged due to rainfall are reported.

With the help of pumping calls received by the Fire Department, CSMC, it was possible to map the waterlogging hotspots in the city against the population density, informal settlement locations, and the degree of jobs and public transportation that would be affected. From the Vulnerability Assessment (VA), it is observed that:

- Central region of the city, which is also densely populated, hosts the majority of the waterlogging hotspots.
- About 2.7% of the population that lives within 50 meters of these hotspots is affected due to waterlogging.
- Such waterlogging also affects the public transportation system in the city as access to 9.5% of the public transport system gets compromised in the event of excess rainfall. (Refer Figure 21-6)

Figure 21-6: Population potentially at risk due to waterlogging



21.6 KEY GAPS AND BARRIERS

Key barriers identified in the categories are as below –

1. Data and information:

- Lack of zone-wise household-level mapping of water supply connections with no details on metering status.
- Lack of data on rainwater water harvesting systems installed in the city.
- Limited groundwater monitoring / aquifer mapping, such as type of well, extraction and recharge rate and potential, and lack of data reporting and monitoring.
- Mapping of agriculture and allied activities in the newly added areas in the city to understand water demand and supply.
- Comprehensive water audits for the city to understand sector-wise and consumer-type water requirements, infrastructure installed, service provision, etc.

2. Infrastructure and service delivery:

- Inadequate water supply with a frequency of once in four days.
- Detailed information on sanitation such as household-level mapping of toilets, sewage network, zone wise type of sewage pipe network in the city (open, closed, etc.).
- Poor network of automated weather stations in the city for better forecasting.

3. Policy, planning and regulation:

- No separate sewage and storm-water drainage network.
- Stronger policies on use of groundwater, re-use of sewage water required.

4. Community awareness on water resources management:

- Sensitisation among communities, especially the newly added areas on water budgeting, use of groundwater sources, rainwater harvesting, disaster preparedness, etc.

Initiatives undertaken by other relevant organizations and agencies, such as the ones listed below, could help in better coherence of sub-sector-specific activities, data compilation and improved capacity building for climate resilience in the near future.

- Groundwater pollution study in industrial clusters of MIDC in Aurangabad[147].
- Wastewater reuse and management by Water Resources Group 2030, a partnership group hosted by World Bank[148]

21.7 RECOMMENDATIONS

21.7.1 Sectoral aspiration

To improve the water and wastewater management systems, providing safe access to drinking water, along with adopting nature-based solutions (NBS) for waterlogging and urban river management.

21.7.2 Approach

In the background of infrastructural and policy gaps and the initiatives taken, CSMC has been planning several initiatives to ensure that city can withstand and overcome projected climate changes in future. In order to streamline these initiatives, the city could adopt the following approach.

Figure 21-7: Approach for water resources management in Chhatrapati Sambhajinagar city.

Source: WRI India analysis

To give an example, the city is depending on both surface and groundwater sources to fulfil its drinking and domestic water requirements. It has augmented several sources over the decades but has been unable to achieve the SLBs prescribed for per capita water supply. It is taking appropriate initiatives, such as upgradation of water supply from Jayakwadi Dam, mapping of borewells, and restoration of Kham River, to overcome some of these constraints. However, if the city can map and monitor both the surface and groundwater sources available for use in the city and their recharge potential by capturing the rainfall received in the city to supplement the existing supply, it can better plan its resources and budgets and regulate its usage. Such an approach could then help streamline the current initiatives and planning for future projects.

21.7.3 Sectoral strategies and actions

The strategies listed in Table 21-5 are recommended for the water and wastewater sector, where each goal has short, medium, and long-term activities that will build resilience of communities, administration and systems in general.

Table 21-5: Sectoral strategies and actions for Water Resource Management

Sub Sector		Strategy
Water supply system management	Strategy WS-1	Provide access to adequate and safe water for all by 2028.
Groundwater management	Strategy GW-1	Expand rainwater harvesting to contribute to atleast 20% of the water supply by 2030 and increase groundwater recharge, and implement innovative solutions for efficient groundwater recharge while managing water quality.
Wastewater management	Strategy WW-1	Enhance sanitation and sewerage systems to ensure 100% coverage of sanitation systems and 100% sewage treatment by 2030 and increase wastewater reuse.
Waterlogging management	Strategy WL-1	Prioritise water logging hotspots and integrate it with the river restoration and storm water drainage augmentation plan.
Capacity building and IEC.	Strategy WS-2	Awareness generation, outreach, and capacity building.

Table 21-6: Strategy WS-1: Access to adequate and safe water for all by 2028

Action Description	Stakeholders & financing	Monitoring Indicators
Implement the proposed water supply project to improve the water supply coverage and ensure water for all by 2028. **Timeline: 2028**	**Stakeholder lead:** Water Supply Department with support from Environment Department, Smart City Corporation **Financing:** Government of Maharashtra, GoI under AMRUT	**Output:** % implementation of network, increase in water supply coverage, **Outcome:** Economic benefits of assured water supply, access to water to socially vulnerable population
Set up a Water Conservation Cell within CSMC with a focus on water conservation, groundwater management and recycling of wastewater. The Cell will plan and implement initiatives focussing on reduction of NRW, water and energy audits of utility at regular intervals (once in 3-4 years), groundwater management, wastewater recycling and reuse, rainwater harvesting and implement actions to manage the consumer wise water demand and supply, incentives on reusing of treated / non-treated water. **Timeline: 2024-25**	**Stakeholder lead:** Water Supply and sewerage Department, GSDA **Financing:** CSMC budget, XV FC grant, AMRUT 2.0,	**Output:** The Water Conservation Cell is established and operational, with a robust institutional structure, water received per capita (lpcd) through metered connections, number of metered connections, % Non-revenue water (NRW), increase in water supply coverage **Outcome:** Saving in water and pumping costs due to loss reduction, increase in revenue due to reduction of NRW

Table 21-7: Strategy GW-1: Expand rainwater harvesting to contribute to atleast 20% of the water supply by 2030 and increase groundwater recharge, and implement innovative solutions for efficient groundwater recharge while managing water quality.

Action Description	Stakeholders & financing	Monitoring Indicators
Map all the tube wells, dug wells and recharge pits in the city; assess their yield, extraction rate, recharge capacity and rates. Prepare a detailed plan to monitor and manage these activities. The potential areas of groundwater recharge are shown in Figure 21-3. **Timeline: 2025**	**Stakeholder lead:** Water Supply and Town Planning Department, Water Conservation Cell, GSDA, ASCDCL **Financing:** CSMC budget, AMRUT 2.0, XV FC grant	**Output:** a database of recharge structures available for decision making **Outcome:** increased understanding of aquifer locations and recharge areas among policymakers, planners, and the engineering community

Action Description	Stakeholders & financing	Monitoring Indicators
Construct recharge wells to strengthen the network of recharge structures along with the existing network of bore wells and open wells. The runoff rainwater can be directed into these recharge wells, which then percolate into the ground. Such consistent recharging can lead to the replenishment of shallow aquifers. Wherever feasible, the run-off can be diverted to structures like bore wells and open wells, where rainwater can be directly charged to the aquifer. Case example: Pune Municipal Corporation (PMC) is taking measures to tackle its water challenges. One of the initiative they are piloting is groundwater recharge in three gardens. The work is led by PMC's Groundwater Cell[149] **Timeline: 2026**	**Stakeholder lead:** Water Supply and Town Planning Department, GSDA, ASCDCL **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** Increased recharge in shallow aquifer system resulting in increased flow **Outcome:** Increased understanding of recharge mechanism and technology among policymakers, planners, and engineering community

Table 21-8: Strategy WW-1: **Enhance sanitation and sewerage systems to ensure 100% coverage of sanitation systems and 100% sewage treatment by 2030 and increase wastewater reuse.**

Action Description	Stakeholders & financing	Monitoring Indicators
Expand sewerage network, increase STP capacity, and adopt decentralised wastewater management system wherever feasible to collect. Treat 100% of the wastewater generated within the city by 2030. **Timeline: 2030**	**Stakeholder lead:** Sanitation, Town Planning Department with support from Environment Department, Smart City Corporation **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** % of wastewater collected, % wastewater treated **Outcome:** Quality of effluent discharged into water bodies, reduction in water borne diseases

Action Description	Stakeholders & financing	Monitoring Indicators
Carry out feasibility study, and explore opportunities to recycle domestic wastewater and re-use it for 1. industrial processes at the Aurangabad Industrial City (AURIC) and 2. non-potable usage, such as gardening, construction and, toilet flushing etc. **Accordingly make relevant amendments in Development Control Rules to allow dual plumbing in the institutional and large residential complexes** For example: The treated wastewater can be reused at AURIC city. The total water demand for the industrial area is 111 MLD, out of which 67 MLD is freshwater demand and 44 MLD of the water demand is for non-potable uses, which will be met through reuse of treated wastewater[150]. **Timeline: 2030**	**Stakeholder lead:** Sanitation and Environment Department, Industrial associations, MIDC, AURIC **Financing: CSMC** budget, Industry association contribution, AMRUT 2.0, XV FC grant	**Output:** Quantity and % of wastewater recycled, quantity and % of wastewater reused by industries **Outcome:** Quantity and % of freshwater saved due to supply of recycled water as an alternative, revenue generation for CSMC towards recovery of O&M cost of STPs

Table 21-9: Strategy WL-1: Prioritise water logging hotspots and integrate it with the river restoration and storm water drainage augmentation plan

Action Description	Stakeholders & financing	Monitoring Indicators
Adopting measures such as NBS, integrating it with stormwater network to make the city permeable and decrease the risk of waterlogging. The vulnerability assessment identifies key water logging hotspots within CSMC area, where further action plan needs to be prepared in terms of taking measures such as connecting it to stormwater/ natural drains, integrating NBS that will have dual benefits – sponge during flooding and recharge of ground water through impounded water. These water logging hotpots are depicted in Figure 21-6. Some waterlogging hotspots are (i) core city area and five informal settlements - Ghati, Gautam Nagar, Ambedkar Nagar, Shanoorwadi, and Indira Nagar areas where population is affected; and (ii) wards no. 59, 60, 62, 68 and 115) where businesses are affected the most. **Timeline: 2030**	**Stakeholder lead:** Environment Department with support from Indian Meteorological Department (IMD), ASCDCL **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant,	**Output:** No. of waterlogging hotspots identified, and action plan prepared **Outcome:** Decrease in water logging incidences, estimated ground water recharge

Action Description	Stakeholders & financing	Monitoring Indicators
Prepare a detailed plan for restoration of Sukhna River and update the DPR for Kham River restoration incorporating following sub-actions - • Map entire stretch of Sukhna river, identify pollution hotpots, and provide measures for mitigation of those. • Demarcate/ update flood-lines (red and blue line) for Sukhna and Kham Rivers. • Prepare a plan for restoration and rejuvenation of both rivers and other types of water bodies through a citizen participatory approach. • Integrate the flooding/ water logging hotspots along both rivers and its streams into the DPR for both rivers. • Provide measures for rejuvenation of inland water bodies such as Kamal Talav. • Provide green cover along the stretches of both rivers to act a sponge during for floods/ water logging. This will also help replenish groundwater sources/ aquifers. **Timeline: 2026**	**Stakeholder lead:** Environment Department with support from Irrigation dept., Smart City Corporation **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant,	**Output:** Updated DPR for Kham River, DPR for Sukhna river **Outcome:** River stretch restoration implemented, reduction in flooding/ water-logging incidences
Develop a local network of automated weather stations spread across the city area to capture weather related information for data gathering, analysis and improved early warning. **Timeline: 2025-2030**	**Stakeholder lead:** Environment Department with support from Indian Meteorological Department (IMD), Smart City Corporation **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** No. of stations installed **Outcome:** Availability of data for wider area, analysis of data used for forecasting and dissemination

Table 21-10: Strategy WS-2: Awareness generation, outreach and capacity building

Action Description	Stakeholders & financing	Monitoring Indicators
Organise workshops with different stakeholders, community members, and associations on water budgeting, judicial use of groundwater resources, rainwater harvesting, disaster preparedness. **Timeframe: Starting 2024**	**Stakeholder lead:** Environment department with support of local NGOs and CSOs and Smart City Corporation **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** No. of workshops organised with various stakeholders **Outcome:** increase in no. of RWH structures, % increase in groundwater recharge

Action Description	Stakeholders & financing	Monitoring Indicators
Develop online dashboard wherein city- specific information on climate change, disasters, water resource management including aspects of supply, demand, wastewater and sanitation, storm water management, initiatives taken, best practices are shared. **Timeframe: Starting 2024**	**Stakeholder lead:** Environment department with support from ICT department / Smart City **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** Creation of dashboard on CSMC website **Outcome:** No. of visitors on the dashboard, no. of initiatives on water conservation and groundwater recharge, % reduction in impact on lives due to heavy, rainfall, waterlogging, other extreme climate events.
Develop early warning advisories in local language for better outreach. **Timeframe: Starting 2025**	**Stakeholder lead:** Environment Department with support of local NGOs, CSOs, and Smart City Corporation **Financing:** CSR, CSMC budget, AMRUT 2.0, XV FC grant	**Output:** No. of early warning advisories put out **Outcome:** % reduction in impact on lives due to heavy, rainfall, waterlogging, other extreme climate events.

Photo credit: ASCDCL

22. AIR QUALITY

22.1 SECTORAL OVERVIEW

Chhatrapati Sambhajinagar is among the 131 cities designated as non-attainment cities under the National Clean Air Programme (NCAP) launched by the Ministry of Environment, Forest and Climate Change in 2019. The city has demonstrated the non-attainment of the National Ambient Air Quality Standards (NAAQS) for various pollutants.

The major contributing factors to the rise in air pollution levels are:

1. An increase in vehicular density and movement, leading to an increase in GHG emissions as vehicles contribute to particulate matter and NO_x: 2W, 4W and HDVs grew with a CAGR of 3%, 13%, and 22% between 2010 and 2021. 34% or 6.5 lakh tCO2e of the city's GHG emissions emanate from the on-road Transport sector.
2. Industrial clusters: There are two MIDCs located within the Chhatrapati Sambhajinagar Municipal Corporation (CSMC) boundary, namely Chikalthana and Railway Station. Two more MIDCs are located outside the CSMC boundary – one in Shendra (15 km from the city) and another in Waluj (12 km from the city). There are 117 air polluting industries in Aurangabad Industrial Clusters, out of which 24 are in Chikhalthana MIDC, 18 in Shendra MIDC, 68 in Waluj MIDC, and 7 in other areas[151].
3. Rise in construction activities: Owing to rapid urbanisation, and the development of industrial bodies in the periphery of the city, Chhatrapati Sambhajinagar has witnessed a rise in construction activities. The source apportionment study states that there are 209 construction sites in the city, spread over 202 acres of land. The particulate matter emitted from the buildings and construction sector forms the sixth highest source of particulate emissions in the city.
4. Waste management: While CSMC generates 500 metric tonnes (MT) of municipal solid waste per day, there is no active landfill in the city. The incineration of waste accounts for 0.64 lakh tCO_2e or 22% within the waste sector.
5. Energy: The stationary energy sector contributes around 49% (9.3 lakh tCO_2e) of the total GHG emissions of city. In the sub-sectors of energy, around 54% of GHG emissions are from LPG consumption, 27% from coal consumption, and the remaining from bagasse, diesel oil, and fuel oil. The statistics highlight the need for increased energy efficiency measures and use of low-carbon fuels in industries.

In 2019, Chhatrapati Sambhajinagar was ranked sixth among the least polluted cities for pollutant PM_{10}. In 2022, its ranking slipped to 44, with PM_{10} having increased by 97.37%as compared with 2019. This increase in PM_{10} concentration was caused by various activities after the COVID-19 lockdown ended, such as construction, vehicular and freight movement, and industries, leading to a deterioration in air quality and, consequently, the slippage in rank. In the overall ranking of the non-attainment cities in 2022, Chhatrapati Sambhajinagar was ranked 10th among the most polluted non-attainment cities for 2022 for pollutant PM_{10} (Trends). With the CAAQMS being located outside the city limits of the CSMC, in Waluj MIDC, there is a need for a wider range of monitoring networks to understand the air pollution trends in the city.

22.1.1 Temporal and spatial variability of pollutants

The air quality in Chhatrapati Sambhajinagar is assessed using temporal data from the CAAQMS at More Chowk, Waluj, the three manual stations at SBES college, CADA office, and Collector office established, and the spatial analysis is based on satellite imagery. For the lone CAAQMS station at More Chowk, Waluj, hourly data is available for pollutants and gases SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, and ozone. While the manual stations collect data for SO_2, NO_x, RSPM, SPM for only two days per week.

As per the analysis, PM_{10} and NO_2 are identified as the pollutants that have either crossed or are close to the safety threshold defined by CPCB[152]. The source apportionment study confirms that vehicular emissions are the primary source of PM_{10} in the city. The analysis too reveals that the seasonal temporal and spatial trends observed in critical pollutants, such as SO_2, NO_2, CO, and ozone, are similar to those observed in particulate matter concentration i.e. higher in winters and relatively lower concentration in the monsoons. As a result, the city faces the worst air quality in winters in terms of all pollutants.

The gridded emissions inventory from the source apportionment study also indicates elevated PM_{10} emission load in the grids coinciding with the areas of brick creation units. In similar regions of the grid, a hotspot for SO_2 also emerges in 2021, indicating the adverse effects of local activity and fuel consumption patterns in the city. As per the city's land use data, there are 65 brick creation areas within the city limits. In a study conducted by Urban Emissions Info to assess Chhatrapati Sambhajinagar's air quality (baseline year 2018), the estimated emissions from the brick kilns were found to contribute to 22,150 tonnes/day of CO and 1,900 tonnes/day of PM_{10}. Brick kilns were also found to account for 15% of $PM_{2.5}$ sources.

According to the spatial analysis for CO, in 2019, the hotspot was over the Waluj MIDC and that it moved closer to the city core in 2020 and 2021, all of which coincided with the brick creation units. Apart from this, a high rise in CO concentration could be attributed to an increase in domestic fuel consumption in households during the COVID-19 lockdown period. Emissions from brick kilns are a significant concern. As many brick kilns use clamp kiln technology, there is a severe need to study the emissions from clamp-style brick kilns and a greater need to incentivise and enforce a shift to cleaner zig-zag technologies (Climate Trends, 2019).

22.1.2 Sources of Pollutants

CSIR-NEERI, IIT-B, and MPCB conducted the source apportionment study in 2017, categorising emissions into area, line, and point sources. The study reveals that HDVs and 4-wheelers, particularly line sources, are the primary PM_{10} emitters, contributing 50% of the city's emissions load, followed by point sources at 31%. Briquettes, a common point source in Chhatrapati Sambhajinagar, contribute 12%, significantly impacting air quality.

Due to rapid industrialisation observed in the district, CPCB introduced the Comprehensive Environmental Pollution Index (CEPI) during 2009-10 as a tool to assess prominent industrial clusters and formulate remedial Action Plans for the identified critically polluted areas (MPCB, 2020). The Aurangabad industrial cluster, comprising Shendra, Waluj, Chikalthana, and the Railway Station MIDCs, hosts 4,699 industries in red and orange categories. The CEPI score for Chhatrapati Sambhajinagar improved from 77.44 in 2009-10 to 69.85 in 2017-18 and further to 59.9 in 2020, reclassifying the industrial cluster from Critically Polluted to Severely Polluted.

22.1.3 Exposure and sensitivity

Strengthening community resilience is critical, but socio-economic variabilities such as access to clean cooking fuel, and housing conditions increase the exposure to hazards. Under the NCAP, the Micro Action plan has identified 24 major traffic junctions in the city as air pollution hotspots, most of which lie on the Jalna Road highway. The communities working in the proximity of these junctions face the risk of lung and heart diseases. Moreover, the vulnerability assessment using the Census 2011 data reveals that 31.41% of households use firewood, crop residue, cow dung cake, coal/lignite, kerosene, etc. as their fuel for cooking and many of these households lie on the outskirts of the city, exposing the population to the risk of indoor air pollution.

The CEPI study by MPCB examined health data (total number of cases of asthma, bronchitis, and acute respiratory infections) of five hospitals for the period 2012-2018 to assess the impact of air pollution on human health. The highest number of patients with asthma and acute respiratory infection were registered in the year 2015. While establishing a clear trend is challenging, ongoing data monitoring should be a crucial performance indicator in the air quality monitoring matrix.

22.2 ONGOING INITIATIVES

Air Quality Monitoring:

- Proposed the installation of two CAAQMS, one in MPCB regional office and another in Deogiri College in Chhatrapati Sambhajinagar city.

Policy:

- Formulated an Action Plan to control air pollution in Chhatrapati Sambhajinagar city in 2019
- Conducted a Source Apportionment study in 2017 and released the same in 2020
- Published a Micro Action plan for Chhatrapati Sambhajinagar city in 2021

Other initiatives:

- Identified 24 junctions as air pollution hotspots
- Procured e-buses, installed public charging stations
- Procured vacuum sweeping machines and white topping of 30 roads; proposed multi-level parking at Paithan Gate
- Post the inauguration of the city's first cycle track in January 2021 under the Cycles4Change Challenge, five more cycle routes identified
- Around 99,125 trees planted in schools, gardens, and open spaces in colonies by CSMC; vertical gardens and water fountains installed
- Awareness workshops to increase outreach under the NCAP conducted in schools and colleges.; electronic display boards showcased air quality-related data for public awareness

22.3 KEY GAPS

1. **Inadequate monitoring network and data deficiency**: Only one CAAQMS is installed in the region, which is outside the city limits. There are three manual monitoring stations within Chhatrapati Sambhajinagar that monitor at a frequency of two days per week.

2. **A serious need to consider the airshed approach:** An airshed is a 'common geographic area where pollutants mix and create similar air quality for everyone'[153]. Air pollution must be addressed in an integrated manner by considering not only the local but also regional levels, and looking beyond the city limits, as all sources of pollutant might not be originating from within the city. As Chhatrapati Sambhajinagar district hosts four industrial clusters, there is a serious need to consider the airshed approach while planning and decision making. The spatial analysis demonstrates the rise of particulate matter from the industrial area of Waluj. Hence, there is a severe need to monitor and mitigate the pollutants arising from the region.

3. **Bridging the gap between estimated budget and actual fund allocation:** While prioritisation, and best alignment of actions within existing programmes should be done by the city, the state government should strengthen the municipal budgets for improved air quality.

22.4 RECOMMENDATIONS

22.4.1 Sectoral aspiration

The overall goal is to improve the air quality of Chhatrapati Sambhajinagar city with an effective air pollution monitoring network, awareness, strict compliance, and alignment with policies and programmes for better public health.

22.4.2 Approach

Based on the assessment of existing data, vulnerability assessment and ongoing initiatives, a three-step approach is adopted, which comprises the strategies to address air pollution risk comprehensively.

- **Identify**: Identify the sources and local activities causing the emissions, pollutants, and affected vulnerable groups immediately.
- **Measure and monitor:** To make effective

evidence based decisions, it is crucial to measure pollutant concentration along with its spatial variability in different seasons of the year. This includes assessing the historical data for air pollution, forecasting, and building a decentralised network of monitoring systems.

- **Mitigate and build resilience**: Sector-specific emission reduction actions reduce the exposure of vulnerable groups, hence building their health resilience capacity. The actions and targets would be integrated with the national and sub-national level policies and programmes, and a meaningful convergence would be showcased.

22.4.3 Sectoral Priorities

The priorities for the air quality sector in Chhatrapati Sambhajinagar arise from the multi-sectoral effect of the air pollution observed in the city.

The air quality sector aligns with air pollution because of emissions affecting air quality. As a part of the assessment of the transport sector, the following strategies have been proposed:

- Public transport: Increasing public transport mode share, and shifting to alternate fuels
- NMT: Building robust infrastructure and policies for non-motorised transport
- Parking and clean fuel vehicles: Improved parking management and shifting towards cleaner private vehicles
- IPT: Low carbon transition of intermediate public transport
- Freight: Reducing emissions from urban freight through fuel-efficient and low-carbon delivery

Apart from the above strategies, the following key strategies are proposed as a part of the air quality improvement:

Strategy AQ-1: Strengthen the air quality monitoring system for better monitoring air quality and providing informed inputs for air pollution mitigation actions.

Strategy AQ-2: Reduce particulate matter concentrations by 20%-30% by 2026 and additional 20% by 2030.

Strategy AQ-3: Building community resilience through identifying priority stakeholders, and engaging with them via various communication mechanism.

Identify the sources and local activities causing the emissions

Measure and Monitor to make effective data-backed decisions

Mitigate and build resilience to reduce the exposure of the vulnerable communities

Table 22-1: Strategy AQ-1: Strengthen an air quality monitoring system for improved monitoring of air quality and providing informed inputs for air pollution mitigation actions.

Action Description	Stakeholder & financing	Monitoring Indicator
Strengthen the air quality monitoring network by installing at least five continuous ambient air quality monitoring stations (CAAQMS) spatially distributed across the city as per the CPCB guidelines. Set up at least one Air Quality Monitoring Station outside the city limits to analyse the background pollutant concentrations. **Timeframe: 2024-2027**	**Stakeholder lead:** MPCB, CSMC, Air Quality Monitoring Cell (AQMC) **Financing:** NCAP budget, XV FC	**Output:** No. of CAAQMS installed within the city limits in a year, set up of AQMS outside city limit **Outcome:** Efficient monitoring of pollutants in the city
Strengthen the monitoring network by setting up low-cost environmental sensors, especially in the hotspot areas, landfill, and compost facilities, MIDC complexes, and major junctions such as Kranti Chowk, and CIDCO, to monitor air quality and analyse the effective implementation of actions related to air pollution mitigation at these areas. It will be useful to put the data on display boards to create public awareness about air quality changes. **Timeframe: 2024- 2027**	**Stakeholder lead:** ASCDCL, CSMC, Air Quality Monitoring Committee **Financing:** Smart Cities budget, Municipal, CSR funds	**Output:** No. of sensors installed per year. **Outcome:** Efficient monitoring of pollutants in the main areas of the city such as at schools, junctions, commercial complexes and low-income neighbourhoods.
Develop a dashboard for real-time AQI and display it on various display boards. Set up a public helpline and a grievance redressal system on CSMC's website and mobile app for complaints on air quality, waste burning incidences, etc. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** AQMC, CSMC- Environment department, ASCDCL - MSI unit **Financing:** NCAP budget, 15th Finance Commission	**Output:** No. of areas identified with poor air quality or as air pollution hotspots, no. of complaints addressed **Outcome:** Immediate steps taken to improve the AQI in the wards. (can be multiple outcomes)

Table 22-2: Strategy AQ-2: Reduce particulate matter concentrations by 20%-30% by 2026 and additional 20% by 2030.

Action Description	Stakeholder & financing	Monitoring Indicator
Make it mandatory to use Anti Smog Guns at construction and demolition sites with an area more than 5,000 sqm, with one device to be installed for every increase of 5,000 sq. metres of area. Case example: NCR has been directed by the Commission for Air Quality Management to deploy anti-smog guns at all construction sites to settle dust and other pollutants. CSMC can refer to Handbook of Clean Construction Practices in Surat by WRI India,[154] which is a guidebook adopted by Surat Municipal Corporation. This handbook provides a snapshot of all the rules, regulations, and best mitigation measures required to curb particulate matter emissions specific to construction activities[155]. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** CSMC, MPCB **Stakeholder support:** Construction companies Financing: NCAP budget	**Output:** No. of construction sites with Smog guns. **Outcome:** % decrease in the particulate matter emission from C&D sites.
Prepare dust management guidelines for the construction sector, and adopt dust control techniques such as: 1. Black topping of unpaved roads. These can be coated with high albedo material. 2. Dust suppressants on C&D waste **Timeframe: 2027**	**Stakeholder lead:** Environment department, Roads department, MPCB **Financing:** NCAP budget	**Output:** No. of initiatives taken to manage dust **Outcome:** % decrease in the particulate matter emissions from C&D sites.
Establish a C&D waste processing plant (100TPD) on a PPP basis, and enforce strictly usage of at least 20% recycled C&D waste (from the ULB's annual generation) in construction and infrastructure development works. Case example: The use of C&D waste in the banking of Kham is an excellent strategy in terms of efficiently reusing the resources and, hence, saving on costs. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** CSMC- Environment department **Financing:** NCAP budget	**Output:** set up of a C&D waste processing plant, % of C&D waste processed in the plant in a year **Outcome:** % of C&D waste recycled and reused by CSMC in the infrastructure development works, % decrease in the particulate matter emissions

Action Description	Stakeholder & financing	Monitoring Indicator
Develop and adopt a phase-wise plan for the improvement of brick kiln industries The plan should include the adoption of energy-efficient measures, alternative fuel for coal like gas, and zigzag kiln technology to achieve reduction in SO_2 and PM emissions. **Timeframe: 2024-2026**	**Stakeholder lead:** MPCB, CSMC-Environment department **Financing:** NCAP budget	**Output:** % of brick kilns shifted to zigzag, % of brick kilns using clean fuels **Outcome:** % improvement in SO_2 emissions monitored via the manual stations and satellite monitoring, % decrease in the particulate matter emissions
Capture information on different types of fuel usage within industries, slums, dhabas, bakeries using coal, wood, biomass, etc. and Promote and incentivise the shift towards cleaner fuels, such as PNG, LPG, and electricity. **Timeframe: 2025 – 2026**	**Stakeholder lead:** MPCB **Financing:** NCAP budget	**Output:** % of industries shifted to low-sulfur fuels, renewables, and natural gas Outcome: % decrease in air pollutants in the areas with air-polluting industries.
Ensure 100% conversion of all crematoria and bakeries to electric or PNG, and the installation of chimneys with filters. **Timeframe: 2024 – 2026**	**Stakeholder lead:** CSMC- Environment department, health department **Financing:** NCAP budget	**Output:** % of crematoria, bakeries converted to electric/PNG and having chimneys with filters **Outcome:** % change in the emission of pollutants from bakeries and crematoria

Table 22-3: Strategy AQ-3: **Building community resilience through identifying priority stakeholders and engaging with them via various communication mechanisms.**

Action Description	Stakeholder & financing	Monitoring Indicator
Roll out seasonal surveys to monitor the health impacts of the pollutants, create a spatial inventory of hotspots, and a health assessment of deaths related to air pollution. The data sets can be made publicly available and published as annual or quarterly reports. Case example: New York city conducts community air surveys to monitor the air quality and pollutants that cause health problems, such as lung and heart disease, in different neighborhoods. This has helped them understand the number of deaths caused by a certain pollutant and pinpoint the sources of the pollutant, making the case stronger for the need for clean air and taking necessary actions to improve the air quality. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** Health department. ASDCL's MSI unit **Stakeholder support:** Government and private hospitals **Financing:** NCAP budget	**Output:** Identification of communities and individuals that are vulnerable to air pollution related health risk. **Outcome:** Health-related interventions adopted to reduce emissions at source, and improve quality of health, especially in vulnerable neighborhoods.

Action Description	Stakeholder & financing	Monitoring Indicator
Develop ward-level awareness campaigns on best practices for improving air quality. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** CSMC- Ward officers, Zonal officers **Financing:** NCAP budget, Majhi Vasundhara Abhiyan, CSR, 15th Finance Commission	**Output:** No. of awareness programmes undertaken **Outcome:** People taking health precautionary measures when exposed to air-polluting activities
Conduct awareness programmes to encourage people to 100% transition towards cleaner cooking fuel (LPG, PNG) to reduce indoor air pollution exposure and reduce the burden of poverty-related diseases. Launch drives against the practices of waste burning and crop residue incineration on priority in the wards with agricultural land. Incentivise the farmers to send this residual to the composting site. **Timeframe: Starting 2024; continuous and regular process.**	**Stakeholder lead:** Environment department, Health department **Stakeholder support:** Civil Society Organizations, NGOs, LPG and PNG suppliers, medical practitioners from public health centres, and government and private hospitals, NGOs, and associations such as the Chamber of Marathwada Industries & Agriculture (CMIA), and Agricultural Technology Management Agency (ATMA) Chhatrapati Sambhajinagar **Financing:** NCAP budget, Majhi Vasundhara Abhiyan, CSR, 15th Finance Commission	**Output:** No. of awareness programmes undertaken **Outcome:** % increase in the no. of new LPG and PNG connections. % decrease in incidences due to airborne diseases. % decrease was observed in crop burning through field visits and surveys. % improvement in air quality over the reaping period

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 Climate Action Plan (CAP) for Chhatrapati Sambhajinagar is in line with 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 inclusivity and equity considerations in Chhatrapati Sambhajinagar CAP were made by adopting the inclusive planning guidance of C40 Cities and WRI.

The roadmap to inclusive CAP aligns with the city's existing needs to address climate action in the form of stakeholders' consultations and workshops for capacity building as well as to validate the actions and net zero targets by 2050. Under the needs assessment and through an extensive Vulnerability Assessment, communities and areas that are prone to higher risk have been identified. Interactions with NGOs, civil society groups and ground truthing were carried out to understand the 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, government and parastatal agencies and those working in the environment space on various initiatives such as greening, transport, water, etc.

In terms of policy considerations, relevant documents under NCAP, city's Source Apportionment study, Development Plan, etc were referred. Chhatrapati Sambhajinagar CAP aligns with national programmes and polices, such as the NCAP, Swachh Bharat Mission and CSCAF, through the five sectoral actions targets identified within them. Moreover, the actions and pilot projects are aligned with the municipal budget, Fifteenth Finance Commission and NCAP budget. The participation by Chhatrapati Sambhajinagar city in Majhi Vasundhara Abhiyan (MVA) ensures that local bodies take up environment-related actions, incorporating the five elements i.e. Earth, Air, Water, Energy and Enhancement. The impact analysis considers an assessment of risks by identifying the 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. In the case of Chhatrapati

Sambhajinagar, we look at heat hotspots, flooding and water logging hotspots and traffic congestion hotspots. The resultant 0.7% of Chhatrapati Sambhajinagar's population is vulnerable to both above average LST and waterlogging. Risk assessment has taken into account the city's historic trends and current situation, based on available scientific evidence from 2005 till date. Basis the historical trend, the major climatic risks are that of heat risk, rainfall variability, water logging and ground water depletion.

Inclusive CAP can advance the development outcomes in cities in domains related to the 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 is 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 is tracked through indoor air quality analysis. 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 resulting 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"[156].

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

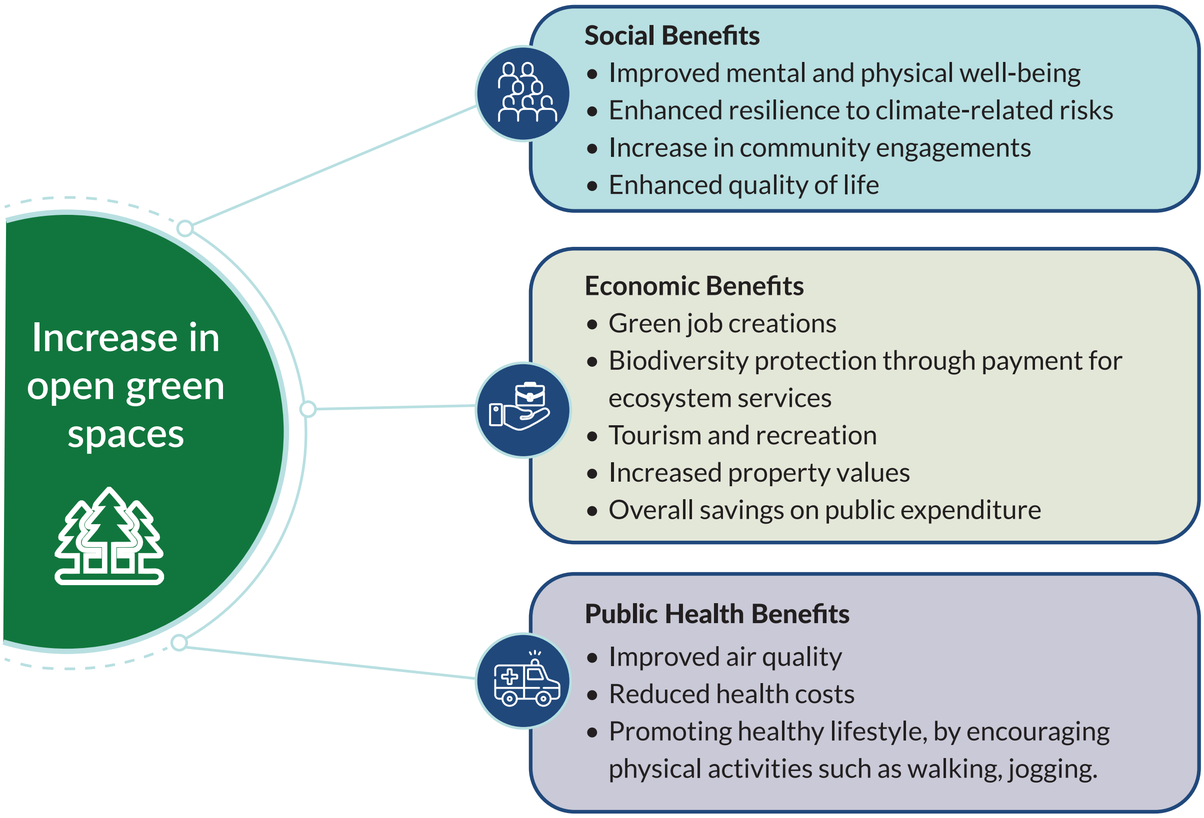


Figure 23-2: Illustration of the co-benefits under increase in public transport mode share

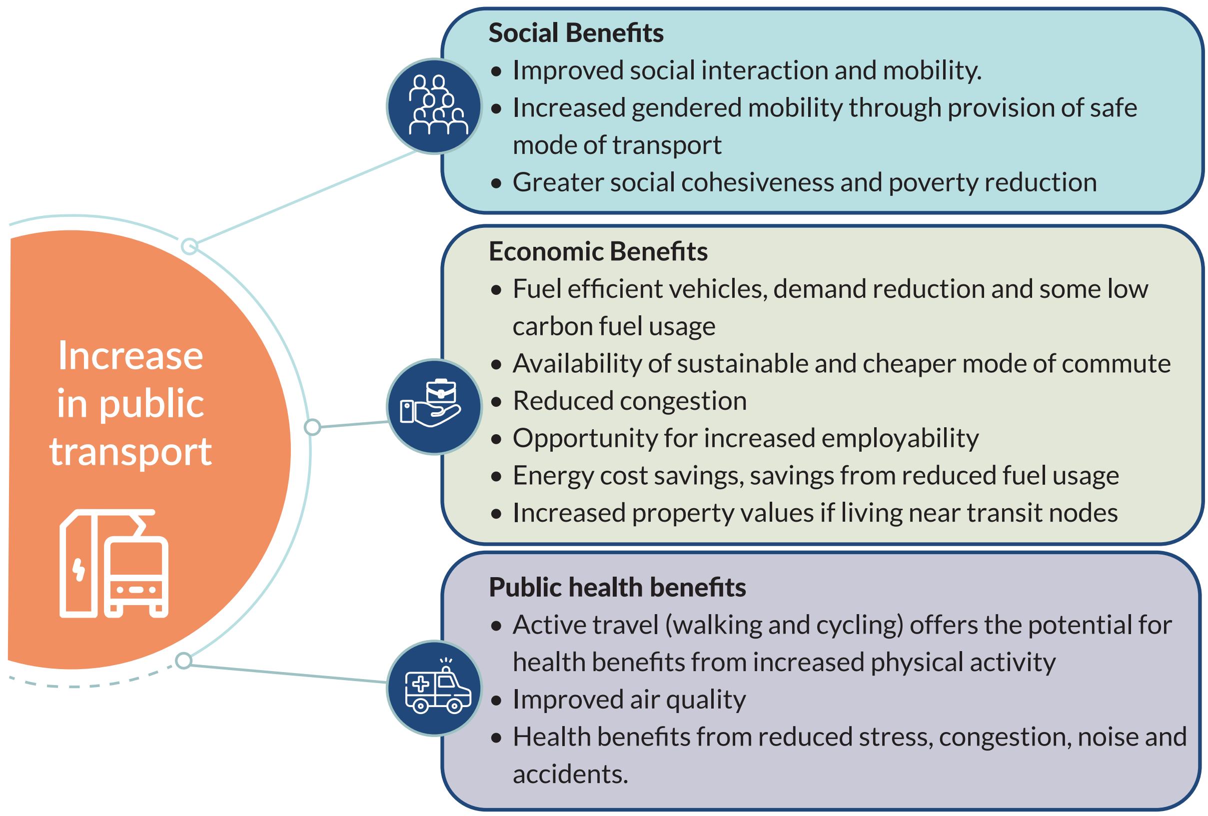


Photo credit: ASCDCL

24. GOVERNANCE & INSTITUTIONAL STRUCTURES

24.1 ORGANISATIONAL STRUCTURE

24.1.1 Existing organisational structure of Chhatrapati Sambhajinagar city

The Chhatrapati Sambhajinagar Municipal Corporation (CSMC) is the governing body of the city of Chhatrapati Sambhajinagar, which consists of democratically elected members (headed by a Mayor) and an administrative wing (headed by a Municipal Commissioner). The two wings together are responsible for the overall administration of the city.

Apart from this, there are various parastatal agencies that are involved in the various capacities as planning, implementation, and regulatory authorities. These are listed in Table 24-1.

Table 24-1: Key agencies and their roles that support Chhatrapati Sambhajinagar city administration

S.N.	Name of agency	Role/ sector
1	Chhatrapati Sambhajinagar Municipal Corporation (CSMC)	City administration managing - water supply, sanitation, solid waste management, roads and bridges, development plan, streetlights, etc.
2	Aurangabad Smart City Development Corporation Ltd. (ASCDCL)	Smart city SPV managing projects related to area based development and pan city.
3	Regional Transport Office (RTO)	Vehicle Registration
4	Oil companies	Sale of petrol, diesel and CNG
5	Maharashtra State Electricity Distribution Co. Ltd (MSEDCL)	Electricity distribution and supply
6	Maharashtra State Power Generation Co. Ltd (MAHGENCO)	Electricity generation
7	GSDA	District ground water management
8	Traffic police	Traffic management
9	Indian Meteorological Department (IMD)	Rainfall and temperature data
10	Maharashtra Pollution Control Board (MPCB)	Control and regulation - Air, Water, and land pollution
11	Forest Department	Social forestry program and greening measures
12	District Disaster Management Authority	Preparation and response during disasters

Source: WRI India analysis

24.1.2 Organisational structure of Chhatrapati Sambhajinagar Municipal Corporation

The organisational structure of CSMC consists of an elected members' wing and an administrative wing.

Elected members' wing:

The city has 9 zones and 115 electoral wards. Each ward is represented by a Corporator elected by the residents of the ward. The Mayor heads the elected representatives. There are two Committees — General Body and Standing Committee — headed by the Mayor and the Chairman, respectively.

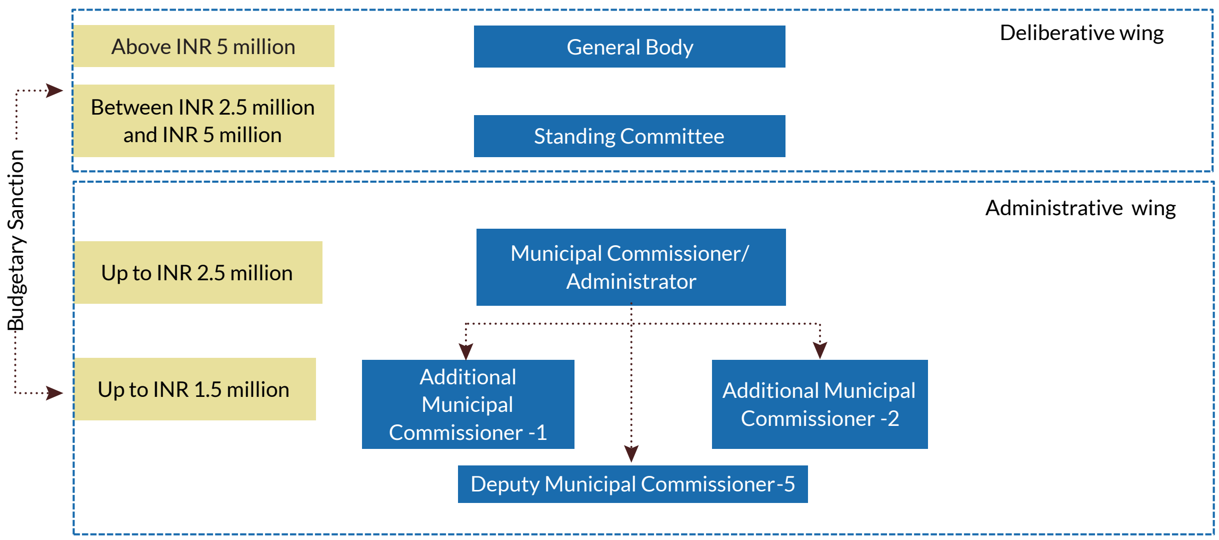
Administrative wing:

The administrative wing of CSMC is headed by the Municipal Commissioner, and their appointment is through the Indian Administrative Services (IAS) cadre. The Municipal Commissioner is supported by two Additional Municipal Commissioners (CSMC-1 and CSMC-2). The Municipal Commissioner and one Additional Municipal Commissioner are appointed by the Government of Maharashtra. There are six Deputy municipal commissioners looking after various departments, ranging from public services and utilities to civil infrastructure to general administration. There are nine zonal officers acting as Assistant Commissioners and four executive engineers.

The two Additional Commissioners are entrusted to approve projects and proposals up to revenue and capital expenditure of INR 15 lakhs, while the expenditure of INR 15 lakhs and above is directly approved by the Commissioner.

The key services rendered by the ULB are town planning, solid waste management, gardens/parks, playgrounds, streetlights, construction and maintenance of roads and drains, water supply, sewerage, and amenities such as cultural halls and shopping stalls. In addition to CSMC, the parastatal agencies, listed in Table 24-1 too support the administration in delivering key utilities to the city.

Figure 24-1: Existing Organisational structure of Chhatrapati Sambhajinagar Municipal Corporation (CSMC)



Source: CSMC, 2022

24.1.3 CSMC - Institutional barriers - Environment and climate change

- The administrative and governance structure of CSMC focuses on public utilities, services and infrastructure maintenance, such as water supply, sanitation, drainage, solid waste management, public transportation, gardens, and public health.
- CSMC has a Department of Environment headed by the Deputy Municipal Commissioner, but various environmental and climate project related challenges are managed across multiple departments. The department is also focussed on projects under the NCAP and the Fifteenth Finance Commission grant, which may be multi-sectoral. The department in its current functioning has limited expertise to advise cross-sectoral projects across departments on environmental and climate change aspects due to a lack of institutional and financial capacity.
- Since various climate risks and their solutions are cross-sectoral, there is a need for a single planning and advisory body to oversee environment and climate forward projects in CSMC area. For such project preparation, a holistic approach is required across departments and agencies. This holistic approach should fulfil the key gap in the current functioning of the department.
- There is a need for a separate department to take ownership for interdepartmental/ interagency coordination for the implementation of strategies and actions, data collection, validation and monitoring of Chhatrapati Sambhajinagar CAP.

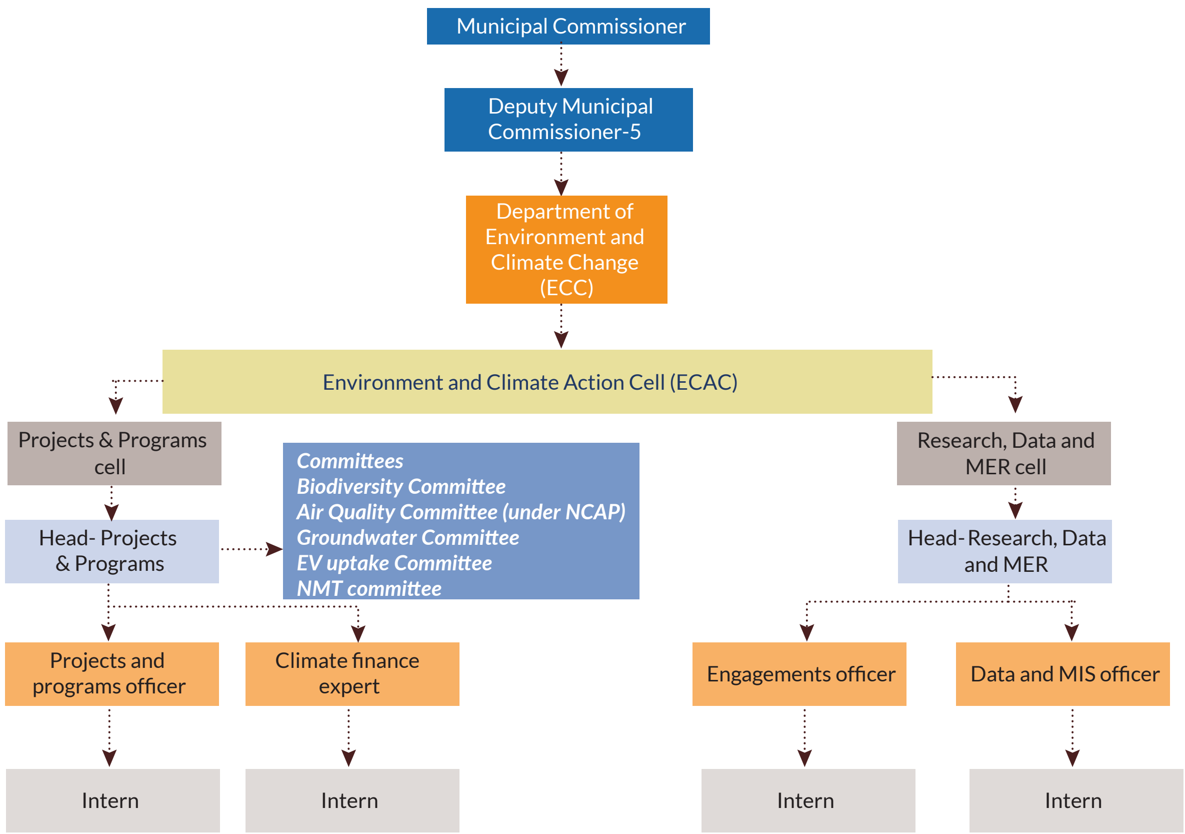
24.1.4 Proposals – Institutional arrangement - Environment and Climate Change

The current Department of Environment is headed by Deputy Municipal Commissioner-5. Currently, there are staff in this department. In carrying out the current responsibilities and workload, the department is supported by the staff of the solid waste management department. The Department of Environment was the nodal department that supported the development and drafting of the Chhatrapati Sambhajinagar CAP and co-ordinated with various parastatal agencies.

In line with the changes made by the Government of Maharashtra, at the state level, the newly named Department of Environment and Climate Change (ECC) addresses the issues pertaining to environment as well as accelerates climate action in the state. Similarly, the Department of Environment at CSMC is proposed to be expanded, strengthened, and renamed as the Department of ECC.

The overall institutional structure for the ECC Department at CSMC is as follows:

Figure 24-2: Structure of the proposed Department of Environment and Climate Change, CSMC



Source: WRI India analysis

As the Department of ECC provides advisory support for developmental projects to a certain extent, it is important to create a Climate Action Cell that will facilitate and support the implementation of the Chhatrapati Sambhajinagar CAP. This Environment and Climate Action Cell (ECAC) would play a critical role in data management and research, coordinate with other interdepartmental and parastatal agencies, support the projects and programmes that pertain to the environment, and monitor the outcomes and outputs of the Chhatrapati Sambhajinagar CAP. The ECAC will be divided into two verticals based on function, as shown in Figure 24-3: Advisory cell to Projects and Programs and Research, Data and MER cell.

Figure 24-3: The two verticals of Environment and Climate Action Cell

Projects & Programs cell

- Responsibility of this cell to ensure climate resilience is built in the city via these programs.
- Co-ordination with internal, parastatal and external agencies to drive climate action
- This cell would act as a Secretariat to various committees in the city, including- Biodiversity Committee, Air Quality Committee (under NCAP), Groundwater Committee, EV uptake Committee
- Advise on the budget, schemes, and grants to streamline projects.
- Technical and institutional capacity to execute plans and projects.

Research, Data and MER cell

- Develop data repository
- Update the GHG inventory and VA every three years and update the Chhatrapati Sambhajinagar CAP every five years
- Monitoring and Evaluation
- Monitor and report on outputs and outcomes of the CAP
- Report on the progress of the Chhatrapati Sambhajinagar CAP

Source: WRI India analysis, 2022

- Projects and Programmes Cell: This cell would be responsible of ensuring that climate resilience is integrated in the city through these programmes. This cell would act as a Secretariat for EV Cell, NMT Cell, and Groundwater Cell. This cell would be headed by the Assistant Municipal Commissioner acting as Head, Projects & Programmes. The Head, Projects & Programmes will be supported by a Projects and Programmes officer.
- Research, Data and Monitoring, Evaluation and Research (MER) Cell: This cell would be responsible for the collection and analysis of data related to climate change, monitoring of the implementation of CAP, etc. The cell would be headed by the Assistant Municipal Commissioner acting as Head, Research, Data and MER. The Head, Research, Data and MER would be supported by an Engagements officer (to co-ordinate and liaise with various departments for data collection) and a Data & MIS officer (to validate and analyse data for VA and GHG inventory).

25. FINANCING ARRANGEMENTS

25.1 CSMC - SECTOR-WISE BUDGET ALLOCATION

The CSMC budget has two major heads - revenue and capital. The share of revenue income in the overall income ranges from 81% in Financial Year 2021-22 (i.e. FY22) to 84% in FY23. It was revenue surplus at INR 220.6 crore in FY 22 and INR 609.2 crore in FY23. Thus, the revenue expenditure and the capital works are largely funded through the revenue income of NMC. The analysis of CSMC finances is done for two financial years FY22 (revised estimates) and FY23 (estimates of administration) based on the CSMC budget document for FY23.

25.1.1 Revenue and capital accounts

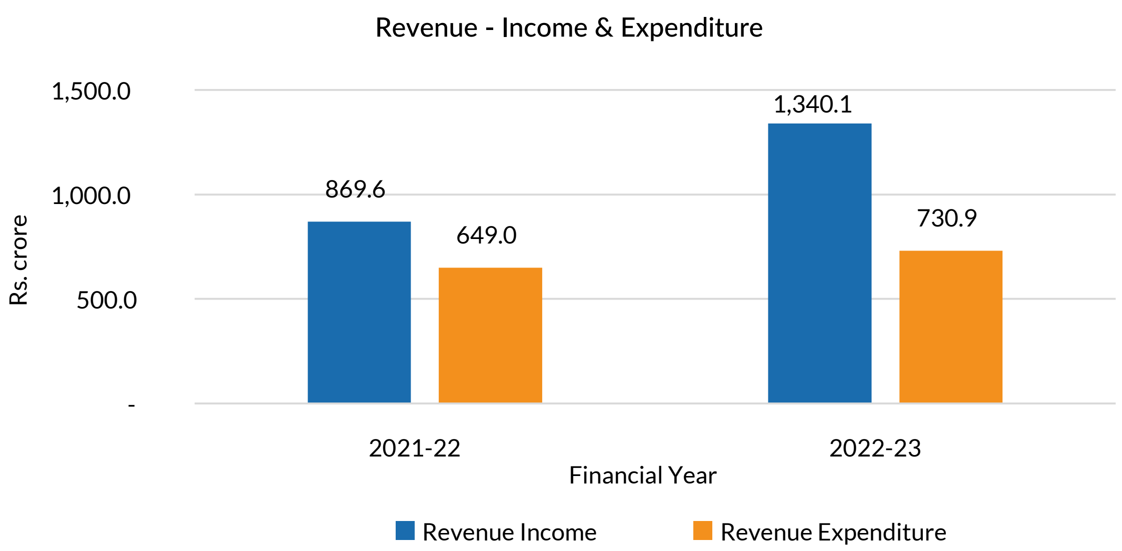
1. Revenue account

The trend of revenue income and expenditure during FY22 to FY23 is shown in Figure 25-1. During this period, the revenue surplus has grown from INR 220.6 crore to INR 609.20 crore at a compounded annual growth rate (CAGR) of 9.1% whereas the revenue expenditure is growing at a slightly lower CAGR of 8.8%. The account is revenue surplus during all these years.

2. Capital account

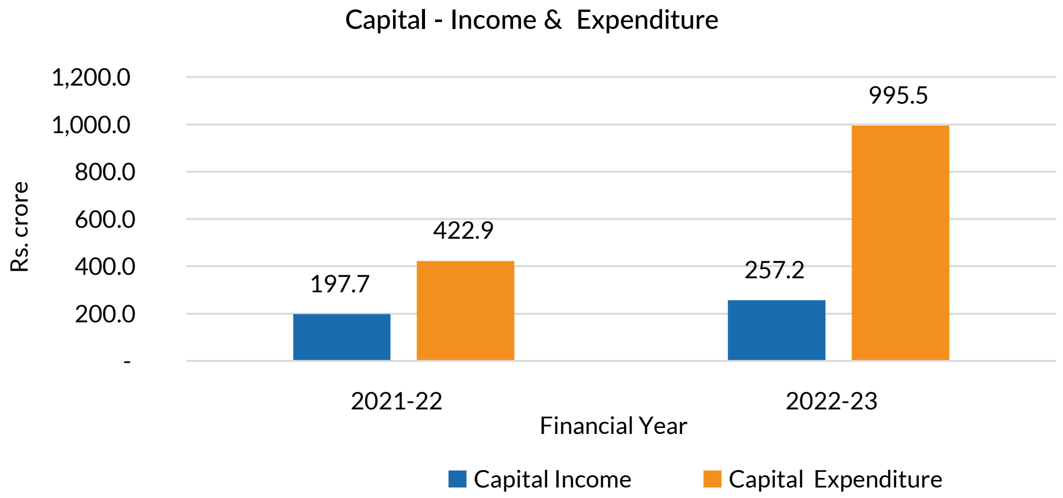
During FY22-FY23, capital income grew at a CAGR of 30% whereas the capital expenditure has grown at 135%. This highlights that CSMC needs to plan for improving its income and, at the same time, manage capital expenditure in a judicious manner. It should also leverage its balance sheet so that it can fund more capital works based on existing income streams.

Figure 25-1: CSMC: Revenue income and expenditure growth trends



Source: CSMC Budget 2023, WRI India analysis

Figure 25-2: CSMC: Capital income and expenditure growth trends

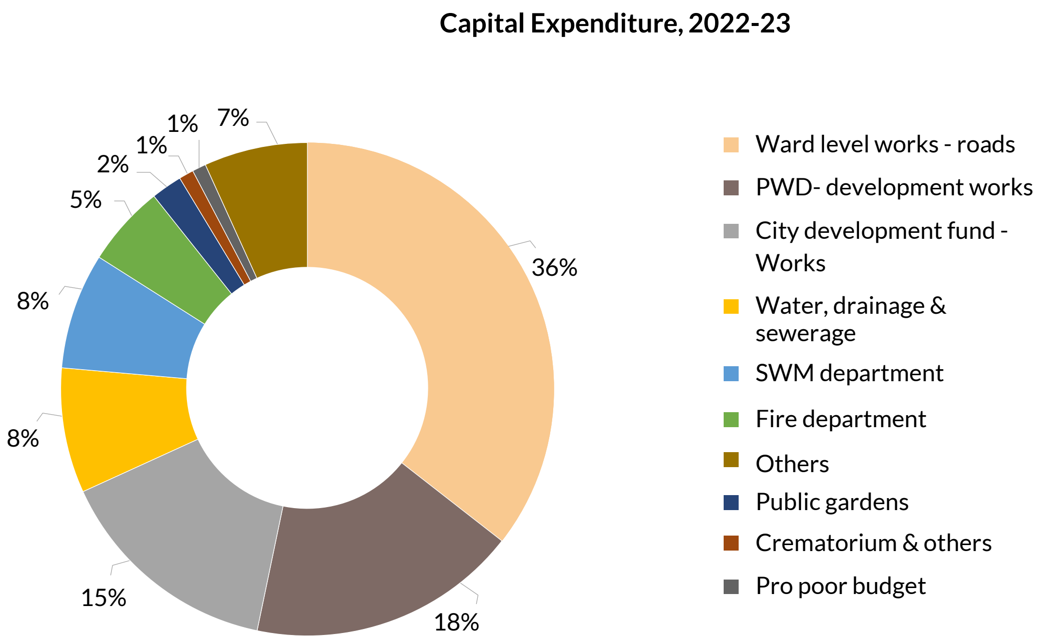


Source: WRI India analysis

25.1.2 Department-wise revenue and capital expenditure

The department/sector-wise capital expenditure assessment was done for FY 2022-23.

Figure 25-3: Department/ Sector wise Capital expenditure for FY 2022-23



Source: WRI India analysis

Key observations are as follows -

- The total estimated capital expenditure for FY23 is INR 995.5 crore against INR 422.9 crore in FY22.
- The major share is that of ward-level capital works on roads (36%), followed by developmental works of PWD (18%).
- Works of city development constitutes 15% share.
- Capital works for water and wastewater constitute 8% share.
- Around INR 20.2 crore (~2%) is spent on gardens.

25.2 FINANCING AND INSTITUTIONAL ARRANGEMENT

Currently, the CSMC implements the capital project through the revenue surplus and scheme grants and manages and maintains the assets through revenue expenditure. The major capital works are taken up through the revenue income as capital income is comparatively less.

The funds allocated for capital works in gardens is INR 20 crore in FY23. In FY22, the budget allocated for SWM department was INR 179.5 crore and for wastewater management and treatment was INR 48.6 crore.

Leveraging existing financial mechanisms
The city also receives grants under various schemes, such as the Fifteenth Finance Commission, NCAP, MVA, AMRUT, and Swachh Bharat Mission-Urban.

Fifteen Finance Commission grant: The city has received a total grant of INR 63.5 crore. INR 32.2 crore and INR 30.9 crore is allocated for work under the components of Air Quality and Solid Waste Management, respectively.

In 2021-22, Chhatrapati Sambhajinagar won the Best AMRUT city at Divisional Level at MVA 2.0 and received prize money of INR 2.0 crore. In 2022-23, in MVA 3.0 Chhatrapati Sambhajinagar won under the same category and received a prize money of INR 2.0 crore. As per the Government of Maharashtra's directives, the winning cities are directed to allocate 50% of the prize money for greening efforts in the city and the remaining 50% is to be allocated to climate action efforts, such as the installation of solar panels. This gives the city an opportunity to align its climate goals with the objectives of MVA. For example, CSMC can leverage this funding opportunity and strategically address the heat risk faced at ward level by tailoring the project DPRs to reduce the heat island effect in vulnerable areas. Such concentrated efforts would ensure timely implementation of the CAP.

Chhatrapati Sambhajinagar can leverage such financial channels and effectively align the project proposals with the objectives of such available grants and schemes. As a part of the Chhatrapati Sambhajinagar CAP, various actions are mapped that could be funded by such existing financial mechanisms. For example, under the Air Quality sector of the CAP, a critical action is 'Setting up of a CAAQMS in the city'. As Chhatrapati Sambhajinagar received funds under the NCAP programme, this action could be converged with the objectives of the NCAP and accessible funding to achieve this target leveraged.

Furthermore, there is a need for reclassification, reallocation, and fresh allocation of some of the budget for climate actions, both for adaption and mitigation.

A few case examples are given below:

- In 2022-23, the budget allocated for the capital works on roads was INR 353.8 crore. 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 the road development works, and some of the road budget can be reallocated to these initiatives.
- Similarly, for waste management, there is funding 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 CSMC and identify areas for convergence, reclassification, and prioritisation. Based on this, a dedicated climate budget can prepared so that the city can take climate actions on priority.

In terms of project structures and business model, CSMC can explore various ways of developing and implementing projects such PPP, CSR etc.

25.3 NEED FOR CLIMATE BUDGET

Given the need for reclassification, reallocation, and fresh allocation of some of the budget for climate actions, a climate budget is essential for CSMC to ensure that dedicated financial resources are available to implement the CAP and to leverage this as a governance tool to overcome institutional barriers identified in the city's existing governance structure.

Although the budget will be anchored within CSMC and prioritise activities that are directly under CSMC's control, the ECCC and the climate budget will ensure that either the department in CSMC or parastatal agencies assume responsibilities 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 quarterly 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 presented in Chapter 26.

25.4 PILOT PROJECTS

During the CAP preparation, a list of pilot projects has been identified and discussed with CSMC. The objective of implementing pilot projects is to demonstrate with CSMC on implementation of the climate action identified under the CAP. A list of such pilots is given in Table 25-1. WRI India will provide technical support to CSMC on select pilot projects from the list. These projects will be selected based on further consultations with CSMC.

Table 25-1: Pilot projects identified under the CAP

Project	Brief
Traffic hotspot mitigation	• Chhatrapati Sambhajinagar has 24 traffic junctions identified as air pollution hotspots, such as Jalna Road junction, Akashvani, Amarpreet Hotel, and High Court junctions. • For a pilot, identify one junction and implement interventions such as traffic junction/ area improvement, stormwater management, and traffic island greening there. Monitor and track the air quality at monitoring stations,/ using environmental sensors.
Support in EV Adoption - EV transition & channelise EV component of XVFC	• Provide support in identifying projects/ components under the Fifteenth Finance Commission funds, and analyse potential areas for setting up public charging infrastructure and business models for the same. • Provide support in setting up and operationalising an EV Cell, similar to Mumbai and Pune
Ground Water – RWH, Recharge structures within gardens and other places	• Utilize the insights from the Vulnerability Assessment (VA), identify groundwater recharge potential areas (GWRP), especially in the north-eastern parts of the city which has witnessed reduced GWRP. In these areas, for a pilot project, identify a garden, develop a recharge structure as per the GSDA norms - Recharge shaft, Borewell, dug-well recharge etc. • RWH can be taken on priority in municipal buildings, schools, hospitals, etc.
Urban heat hotspot mitigation	• Select a heat hotspot area, such as Shahganj and Chikalthana, carry out activity mapping, develop further on the analysis done under CAP • Implement interventions such as greening, groundwater management, energy conservation, waste management, and cool roofs in informal settlements., and monitor with environmental sensors and CAAQMS
Rooftop solar on government buildings and utilities	• Map the existing solar roof-top projects on government buildings in the city, and identify business models to adopt solar rooftops. • Provide rooftop solar on ◊ Municipal buildings such as CSMC buildings, schools, and hospitals and for municipal utilities such as SWM facilities, WTPs, and STPs.
Mainstreaming climate actions in Chhatrapati Sambhajinagar DP	• Integrate the VA findings and insights into the city's Development Plan, specifically, incorporating the accessibility analysis to inform planning strategies for the establishment of gardens, playgrounds, fire stations and mobility infrastructure like bus stops, etc. • To mitigate the waterlogging hotspots: Provide provision in Development Plan for stilt construction, more open areas for water passage and percolation, mandatory use of paver blocks and other filter media, etc. • To increase the city's GWRP, preserve some of the areas around water bodies and greener areas to allow water percolation.
Climate Change Department	• Restructure Environment Department into Environment and Climate Change Department

Source: WRI India analysis

26. TRACKING PROGRESS

Implementation of the Chhatrapati Sambhajinagar CAP would be tracked by a monitoring, evaluation, and reporting framework that is crucial to ensure the effectiveness of the CAP. Monitoring will help establish a system that collects and monitors data and aligns with the progress of the CAP. This will also help the city authority make informed data-driven decisions in the future.

26.1 MONITORING

The monitoring the Chhatrapati Sambhajinagar CAP would be undertaken by the Research, Data and MER Cell.This cell would be led by Head - Research, Data and MER who in turn would be supported by the a Data and MIS officer and an Engagements officer. The Research, Data and MER cell will conduct a biennial updating of the GHG inventory and the climate risk and vulnerability. This cell will monitor the outcomes and progress of the Chhatrapati Sambhajinagar CAP against the targets set in the plan, report on a list of key performance indicators, and communicate progress against indicators. The cell would also be responsible to establish a mechanism to capture insights and lessons learned during the CAP implementation.

This Environment and Climate Action Cell (ECAC) within the Department of Environment and Climate Change would play a critical role in data management and research, coordinating with other interdepartmental and parastatal agencies, supporting the projects and programs that pertain to the environment, and monitoring the outcomes and outputs of the Chhatrapati Sambhajinagar CAP. Defining clear objectives and indicators is key to framing the MER. The major tasks are listed:

- A Monitoring, Evaluation and Reporting (MER) cell will be formed within ECAC.
- The GHG inventory and climate risk assessment will be updated every three years.
- Once in five years, it will monitor the progress of Chhatrapati Sambhajinagar 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 Chhatrapati Sambhajinagar CAP.

26.1.1 Key Performance Indicators

In order to track the progress of CAP implementation by various stakeholders, key performance indicators (KPIs) have been identified, which relate to the outcome indicators for each of the six priority action areas.

1. **Energy and Buildings**

Table 26-1: Key Performance Indicators for Energy and Buildings sector

Action Area	Key Performance Indicators
Increase in the proportion of renewable energy in the grid mix	• No. of MW renewable energy capacity installed within municipal buildings and utilities. • Percentage of renewable energy in the grid mix

Action Area	Key Performance Indicators
Promoting energy efficiency and conservation in buildings	• No. of ECBC- compliant buildings
Shifting towards energy efficient fuel switch in residential and commercial segments	• % of houses with clean fuel for heating, cooking purposes. • No. of low-income houses with clean fuel resources
Low carbon transition of industrial segments in the city	• No. of RE captive power plants in industries

2. Sustainable Mobility

Table 26-2 Key: Performance Indicators for Sustainable Mobility sector

Action Area	Key Performance Indicators
Public transport and access	• % achievement of service level benchmark for extent of supply availability of public transport • No. of public transport trips per capita • % change in mode share • % of population within 500m walk of public transportation option
NMT and parking management	• No. of kms of footpaths and cycling infrastructure • Percentage of mode share (disaggregated by gender and income level) • Percentage availability public parking services
Clean fuel transition in mobility	• % of CNG or electric vehicles in the city • % of CNG refill stations and electric vehicle charging stations in the city • Reduction in total annual fossil fuel consumption from transport
Urban freight management	• % of low-carbon road freight

3. Sustainable Waste Management

Table 26-3: Key Performance Indicators for Sustainable Waste Management sector

Action Area	Key Performance Indicators
Bioremediation and scientific closure of landfill	• Area of land recovered/ reclaimed
Waste minimization and reduced disposal	• Percentage reduction in waste generation per capita • Percentage increase in waste management efficiency (collection, processing, treatment), no. of green jobs created • Percentage reduction in open burning of waste

Action Area	Key Performance Indicators
Emissions from waste collection and transportation	• No. of clean fuel vehicles used in collection and transportation of waste
Sustainable C&D waste management	• Percentage efficiency of collection, treating, recycling and reuse of C&D waste

4. Urban Greening and Heat Mitigation

Table 26-4: Key Performance Indicators for Urban Greening and Heat Mitigation sector

Action Area	Key Performance Indicators
Increase in green cover, open spaces and permeable areas	• Per capita green space and open space (especially in vulnerable areas, low areas), volume of water retention capacity created (m3), tree census
Increase in accessibility to open spaces, parks, and gardens	• Percentage of residents within a 10-minute walk to a park/garden/ open space
Increase in biodiversity	• Functional biodiversity committee • Biodiversity index
Heat resilience	• No. of heat hotspots mitigated • Land surface temperature (across wards with different income levels)

5. Water Resources Management

Table 26-5: Key Performance Indicators for Water Resources Management sector

Action Area	Key Performance Indicators
Water supply access	• Percentage of households with piped connection, percentage of households receiving treated water • Non-revenue water loss
Groundwater Management	• No. of rainwater harvesting, groundwater recharge structures and the estimated quantity of water conserve
Resilient wastewater management systems	• Percentage of wastewater treated, recycled, and reused
Urban waterbody conservation	• No. of water bodies (rivers, lakes, streams, nehers, wells) restored and rejuvenated • Percentage improvement in water quality
Waterlogging and disaster resilience	• No. of incidences of flooding, population affected, hotspots mitigated (especially in low-income settlements) • Response time of Fire brigade

6. Air Quality

Table 26-6: Key Performance Indicators for Air Quality sector

Action Areas	Key Performance Indicators
Data and monitoring	• No. of monitoring stations (CAAQMS, manual) installed per year, no. of days above CPCB thresholds, % reduction in PM levels • $PM_{2.5}$ and PM_{10} targets achieved as per the NCAP
Air quality improvement	• Annual average for daily $PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3 concentration in µg/m3 • Emissions ($PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3) in key areas of the city (e.g., near hospitals, schools, low-income neighbourhoods, heat hotspots)
Community resilience and health	• Patients suffering from respiratory diseases (bronchitis, asthma, acute respiratory infection). Mortality and morbidity rates due to air pollution (disaggregated by gender and income level)

26.2 DATA MANAGEMENT

Data collection is the starting point of any project or plan. The data collection exercise undertaken to draft the Chhatrapati Sambhajinagar CAP was an extensive one. Data collection is not restricted to the gathering of data from various primary/secondary sources. The form in which the required data is stored has to be determined. In India, since the onset of the Smart Cities Mission, data catalogues have become streamlined but still a few gaps continue to exist. During the development of the CAP, various data gaps were 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.

1. Data for analysing climate risks: For the vulnerability assessment, socio-economic data and demographic differences at ward level were extracted from Census of India 2011, which is a decade old. Data on the impact of climate risks (such as heat and flooding) on employment, access to services, and livelihoods was accessed from Economic Census 2015 of Directorate of Establishments sample data, with the recognition that the conditions may have changed. The strategies and actions lised under CAP incorporates crucial aspects for improving the quality data by establishing better monitoring for data related to climate risks, such as pollutant concentrations, air temperature, rainfall variability (IMD station), and groundwater depletion.

Setting up dashboards at the municipal level for information gathering and dissemination **can be a starting point for data management.**

The use of open files can 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 GHG emissions inventory: For the GHG emissions inventory, scope 1 and 2 were studied for three sectors: solid waste and wastewater, energy, and buildings and transportation. Data pertaining to these three sectors requires co-ordination from various government departments, parastatal agencies as well as private players. The ECCC can play a role to gather 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 toolkits such as MVA, Swachh Survekshan, and Urban Outcomes framework.

3. Data for sectoral analysis can be within the scope of CSMC departments and parastatal agencies. The CAP has established baseline data for the identified sectors. However, there are certain segments where the baseline was not being set due to the lack of primary data. Monitored data to analyse climate risk assessment, such as air pollution, was available intermittently for some stations. This hinders the approach to project future risks, influence decisions, and incorporate climate resilience in projects, proposals, and infrastructure. The ground water data (geo-codded locations of borewells, tube wells, 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 and coal as fuel needs to be accounted for, which can be under the purview of the District Collector Office along with Environment department at the CSMC. There are multiple such data points as a part of the sectoral analysis under CAP. Apart from the monitored data, certain sector specific data and reports were not available during the drafting of the CAP, such as the Comprehensive Mobility Plan, City Development Plan, tree census, geospatially mapped slum data, and locations of groundwater resources. This particularly poses a challenge in evaluating sectoral deficiencies and adopting a nuanced approach to sectoral assessment.

In the process of making Chhatrapati Sambhajinagar 'DataSmart', it is recommended that CSMC integrates data management tools and ensures effective data-driven decisions in proposals and projects. The proposed Research, Data and MER Cell in CSMC can begin working towards this end and monitor the progress.

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 newly formed Department of Environment and Climate Change's Research, Data and MER Cell. This cell's work would be supported by the Head of Departments, Chief Engineer, Garden Superintendent, Executive Engineers of internal departments of the CSMC, 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 CSOs, NGOs, and research agencies. This collaborative effort aims to enhance the effectiveness of the Chhatrapati Sambhajinagar 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.

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: Installing 22 MW of solar PV by 2030, 148 MW by 2040 and 240 MW by 2050 for municipal buildings and utilities			
Output Indicator	**Target (year)**	**Current progress (year)**	**Evaluation criteria**
% of power generated from solar PV	22 MW (2030)	18 MW (2027)	Electricity bills and energy audits of the municipal buildings and utilities

26.4 REPORTING

The Research, Data and MER Cell, under the newly formed Department of Environment and Climate Change, would be responsible for monitoring the progress of the CAP. The Climate Cell, which would be responsible for monitoring Chhatrapati Sambhajinagar 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 (part of the Department of Environment & Climate Change) will prepare the Chhatrapati Sambhajinagar 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 list of indicators proposed for aggregate city-level progress assessment are listed 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 Chhatrapati Sambhajinagar CAP, which would result in emission reduction
- Climate risks and VA: Monitoring of air temperature levels, air pollution concentration, and the impact of heat and increased air pollution on people; assessment of rainfall variability, depletion of ground water and water shortages
- GHG inventory updated and vulnerability assessment of the city undertaken every three 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 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 Environment and Climate Change in CSMC. It would be the responsible for updating the progress on the KPIs on an annual basis. A sample of the proposed format is give in Table 26-9.

Table 26-9: Proposed format for annual updating of KPIs

Sr. No	KPIs	Progress through the years				
		% (2024- Year 1)	% (2025- Year 2)	% (2026- Year 3)	% (2027- Year 4)	% (2028- Year 5)
1.	Procurement of e-buses					
2.	Installation of solar PV in public buildings					
3.	Increase access to public spaces					

Photo Credit: WRI India

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 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.

Technical solutions alone cannot solve the challenge of climate change. Instead, it requires integrated efforts on the part of the entire society as well as world. In India, the state of Maharashtra is committed to achieving net zero by 2050, with Mumbai leading the way towards achieving a reduction of GHG targets through the strategies and actions in Mumbai Climate Action Plan (MCAP). The Chhatrapati Sambhajinagar CAP serves as a roadmap of CSMC's commitment to combat climate change and to increase the climate resilience of the city.

Chhatrapati Sambhajinagar CAP aligns with the policies and plans developed at the national, state, regional, and city levels. The CSCAF, NCAP, Development Plan, etc. have provided a strong base for planning the current and future strategies related to climate action in the city. Moreover, the institutional structures and financing mechanisms in Chhatrapati Sambhajinagar CAP are aligned to work towards policy reforms and regulatory amendments to mainstream climate actions with CSMC's planning ethos.

Climate-resilient development emerges from explicitly bringing together actions to adapt to climate change, with actions to reduce GHG emissions, in order to advance sustainable development. The consultative processes conducted for identifying climate and environmental risks, presenting the findings from the GHG Inventory and the sectoral actions and strategies included participation from leadership within CSMC and various departments, external stakeholders, parastatal agencies and sectoral experts. However, the most important stakeholders are the residents of the city and their willingness to act at a personal, household or community level to help achieve the city's net zero targets, thus promoting sustainable development.

Annexures

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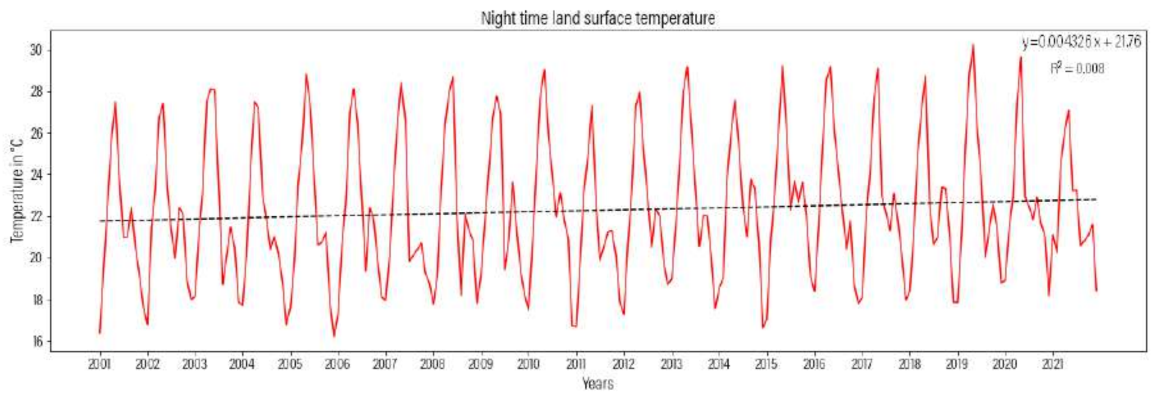
ANNEXURE 1: VA PROCESS METHODOLOGY

Annexure 1-1: Urban Heat Risk- Assessment parameters and attributes

Parameter	Vulnerability	Methodology	Data Source
Air temperature trend	Positive relation	Annual Air Temperature Trend	NCEI, 1975-2021
Annular temperature deviations	Positive relation	Deviations of annual average temperatures from the baseline temperature (1981-2010)	NCEI, 1975-2021
Extreme heat events	Positive relation	Heatwaves	NCEI, 1975-2022* (up to July*)
Extreme heat events	Positive relation	Heat index classification	NCEI, 1975-2021
Land Surface Temperature	Positive relation	Urban Heat Island • Urban-rural comparison • Night-time LST trend	MODIS LST Product, 2001-2021
		Average land surface temperature, seasonal variations, LST hotspots, relationship with vegetation and roofing material.	Landsat 8, 2019-2021; Census 2011

Source: WRI India analysis

Annexure 1-2: Long-term LST trend over Chhatrapati Sambhajinagar city-core



Source: WRI India Analysis 2022, MODIS, CSMC

Annexure 1-3: 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 1-4: 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 1-5: Duration of Extreme Rainfall Events between 1970 and 2020, Chikalthana, Chhatrapati Sambhajinagar

Category/Duration	1 Day	2 Days	3 Days	4 Days	5 Days
Rather Heavy (35.6-64.4 mm)	194	10	0	0	0
Heavy (64.5- 124.4 mm)	80	4	0	0	0
Very Heavy & Extremely Heavy (>124.5 mm)	7	0	0	0	0

Source: WRI India using meteorological data from IMD

Annexure 1-6: 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 symbolised 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 1-7: Evolution of Stage of Groundwater Development in Chhatrapati Sambhajinagar District

Year	2009	2013
Administrative Unit	Stage of GW Development	
Chhatrapati Sambhajinagar	66.92	76.34
Phulambri	84.34	83.24
Gangapur	76.59	84.75
Kannad	56.65	71.89
Khuldabad	54.66	65.13
Paithan	49.00	71.97
Sillod	57.55	74.27
Soygaon	34.88	65.76
Vaijapur	72.65	83.76
District Total	91.99	75.92

Source: CGWB publication 2019

Annexure 1-8: Indicators based on demographic context

Indicator	Description	
Literacy	Definition	Literacy indicator consists of overall effective[157] literates, effective female literates, and access to educational institutes like schools, for preliminary educational facility.
	Rationale For Selection	Literacy is important for raising awareness regarding climatic hazards and building resilience capacities for preparedness and 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) offer development of better adaptive capacities by enhancing the opportunity to access stable jobs thereby increasing socio-economic stability and decreasing one's sensitivity to climatic hazards. Disaster responsiveness, knowledge of saving mechanisms, etc. is observed to be better in educated individuals/ families.
Gender Profile	Definition	Gender profile is calculated as sex ratio.
	Rationale For Selection	Disproportionate impact on women and girls with increased care-giving tasks after the disaster, unequal access to resources and services, plays a crucial role for women in disaster response.
Social Composition	Definition	The percentage of Scheduled Castes (SC) and Scheduled Tribes (ST) population is estimated to understand the extent of social vulnerability based on caste.
	Rationale For Selection	Caste also serves as an equity indicator to identify underserviced neighborhoods. SC and ST populations potentially have higher exposure, higher sensitivity and lower adaptive capacity

Annexure 1-9: 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[158]
	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 10 minutes of walking distance using service area polygons around school locations	Census 2011, Education Department (CSMC)2022
Gender Profile	Sex Ratio	(Total female population)/ (Total male population) *1000	Ward level: Census 2011 - Primary Census Abstract[3]
Social Composition	Percentage of SC and ST population	(Total SC population + Total ST population) / (Total Population) *100	

Annexure 1-10: Indicators relative to socio-economic aspects

Indicator	Description	
Access to Information	Definition	This indicator is measured as a function of ownership of a phone (landline, mobile and both), computer with internet, television and/or radio/transistor. Access to these assets indicates access to related information/ news/ broadcasting significantly reducing the vulnerability.
	Vulnerability Rationale	Census 2011 house listing and housing data have been used for ward-level analysis to understand access to assets that remain important for preparedness, response during a disaster and post-disaster relief measures. The percentage of households with access to various assets in the vertical axis has been visually represented in the form of a bar chart, corresponding to Census wards on the horizontal axis. Given the potential change in asset ownership over the last decade, this analysis does not correlate it to any particular hazard. It is being used as an indicative statistic with the assumption that ownership of these devices improves one's adaptive capacity to a climatic hazard.
	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.

Indicator	Description	
House Ownership	Definition	Home ownership is understood based on the census data that indicates households which own the house they live in.
	Vulnerability Rationale	Higher ownership increases the ability to take up adaptation measures against climatic hazards thereby reducing vulnerability. Census 2011 house listing and housing data have been used here for ward-level analysis to evaluate the house ownership status in Chhatrapati Sambhajinagar. This analysis is limited to house ownership, i.e., using the Census data. It does not consider rental policy and tenure mechanisms in the city due to their different forms, regulations and non-spatial nature. This is also an indicative statistic at the ward and city level and does not make correlations to any climate hazard.
	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 1-11: 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 1-12: 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 at	Ward Level: Census 2011 HH14 table– Ownership Status

Annexure 1-13: 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" having limited constructional durability are considered as vulnerable.
	Vulnerability Rationale	Census 2011 house listing and housing data have been used for Census ward-level analysis to understand the percentage of households in each ward with predominant roofing material, which is presumably considered as 'Temporary'1 as it has limited constructional durability, especially during extreme weather events.
	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.
Access to public recreational spaces	Definition	Recreational spaces include parks, gardens, playgrounds and maidans affiliated to the government and are freely accessible by the public and are non-ticketed.
	Vulnerability Rationale	Public recreational spaces, such as parks, gardens and playgrounds or *maidans* act as cushions to floods and to 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 for any climate-resilient city.
	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 risks associated with urban flooding. Green areas also play a pivotal role in reducing the 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 are more vulnerable. During slow onset events like extreme summers, properly shaded open spaces offer weaker and more exposed sections of society like those living in informal settlements, houseless population, daily wage earners with necessary respite from extreme heat stress.

Annexure 1-14: House Condition — Assessment parameters and attributes

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 1-15: House Condition — Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with > 32.5°C LST overlaid to ward areas	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation, Census 2011
Urban Flood Risk**	Positive	50 m buffer zone overlaid on wards with highest share of 'temporary' roof households	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation

**Urban heat risk is assumed for areas with LST >32.5°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021. **Using a buffer of 50m from the flood hotspots.*

Annexure 1-16: 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 or maidans. Ped shed of 10 minutes walkable distance was considered for parks, institutional playgrounds or maidans.	Existing Land Use (2021) from Chhatrapati Sambhajinagar Municipal Corporation, World Settlement Footprint 2019, Census 2011

Annexure 1-17: Access to Public Recreational Spaces — Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk	Positive	Area with >32.5°C LST overlaid to gridded population density with limited access to public recreational spaces (unserviced population)	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation, World Settlement Footprint 2019, Census 2011
Urban Flood Risk	Positive	A 50 m buffer zone overlaid to gridded population density, having access to public recreational spaces.	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation, World Settlement Footprint 2019, Census 2011

Annexure 1-18: Indicators relative to Infrastructure and Service Aspect

Indicator	Definition	
Access to Drinking Water	Definition	Access to drinking water is calculated as a function of source of drinking water and its proximity. It is shown by illustrating wards which lack access to drinking water sources within premises and treated drinking water facilities
	Vulnerability Rationale	Using Census of India 2011 house listing and housing data, ward-level assessment and mapping are carried out to evaluate the percentage of households by each ward. For sources of drinking water, households with drinking water sources from untreated tap water, covered wells, uncovered wells, handpump, tube well/borewells, springs, river/canals, tanks/ponds/lakes and other sources have been combined to obtain the percentage of households lacking access to treated drinking water. For evaluating the proximity of drinking water, households with latrines near and away from premises have been aggregated to obtain the percentage of households with drinking water sources outside premises.
	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 cuts 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 increases vulnerabilities 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 shown by illustrating wards which lack access to latrine availability within premises, lack access to treated sewage disposal, wastewater disposal methods and serviceable/ unserviceable slum area of public toilets.
	Vulnerability Rationale	Census 2011 house listing and housing data have been used for ward-level assessment to assess the percentage households by each ward. This indicator is divided into four separate parameters namely, proximity of latrine, sewage, and waste disposal methods and the access to public toilets (with respect to informal settlements). Each of the parameters has been mapped by aggregating two or more relevant data fields from Census 2011 to provide a robust view
	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, escalating air pollution and can 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, having access to public toilets provide sanitation facilities to them. However, during extreme event like that of flood or heat, physical access to such services gets restricted making them more vulnerable.

Indicator	Definition	
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 shown by illustrating wards which lack access to these non-polluting fuels.
	Vulnerability Rationale	Using Census 2011 house listing and housing data, ward-level assessment and mapping are carried out to evaluate the percentage of households by each ward using polluting fuels such as firewood, crop residue, cow dung cake, coal/lignite/ charcoal, kerosene, others for cooking purposes. It impacts indoor air quality first, hence this indicator has not been mapped against a specific climate-induced hazard. It is used as an indicator to represent the quality of living environment and identify wards with population that are generally more vulnerable given their exposure to a more polluted indoor space. Pradhan Mantri Ujjwala Yojana (PMUY) was launched in 2016 with the aim of promoting non-polluting fuel such as LPG in houses. The state of Maharashtra has seen per capita consumption increase from 3.17 refills in 2019- 2020 to 4.19 refills in February 2022[159]. In the district of Chhatrapati Sambhajinagar, altogether 154116 LPG connections have been released including Ujjwala 2.0 connections[160].
	Vulnerability to Climate-Induced Hazards	• Several low-income households continue to rely on firewood, kerosene, and others 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, 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	It is shown by illustrating wards which lack access to the electricity grid and is estimated based on non-usage of electricity as the main source of lighting.
	Vulnerability Rationale	Census 2011 house listing and housing data have been used for ward-level assessment and mapping, to evaluate the percentage of households without electricity as the main source of lighting. Since, electricity is provided by Maharashtra State Electricity Distribution Co Ltd (MSEDCL), majority of Chhatrapati Sambhajinagar's households fare well on this indicator. Hence, very few households are vulnerable due to lack of power/electricity and therefore this section does not make specific correlations with any climate induced hazard. Though as per the Census 2011, only 0.1% of households have solar energy as main source of lighting, renewable energy has received impetus from state government recently.
	Vulnerability to Climate-Induced Hazards	Lack of access to electricity as a 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 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 to improve household income. Women and children also have access to these networks, allowing them to opt for better jobs and education opportunities, and therefore 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, 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 captive 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 to 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 1-19: 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 1-20: Access to Drinking Water – Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk	Positive	Area with > 32.5°C LST overlaid to ward areas	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation
Urban Flood Risk	Positive	50 m buffer zone overlaid to ward areas	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation

Annexure 1-21: 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 1-22: 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	Chhatrapati Sambhajinagar Municipal Corporation
Vulnerability to Climate Induced Hazard			
Parameter Mapped	**Relationship to Vulnerability**	**Method Used**	**Data Source**
Urban Flood Risk[3]	Positive	50 m buffer zone overlaid to ward areas	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation

Annexure 1-23: 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 1-24: Access to Public Transit (Access to Bus Stops) – Assessment Parameters and Attributes

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	Chhatrapati Sambhajinagar Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

Annexure 1-25: Access to Public Transit - Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Flood Risk	Positive	50 m buffer zone overlaid to gridded population density with access to bus stops	Chhatrapati Sambhajinagar Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011

Annexure 1-26: 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	Chhatrapati Sambhajinagar Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011, Google API

Annexure 1-27: Access to Emergency Healthcare services- Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with >32.5°C LST overlaid to gridded population density with limited access to hospitals (unserviced population)	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation 2020, World Settlement Footprint 2019, Census 2011
Urban Flood Risk**	Positive	50 m buffer zone overlaid to gridded population density with access to hospitals	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation 2021, World Settlement Footprint 2019

**Urban heat risk is assumed for areas with LST >32.5°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 -2021 **Using a buffer of 50m from the flood hotspots.*

Annexure 1-28: Access to Emergency Fire Services – Assessment Parameters and Attributes

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	Chhatrapati Sambhajinagar Municipal Corporation 2021, World Settlement Footprint 2019, Census 2011

Annexure 1-29: Access to Emergency Fire Services – Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Heat Risk*	Positive	Area with >32.5°C LST overlaid to gridded population density with limited access to fire stations (unserviced population)	Landsat 8, Chhatrapati Sambhajinagar Municipal Corporation 2021, World Settlement Footprint 2019, Census 2011
Urban Flood Risk**	Positive	50 m buffer zone overlaid to gridded population density with access to fire stations	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation 2020, World Settlement Footprint 2019

**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 **Using a buffer of 100m from the flood hotspots. (No. of slums not being accessible by any public toilet within 5 minutes walking distance/ Total no. of slums) *100*

Annexure 1-30: Access to Relief Shelters – Assessment Parameters and Attributes

Parameter Mapped	Relationship to Vulnerability	Method Used	Data Source
Access to Relief Shelters	Negative	Population coverage within 10-minute walkable service area polygons around relief shelter locations	Chhatrapati Sambhajinagar Municipal Corporation 2021, World Settlement Footprint 2019, Census 2011

Annexure 1-31: Access to Relief Shelters – Vulnerability to Climate Induced Hazard

Parameter	Relationship to Vulnerability	Method used	Data Source
Urban Flood Risk[3]	Positive	50 m buffer zone overlaid to gridded population density with access to relief shelters	Census 2011, Chhatrapati Sambhajinagar Municipal Corporation 2021, World Settlement Footprint 2019

Assumptions related to the Vulnerability Assessment to Census 2011 data:

1. Assumptions for Vulnerability Assessment: Demographic context:

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).

2. Assumptions for Vulnerability Assessment: Accessibility Analysis- Socio-economic aspects:

Assumption: Local news, weather updates are broadcast on radio, telecast, can be accessed via the internet or circulated via mobile phone SMS.

Caveat - Since this data is from 2011, population owning mobile phones is lower than 2021. No data is available for print media in Census 2011.

Caveat: While ownership as a single parameter cannot illustrate exposure or sensitivity as it depends on the condition and location of the house, this indicator only includes tenure. Cases of displacement and damage to houses caused due to a climate-induced hazard are not included.

3. Assumptions for Vulnerability Assessment: Accessibility Analysis- Physical Environment Aspects

Based on Census data, the households having the following roofing material have been clubbed under households with temporary roofing as these materials are most vulnerable to impact of extreme weather events such as heavy rainfall, flooding or heat stress. Roof material type: Grass/ Thatch/ Bamboo/ Wood/Mud etc., Plastic/ Polythene, Stone/ Slate, and Galvanized Iron/Metal/ Asbestos sheets etc

Chhatrapati Sambhajinagar District, Maharashtra Table H-14 – Table on Houses, Household Amenities and Assets, Office of the Registrar General & Census Commissioner, India. Census India-2011, https://censusindia.gov.in/census.website/data/census-tables. Urban heat risk is assumed for areas with LST >32.5°C. This has been calculated by taking mode of average annual temperature from cloud free thermal band images from Landsat 8 within 2019 –2021. Using a buffer of 50m from the flood hotspots.

Caveat: 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).

4. Assumptions for Vulnerability Assessment: Accessibility Analysis- Infrastructure and Service Aspects

Assumption: Tap water from treated source is assumed to be a safe source for drinking water. Hence, the other sources listed in H-14 table of Census 2011 are considered to untreated drinking water source. Spatial data regarding frequency, quantity and coverage of supply network are unavailable and hence not considered.

Assumption: Kitchen is assumed to be located inside the premises for this analysis.

Assumption: Access to Public Toilets is mapped using service area polygons that are created for analyzing access within 500 metres. It has been considered based on pedestrian accessibility standards within 5 minutes walkable distance (Bernard van Leer Foundation, 2018).

Assumption: Off-grid sources of electricity such as solar energy are not accounted for in this analysis.

Assumption: Analysis includes both operational and proposed bus stops. Access to Bus stops is mapped using service area polygons that are created for analyzing access within 500 metres. It has been considered based on pedestrian accessibility standards within 5 minutes walkable distance (Bernard van Leer Foundation, 2018)

Caveat: Affordability, reliability and quality of service are not included in this analysis.

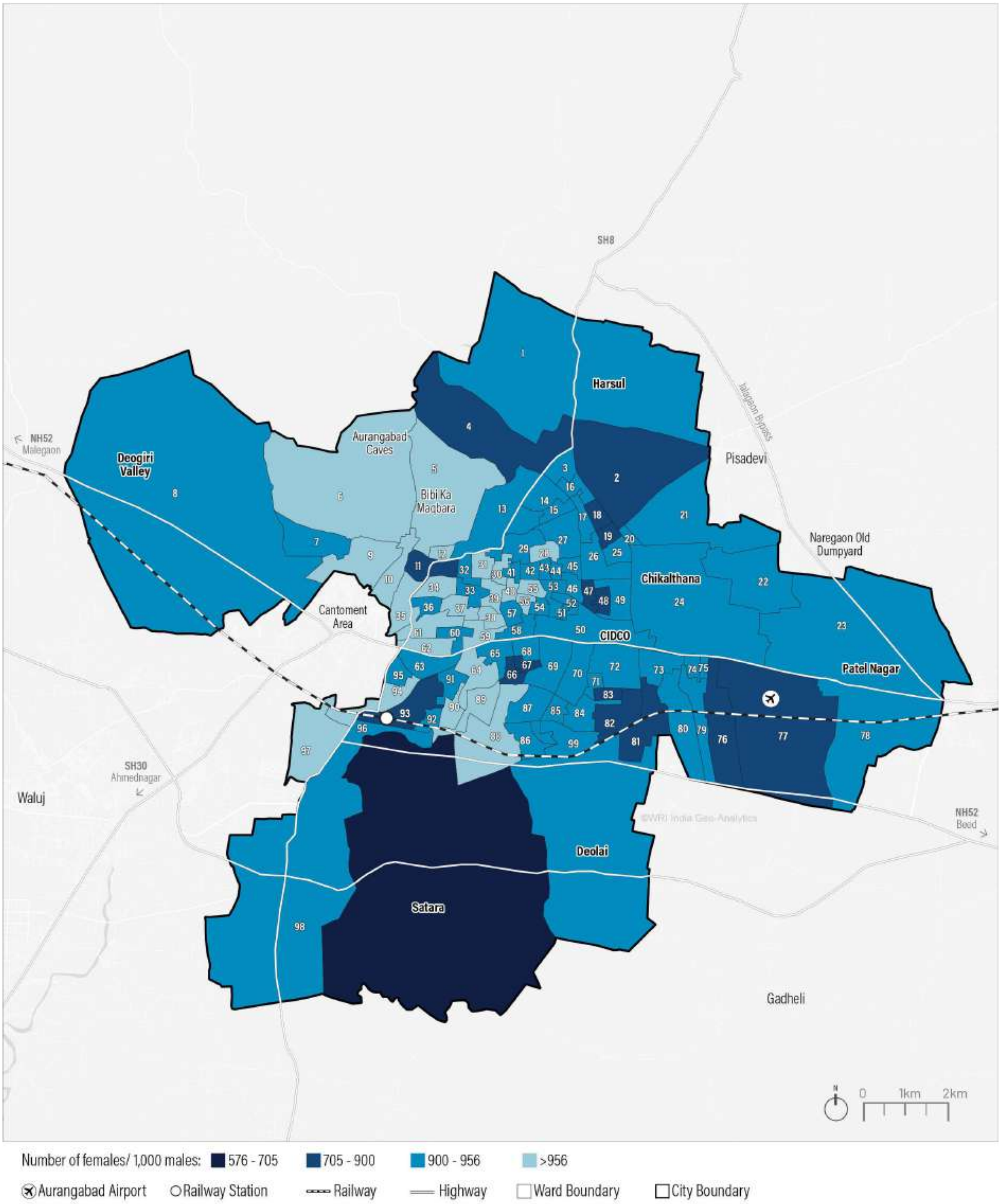
Assumption: Access to Hospital is mapped using service area polygons that are created analyzing access within 4 km. It has been obtained considering average primary response time of 8-10 minutes (Ministry of Road Transport & Highways) and 30 kmph average speed on city road network (Urban Mass Transit Company Limited, 2016)

Caveat: The real-time traffic is not accounted for in the city level analysis while in live circumstances it does impact the time taken to reach the destination. Affordability, quality of service, medical staff to patient ratio are not included in the city-level access analysis. Dental Hospitals, Eye Hospitals, Clinics are excluded.

Assumption: Analysis at the city level includes vehicular access from the location of fire stations based on a constant speed assumed at 30 kmph (Urban Mass Transit Company Limited, 2016) within 5 -7 minutes response time standard (Ministry of Home Affairs). Variation in traffic conditions, road conditions and capacity of individual fire stations are not accounted for.

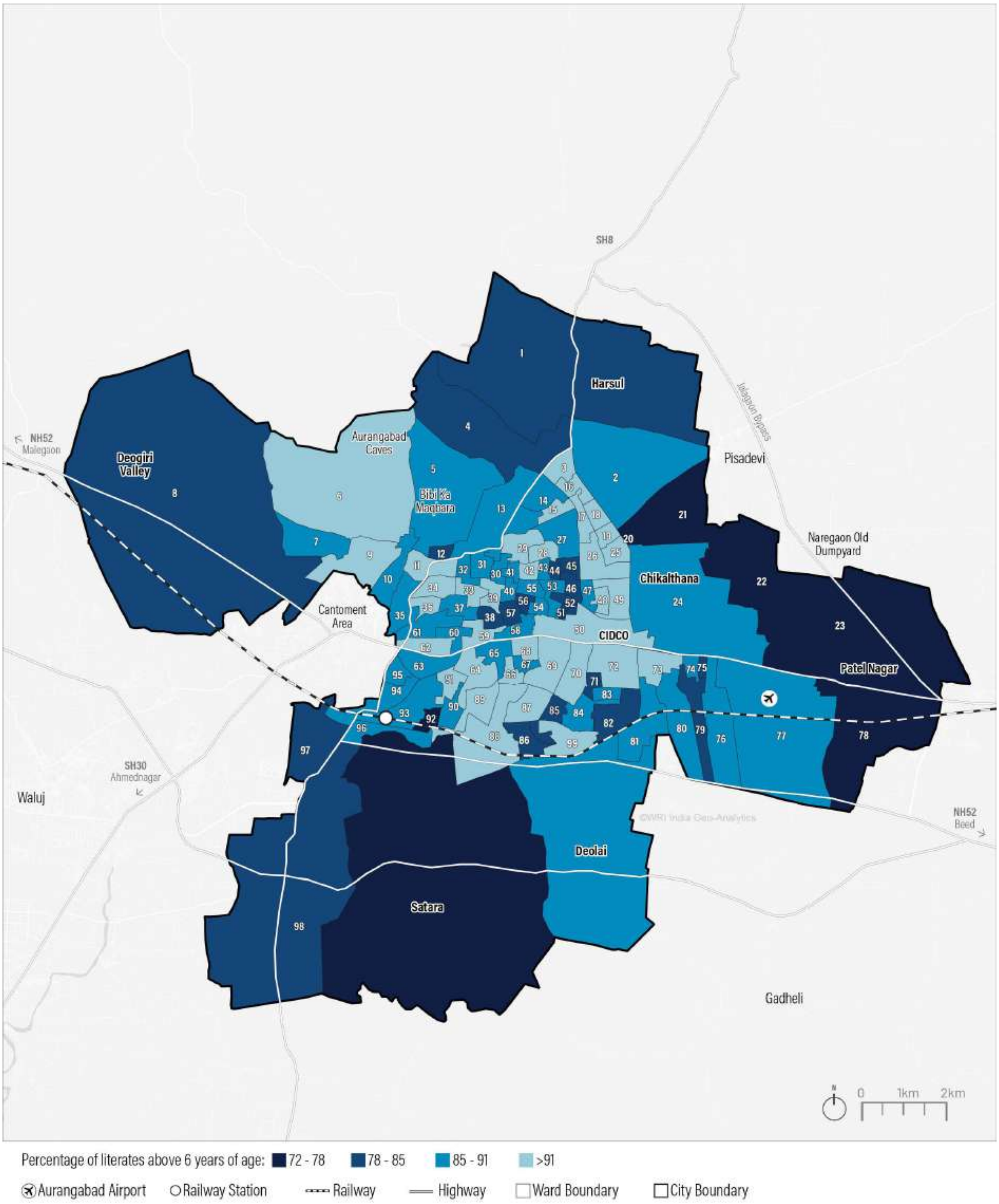
ANNEXURE 2: MAPS & FIGURES

Annexure 2-1: Gender Profile



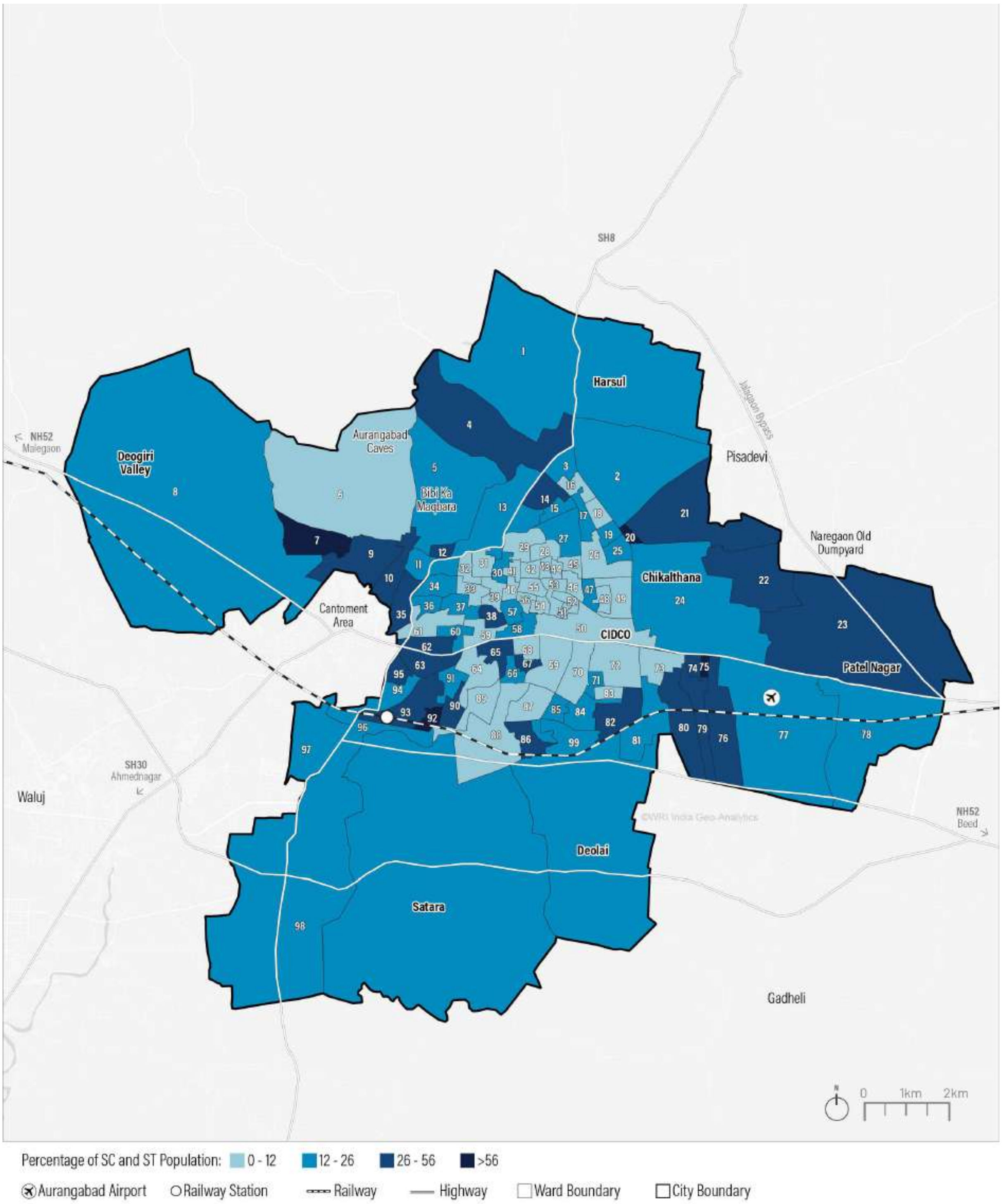
Source: WRI India using Census 2011

Annexure 2-2: Effective Literacy Rate



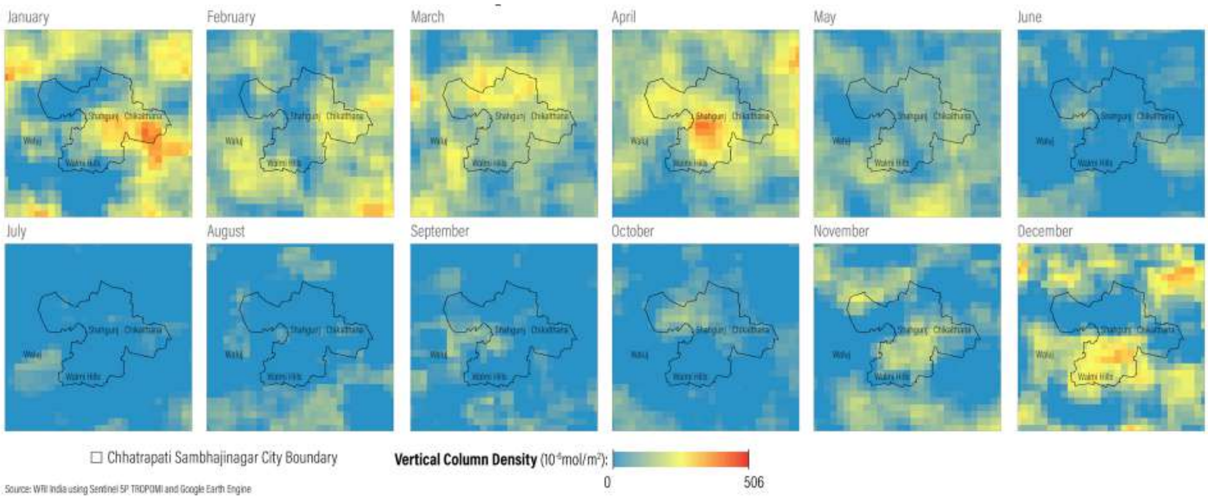
Source: WRI India using Census 2011

Annexure 2-3: Social Composition



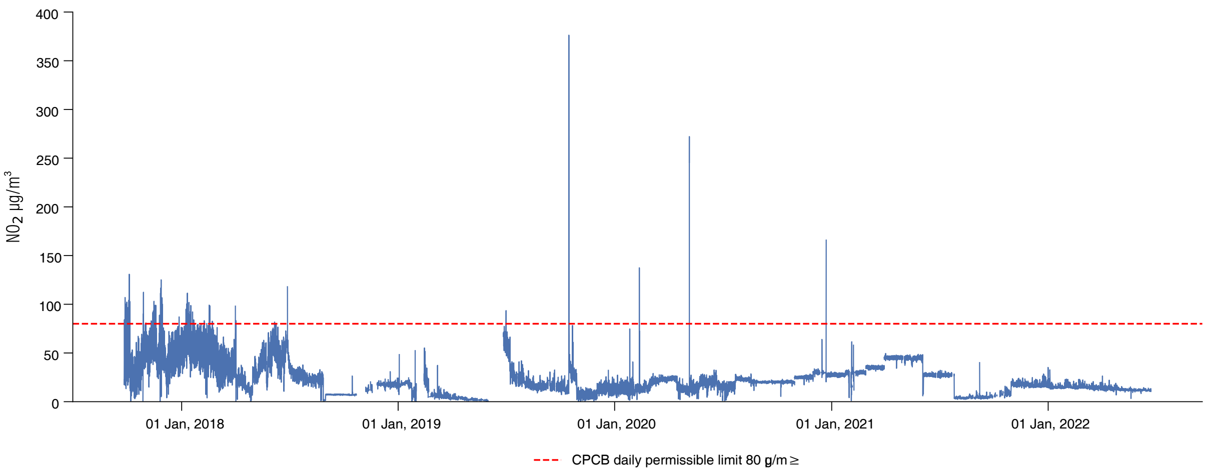
Source: WRI India using Census 2011

Annexure 2-4: Monthly average concentrations of SO_2 in Chhatrapati Sambhajinagar during 2019-2021



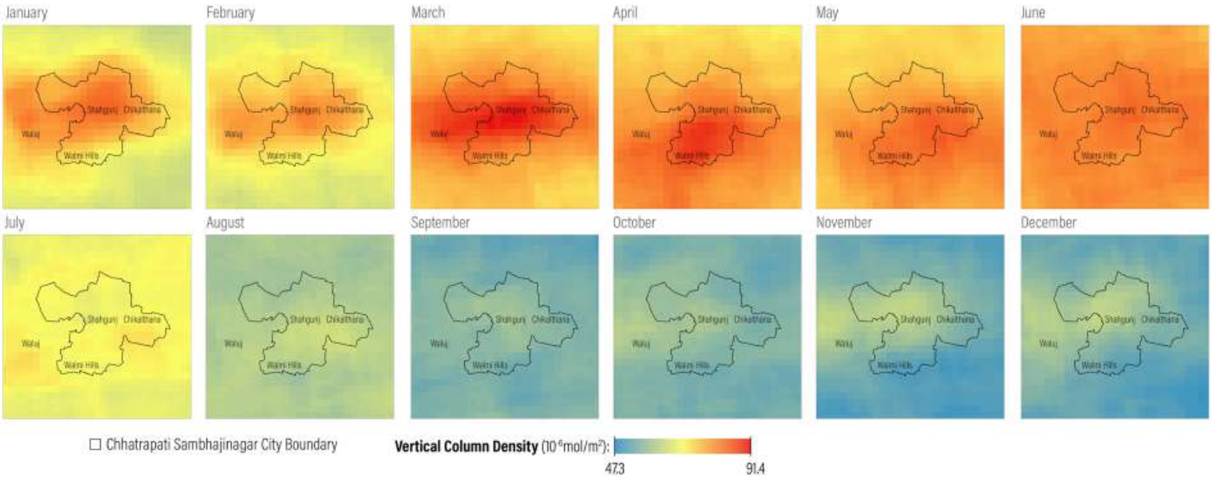
Source: WRI India using Sentinel data

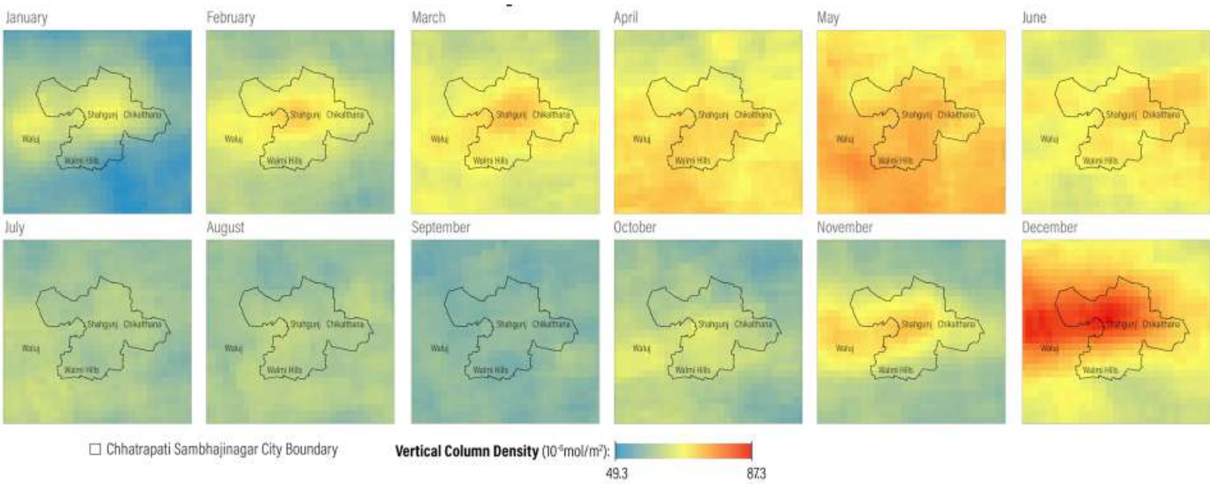
Annexure 2-5: Hourly Nitrogen Dioxide (NO2) concentrations at the Waluj MIDC air quality monitoring station between September 2017 and June 2022

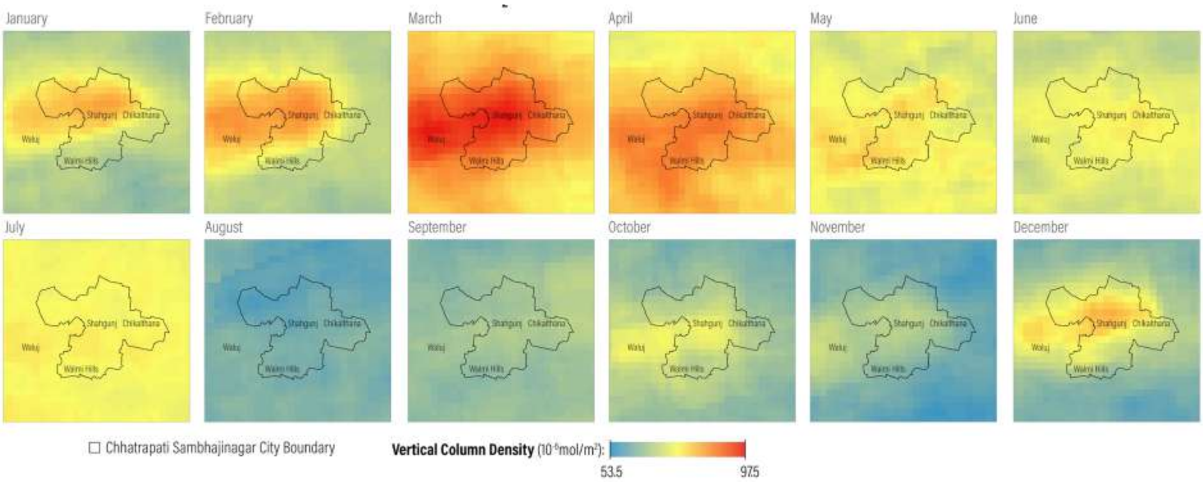


Source: CPCB

Annexure 2-6: Monthly average concentrations of Nitrogen Dioxide (NO2) in Chhatrapati Sambhajinagar during 2019-2021

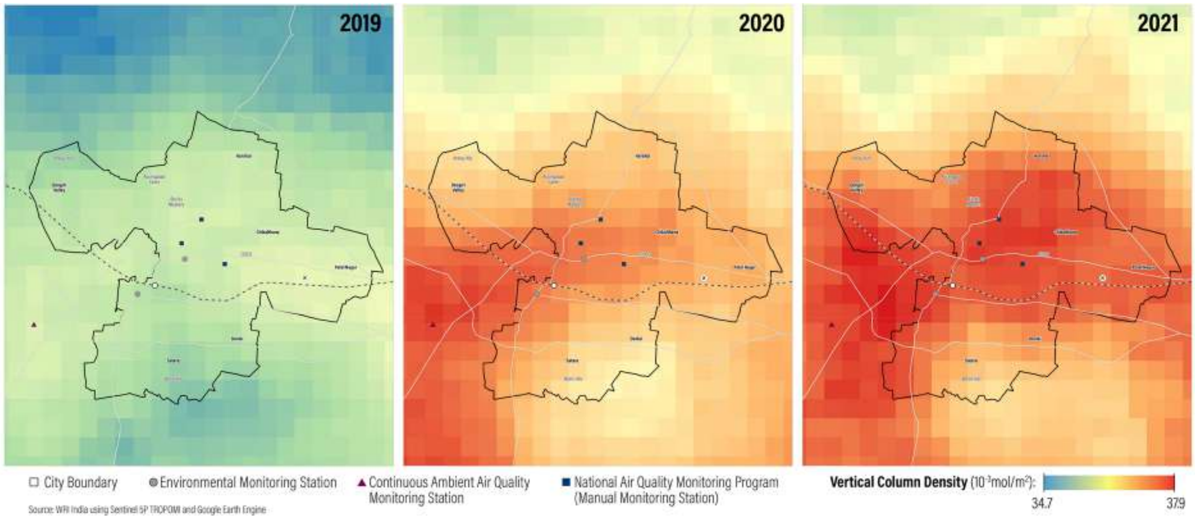






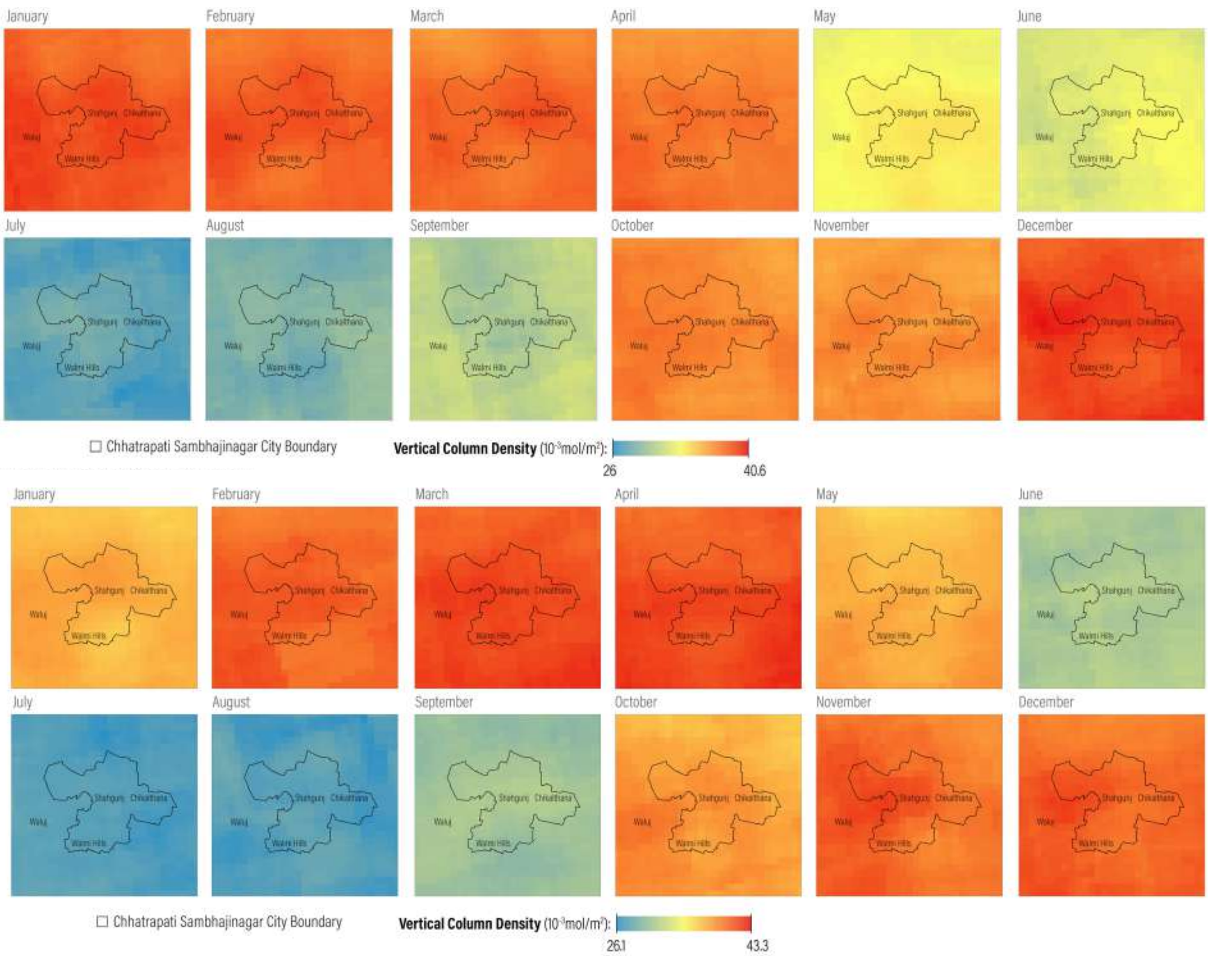
Source: WRI India using Sentinel data

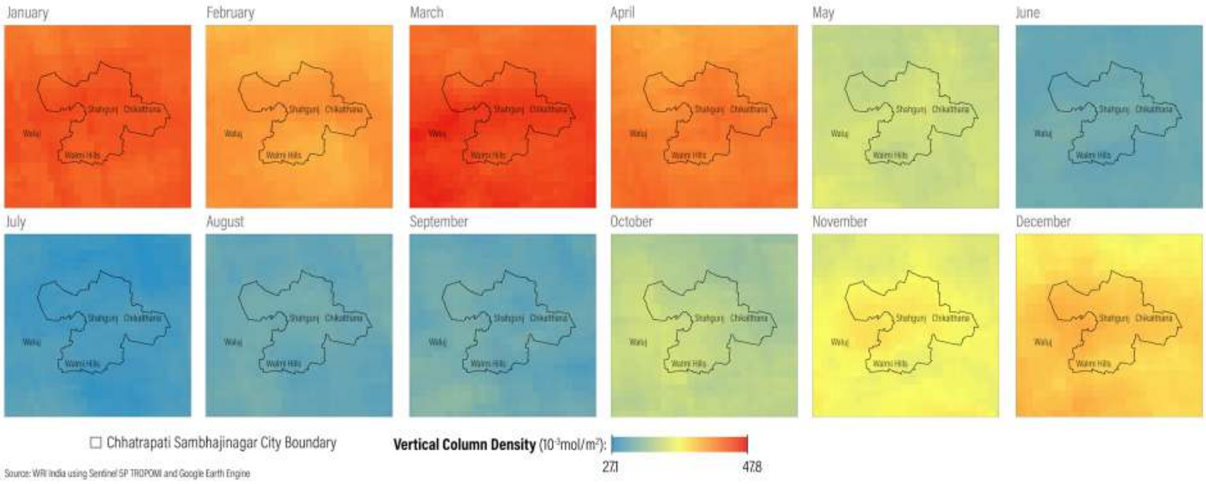
Annexure 2-7: Annual average concentrations of Carbon Monoxide (CO) in Chhatrapati Sambhajinagar from 2019- 2022



Source: WRI India using Sentinel data

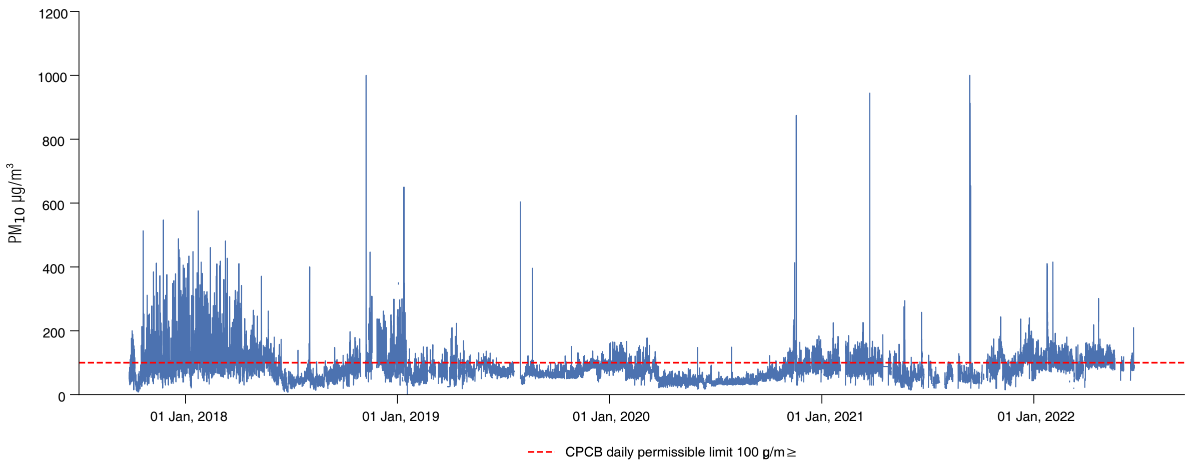
Annexure 2-8: Monthly average concentrations of Carbon Monoxide (CO) in Chhatrapati Sambhajinagar from 2019-2021





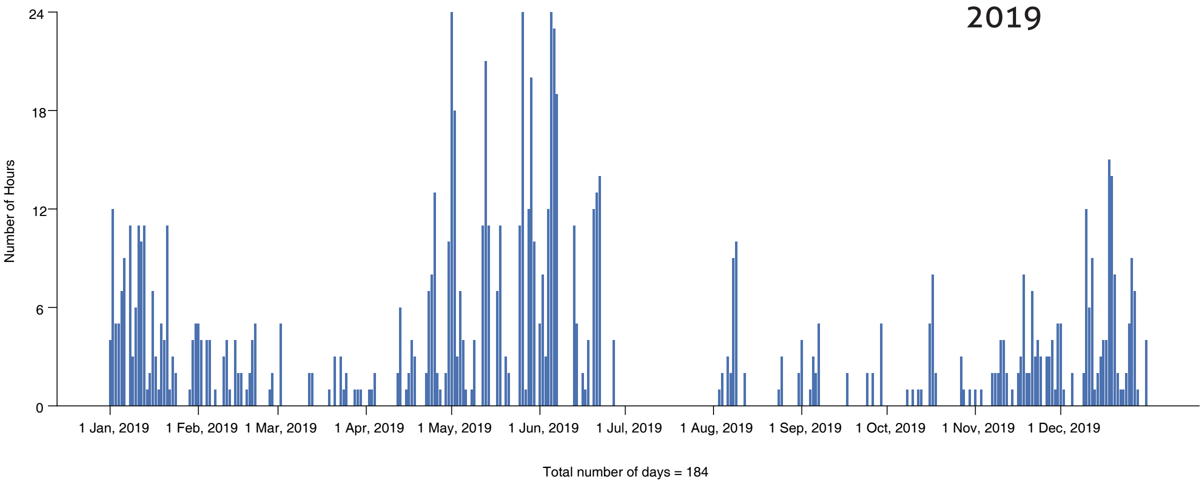
Source: WRI India using Sentinel data

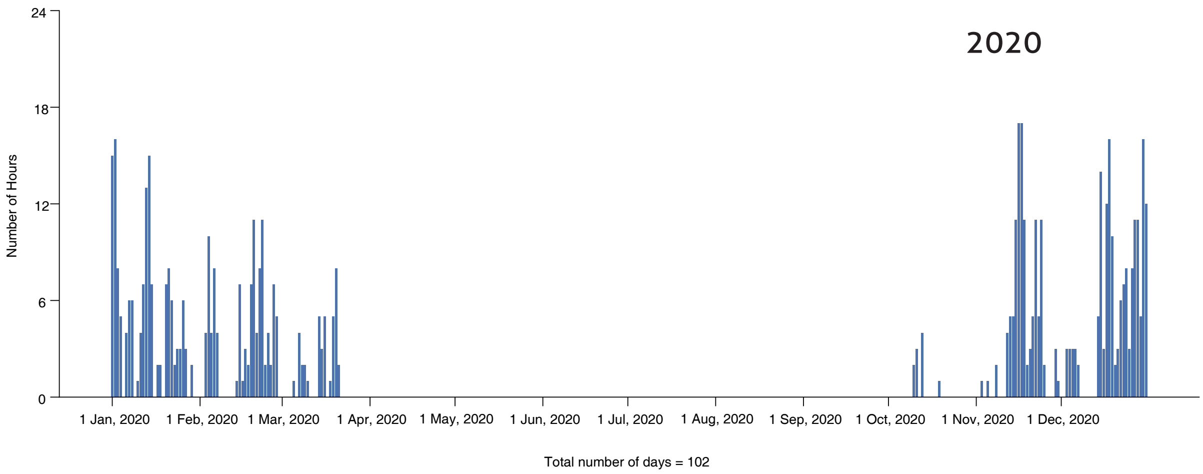
Annexure 2-9: PM_{10} concentrations at the Waluj MIDC AQMS between Sept 2017 - Jun 2022



Source: CPCB

Annexure 2-10: CPCB threshold crossings of PM2.5 in Chhatrapati Sambhajinagar in 2019 (top) and 2020 (bottom)

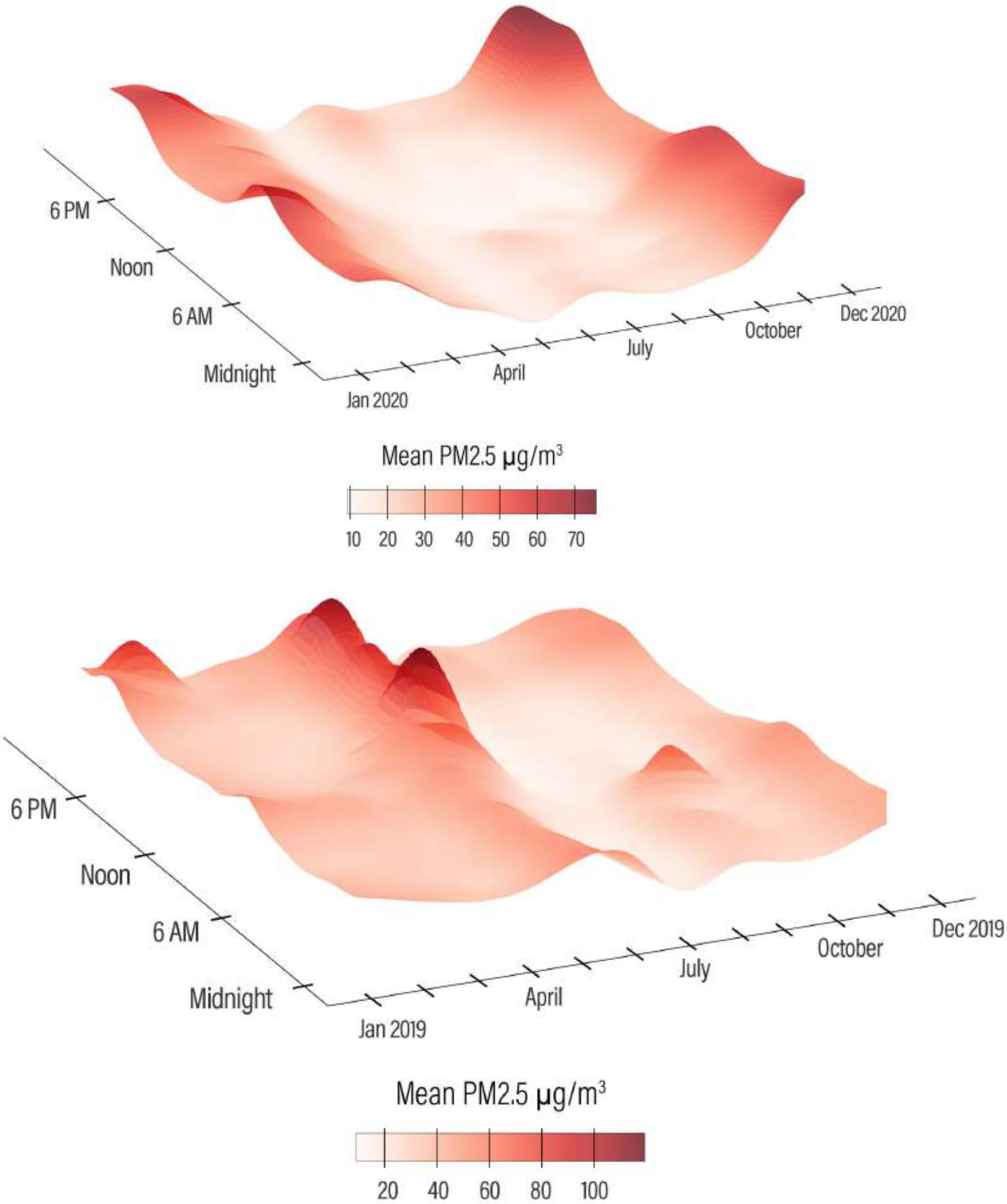




Source: WRI India analysis using CPCB data

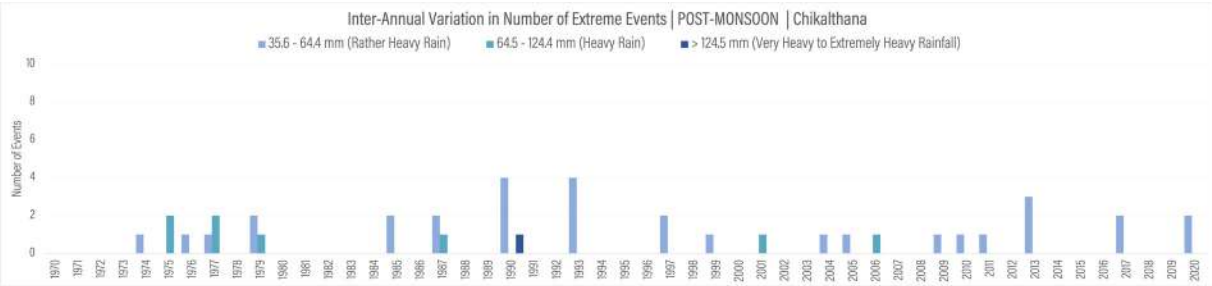
A comparison of graphs for 2019 and 2020 in Annexure 2-10 shows that the number of days when $PM_{2.5}$ levels breached the annual limit was 184 in 2019 and 102 in 2020. This decrease reflects the lockdown period in 2020. While 2019 monsoons had numerous peaks, 2020 had a more conspicuous gap from late March to mid-October.

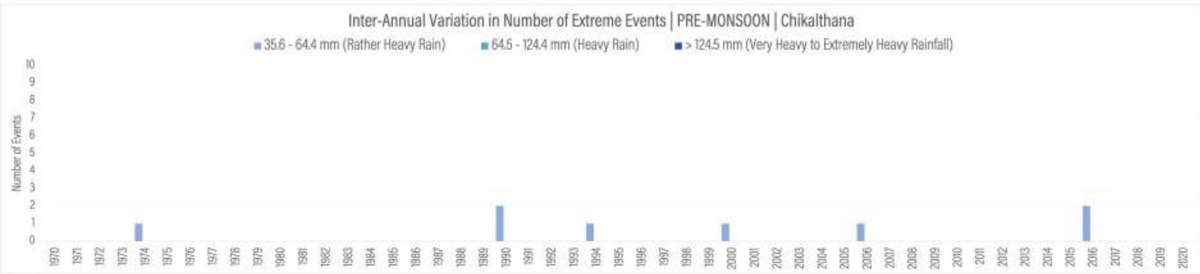
Annexure 2-11: Timeseries of monthly-hourly average concentration of PM2.5 in 2019 (top) and 2020 (bottom)

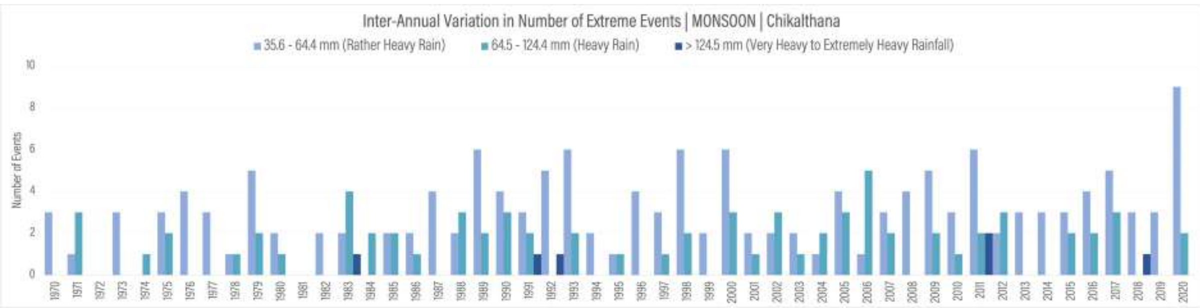


Source: WRI India analysis using CPCB data, 2022

Annexure 2-12: Interannual Variation in Number of Extreme Rainfall Events at Chikalthana gauge station in Chhatrapati Sambhajinagar

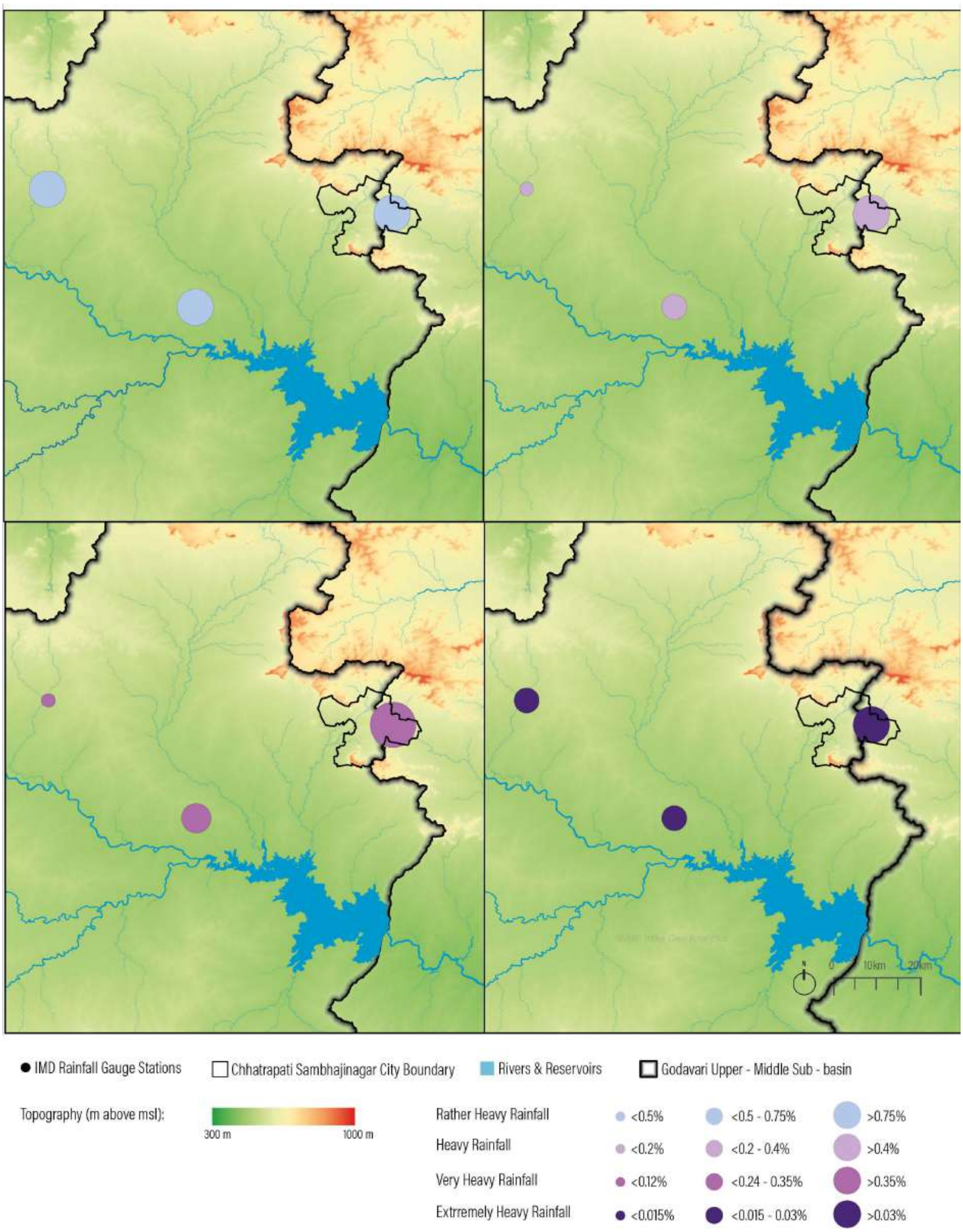






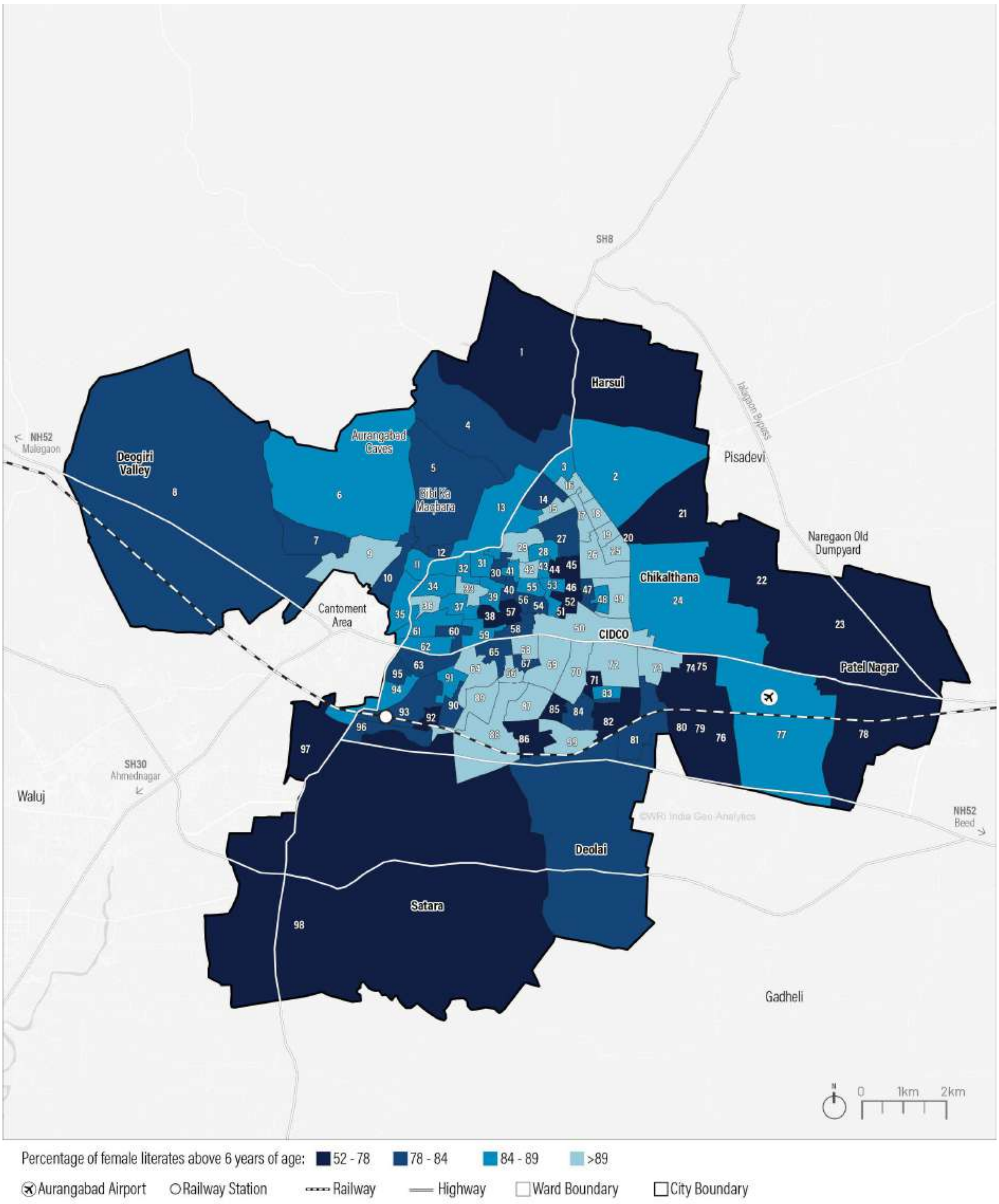
Source: WRI India using meteorological data from IMD

Annexure 2-13: **Inter-annual Spatial Variation in Frequency of Different Rainfall Events in and around Chhatrapati Sambhajinagar between 1970 and 2020**



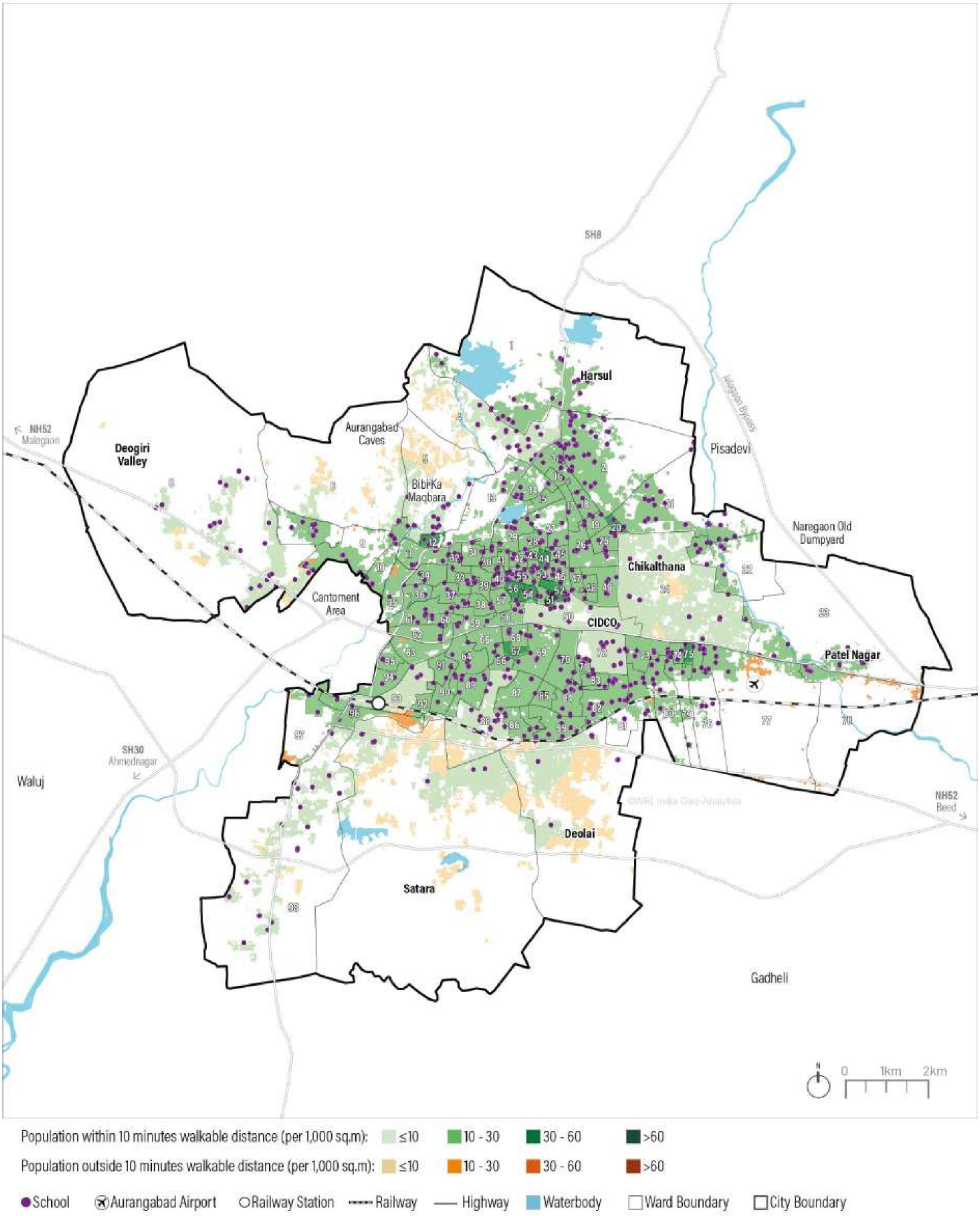
Source: WRI India using meteorological data from IMD

Annexure 2-14: Effective female literacy rate



Source: *WRI India using Census 2011*

Annexure 2-15: Access to All Schools

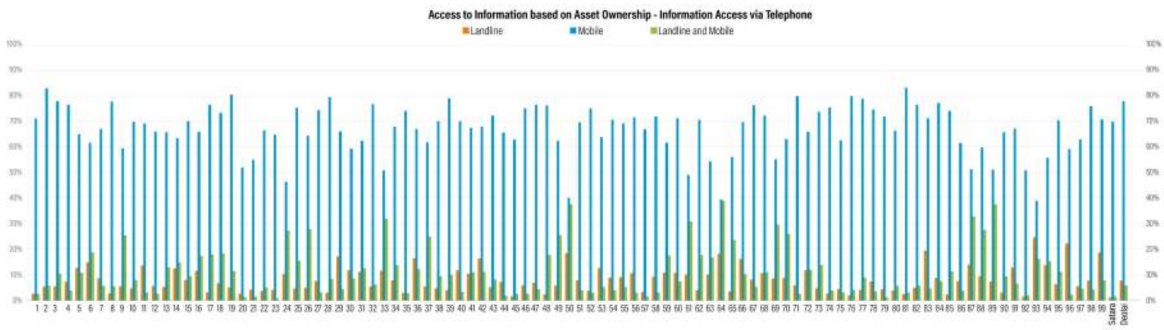


Source: *WRI India using Census 2011, World Settlement Footprint 2019, Education Department CSMC 2022*

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 Standards 11t and 12) are excluded.

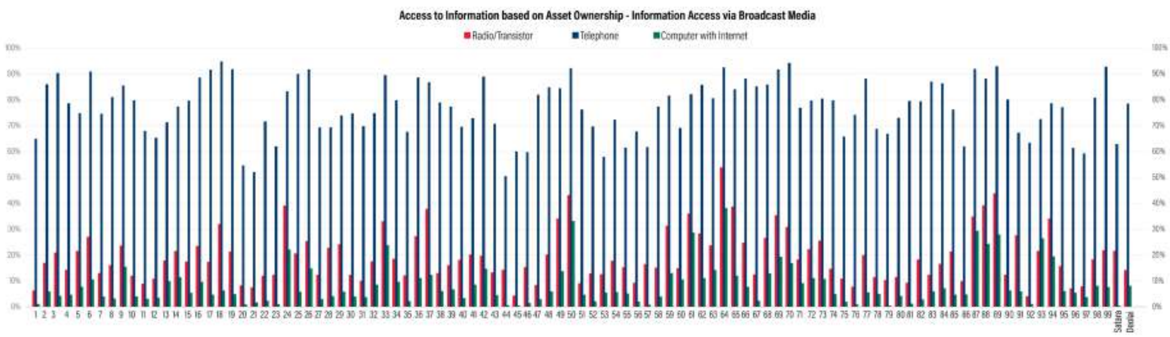
Assumption: Access to schools is mapped using service area polygons that are created for the schools for analysing access within 1 km. It has been considered based on pedestrian accessibility standards within 10 minutes walkable distance (Bernard van Leer Foundation, 2018).

Annexure 2-16: Access to Information based on asset ownership- information Access via Telephone



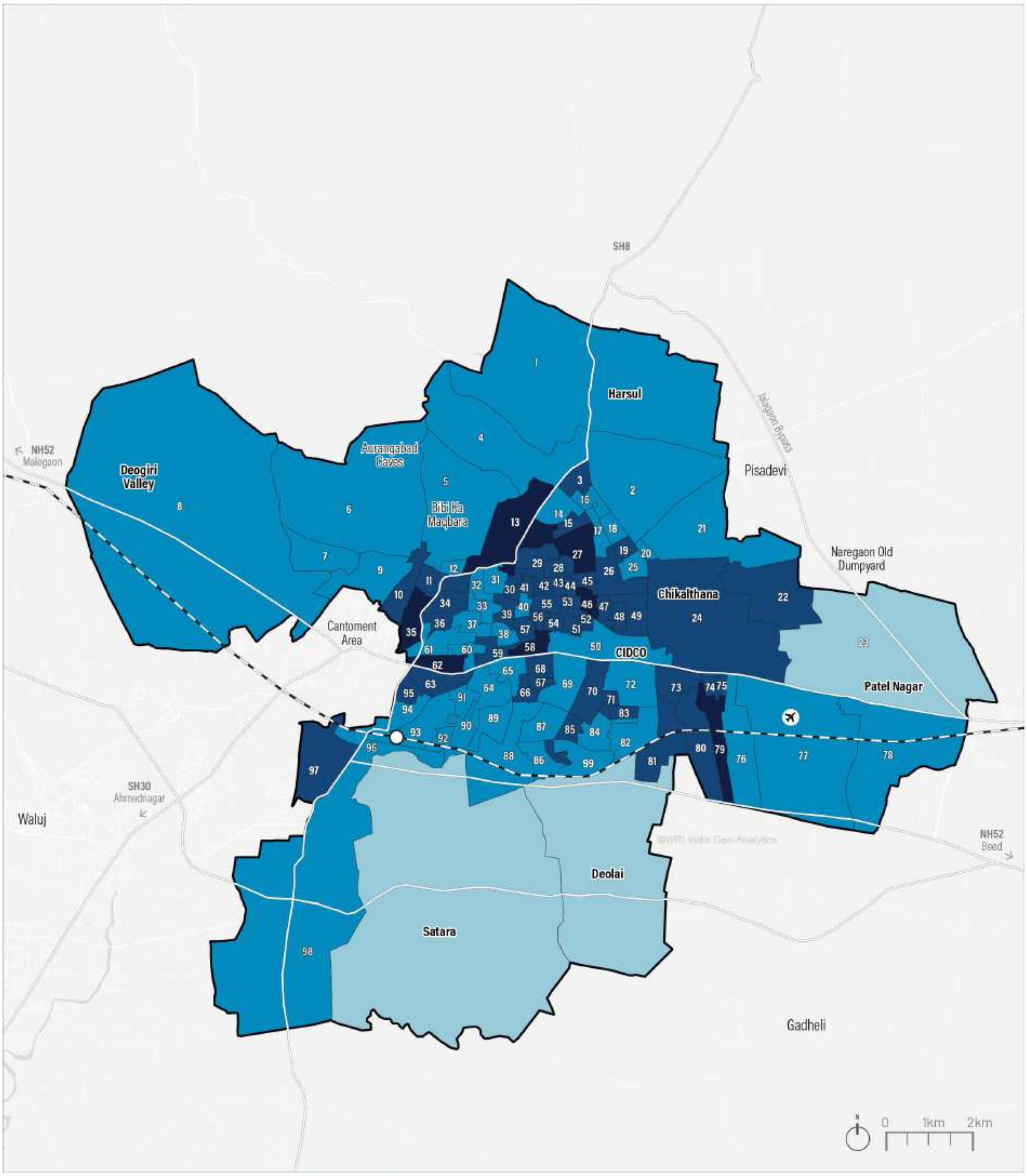
Source: WRI India using Census 2011

Annexure 2-17: Access to Information based on asset Ownership- information access via Broadcast Media



Source: WRI India using Census of India 2011

Annexure 2-18: House Ownership

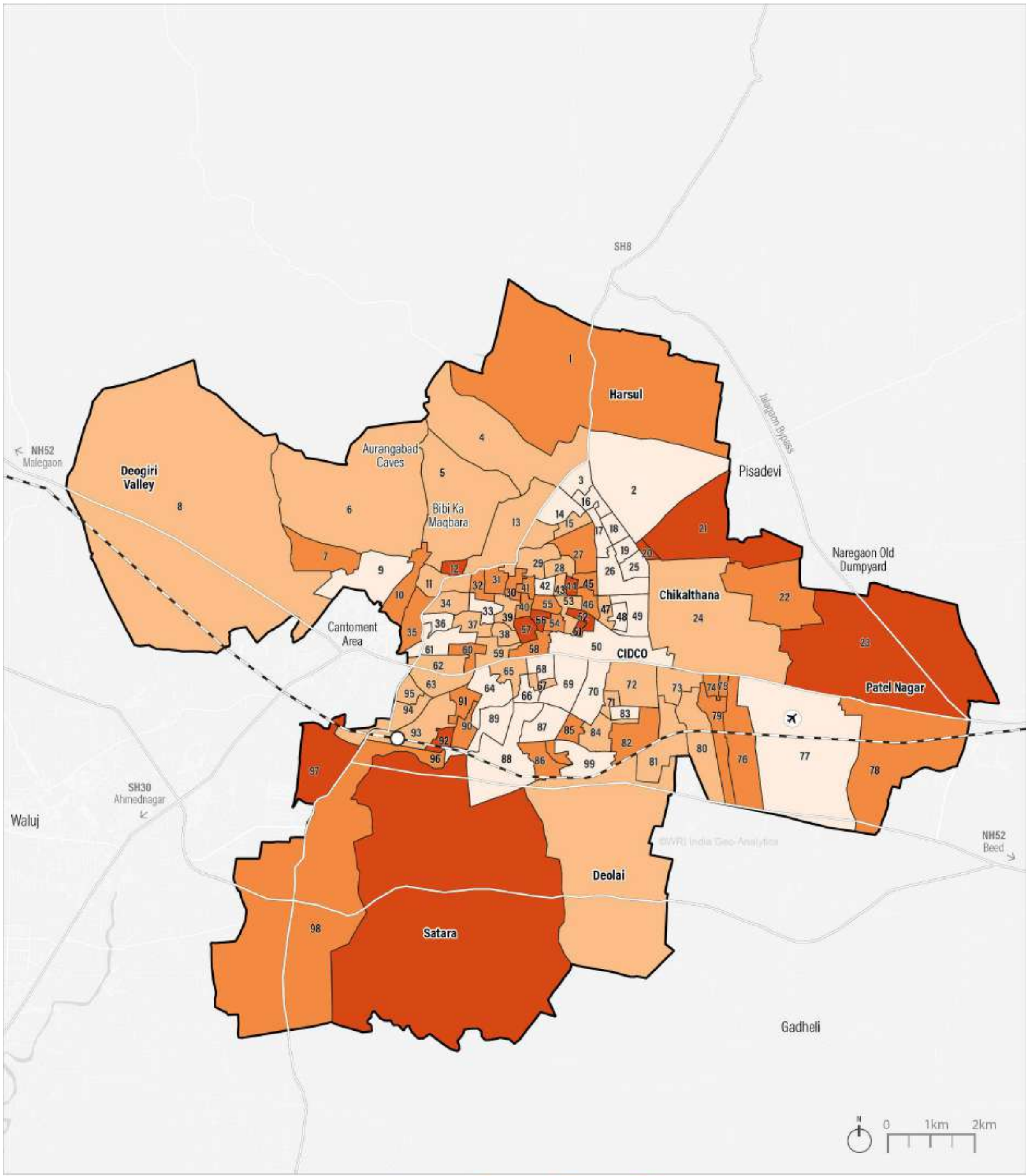


Population of households living in own house: 40 - 52 | 52 - 64 | 64 - 76 | >76

Aurangabad Airport | Railway Station | Railway | Highway | Ward Boundary | City Boundary

Source: WRI India using Census of India 2011

Annexure 2-19: Housing Condition

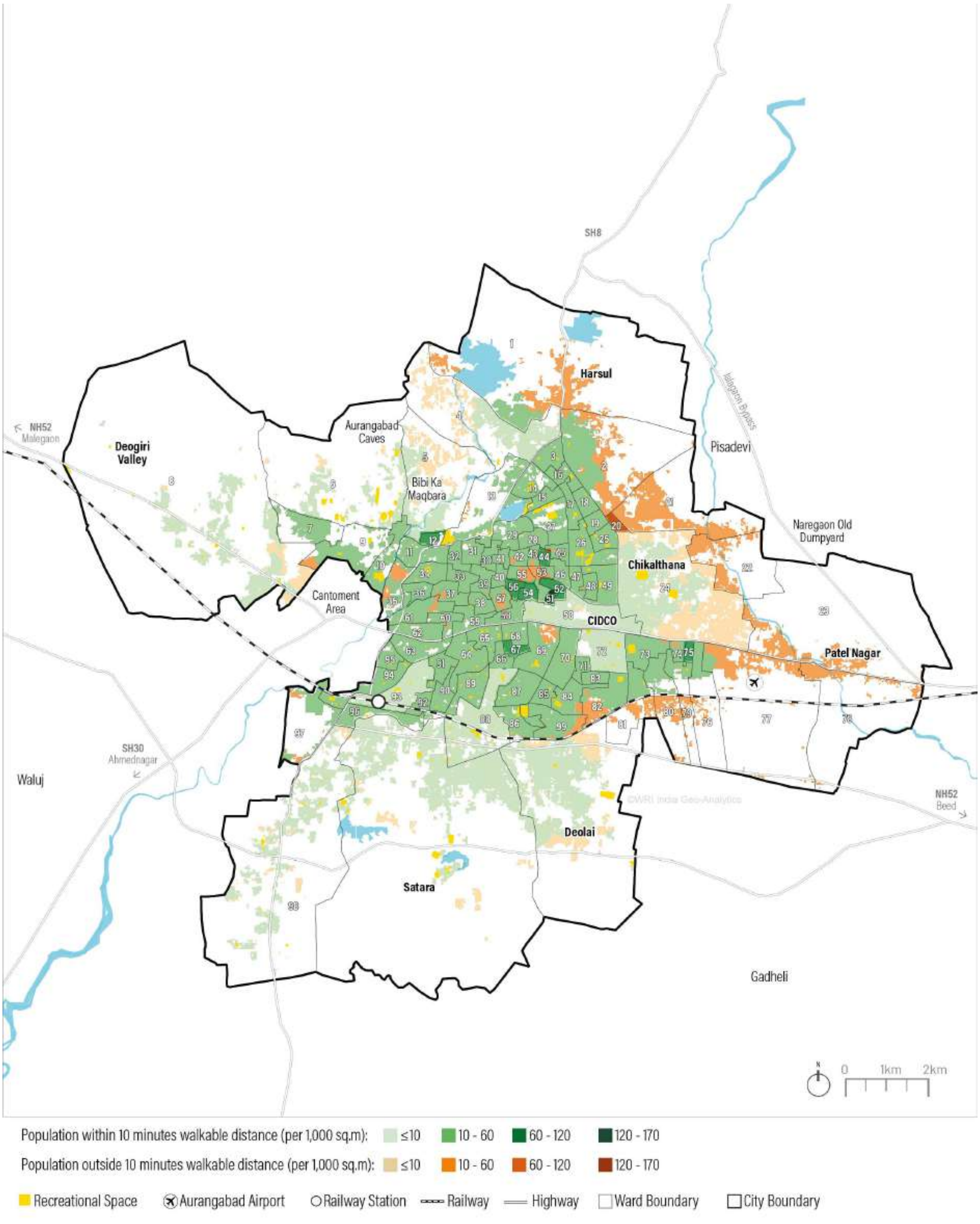


Percentage of households with temporary roofing materials: 5 - 27 | 27 - 49 | 49 - 72 | >72

Aurangabad Airport | Railway Station | Railway | Highway | Ward Boundary | City Boundary

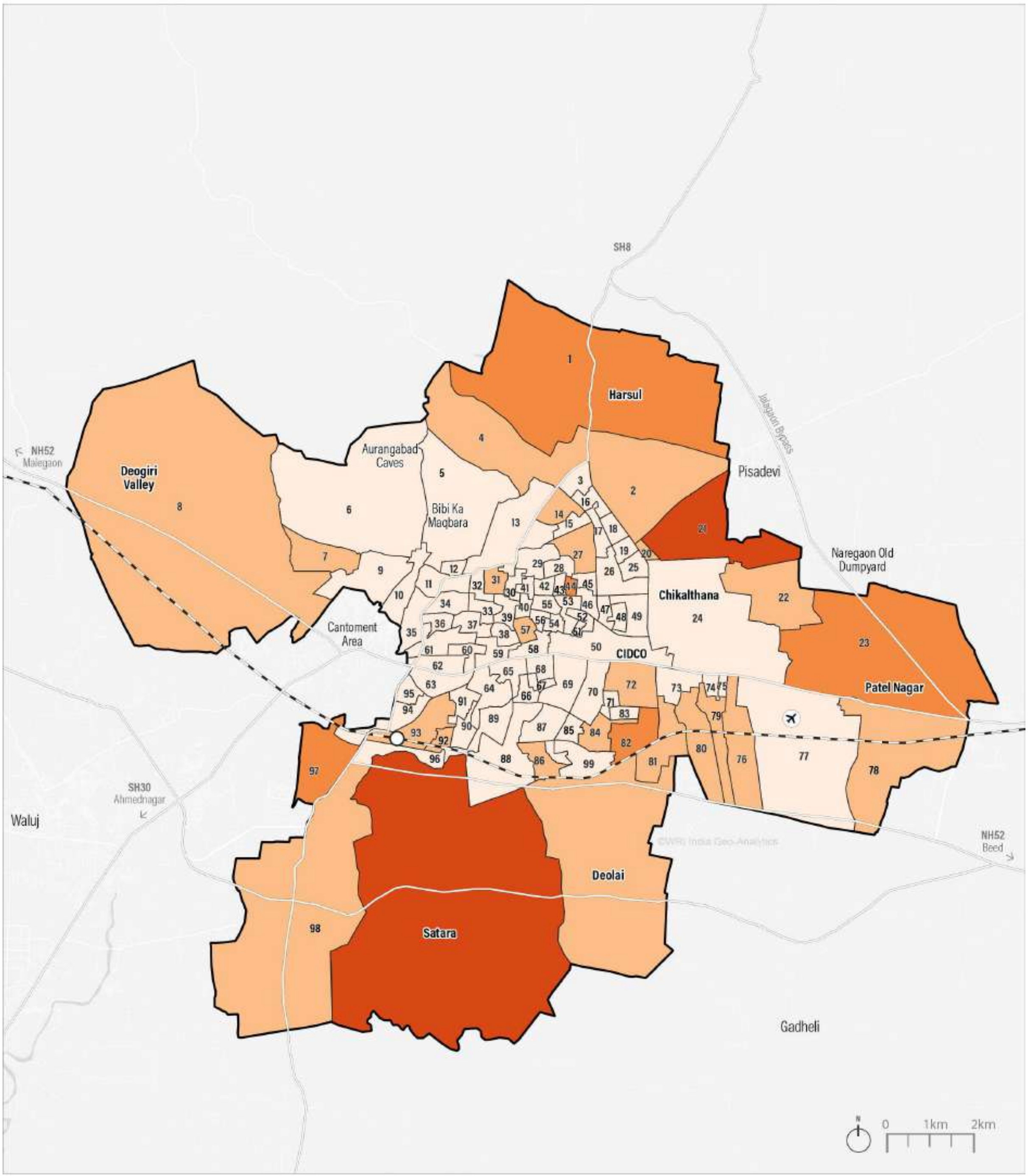
Source: WRI India using Census of India 2011

Annexure 2-20: Access to Public Recreational Spaces



Source: WRI India using Census 2011, World Settlement Footprint 2019, Existing Land Use CSMC (2021)

Annexure 2-21: Limited ease of access to drinking water (outside premises)

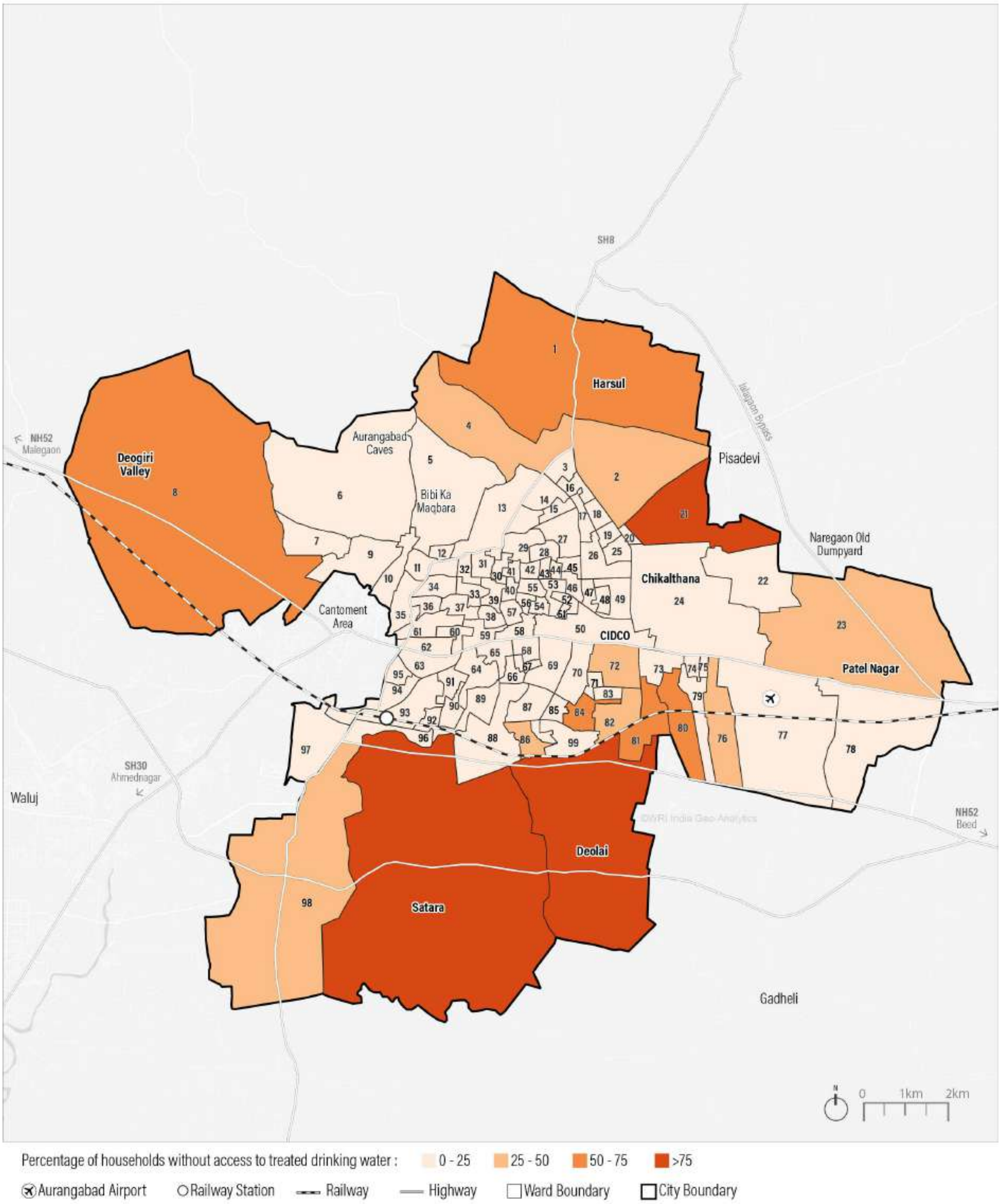


Percentage of households without drinking water inside premises: 0 - 18 | 18 - 35 | 35 - 53 | >53

Aurangabad Airport | Railway Station | Railway | Highway | Ward Boundary | City Boundary

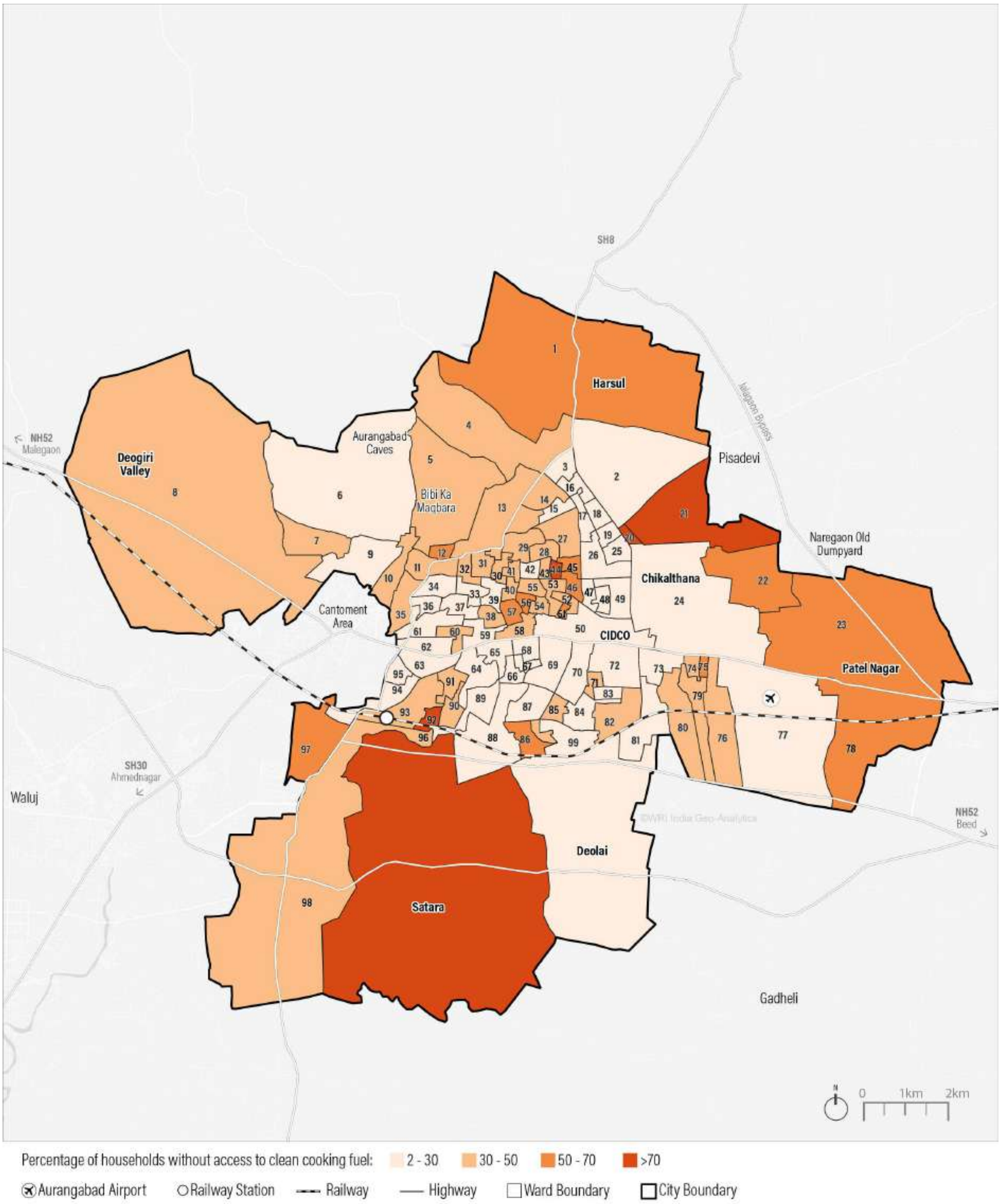
Source: WRI India using Census of India 2011

Annexure 2-22: Lack of access to treated drinking water



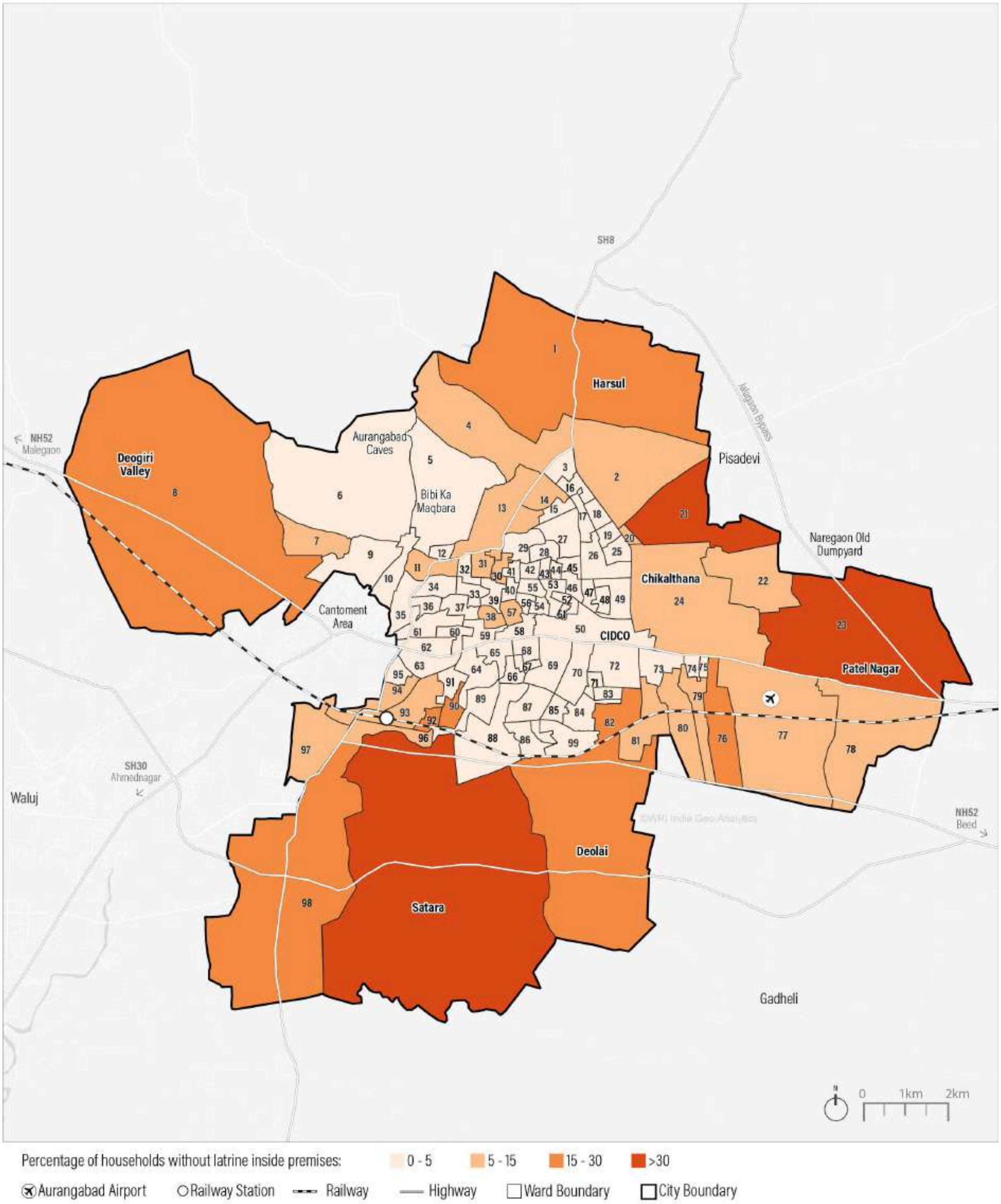
Source: WRI India using Census 2011

Annexure 2-23: Lack of Access of Clean Cooking Fuel



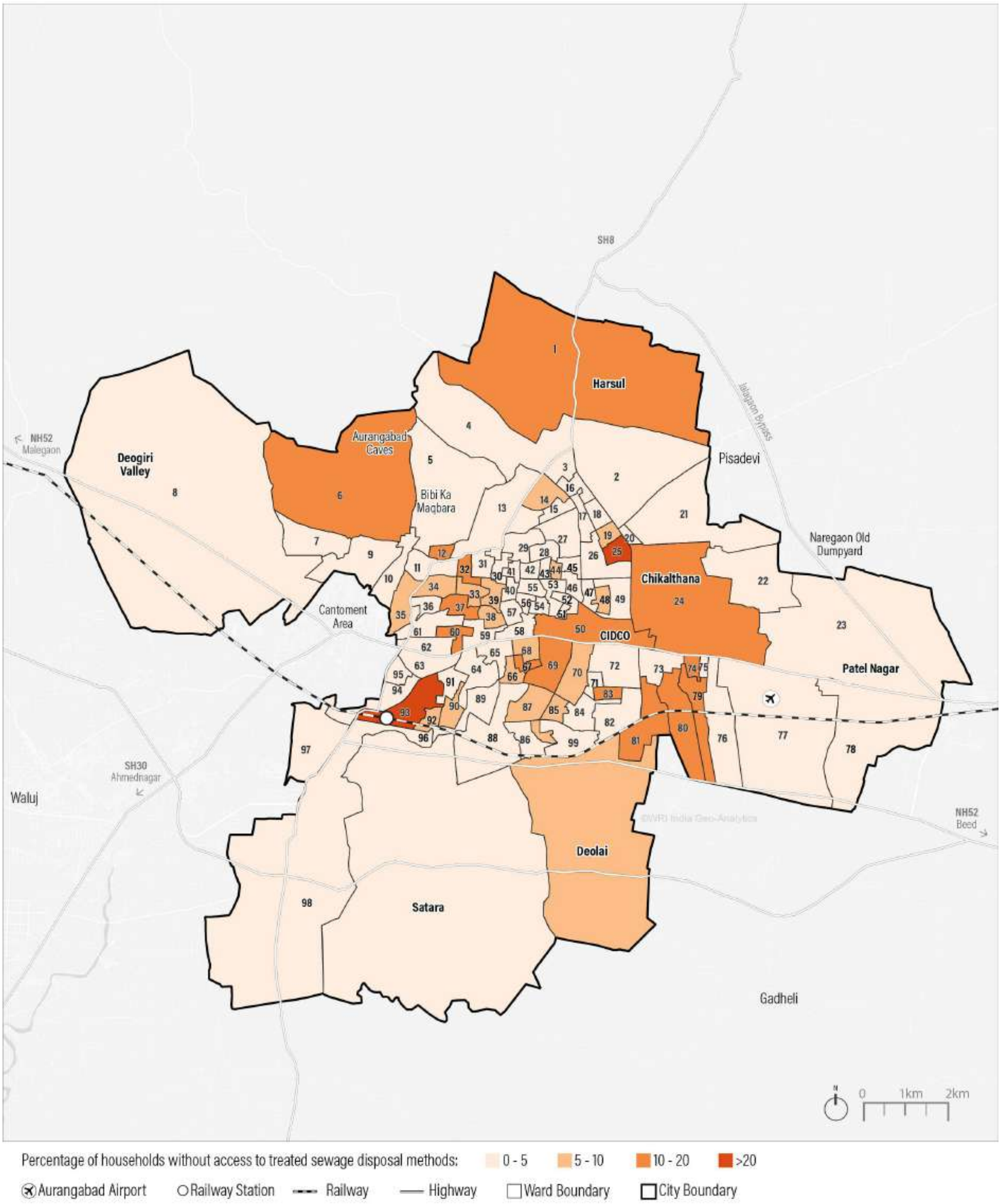
Source: WRI India using Census 2011

Annexure 2-24: Limited ease of access to latrine (outside premises)



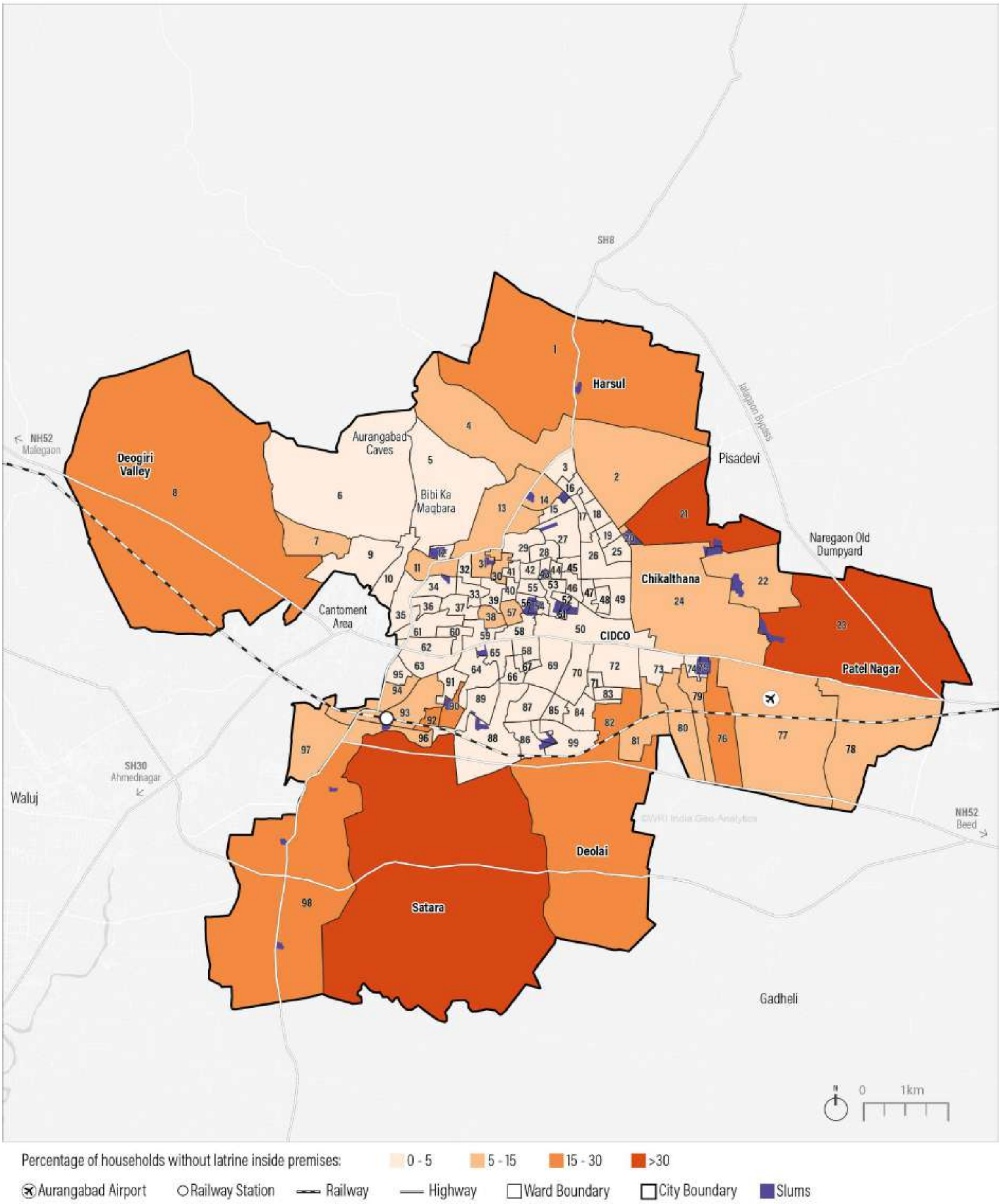
Source: WRI India using Census 2011

Annexure 2-25: Lack of access to treated sewage disposal methods



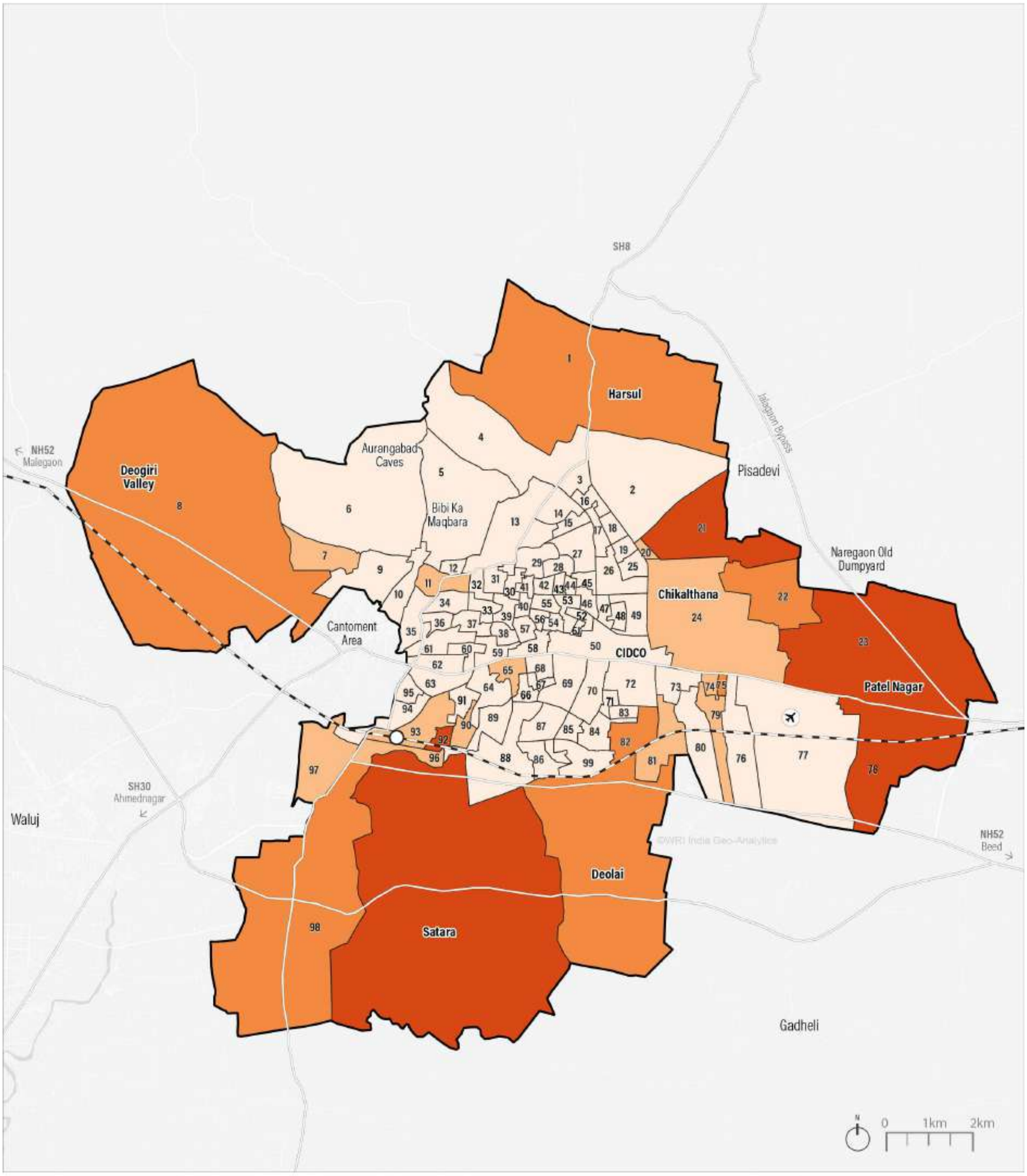
Source: WRI India using Census 2011

Annexure 2-26:: **Limited ease of access to latrines**



Source: WRI India using Chhatrapati Sambhajinagar Municipal Corporation 2022

Annexure 2-27: Lack of treated wastewater disposal methods

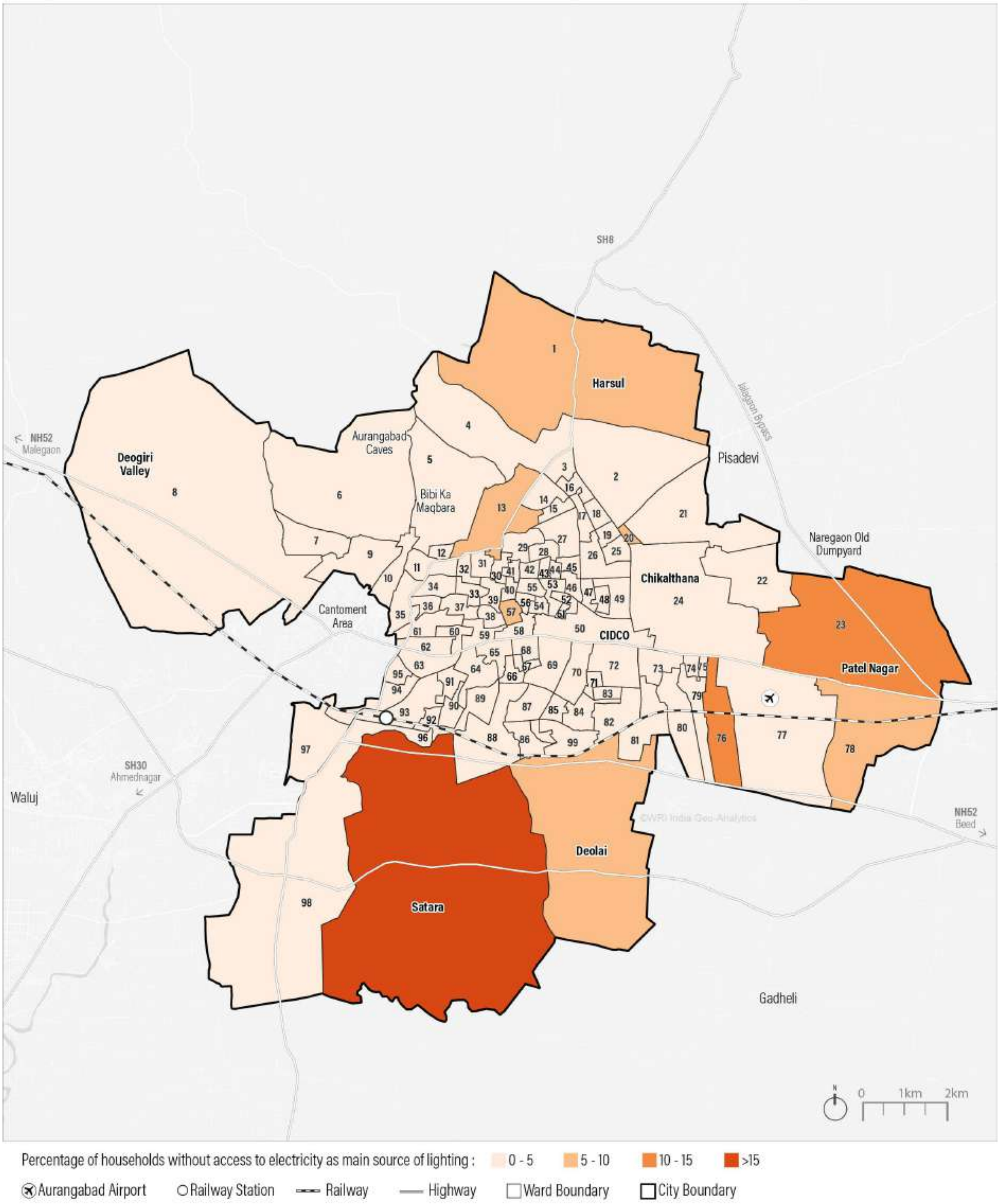


Percentage of households without access to treated waste water disposal methods: 0 - 20 | 20 - 40 | 40 - 60 | >60

Aurangabad Airport | Railway Station | Railway | Highway | Ward Boundary | City Boundary

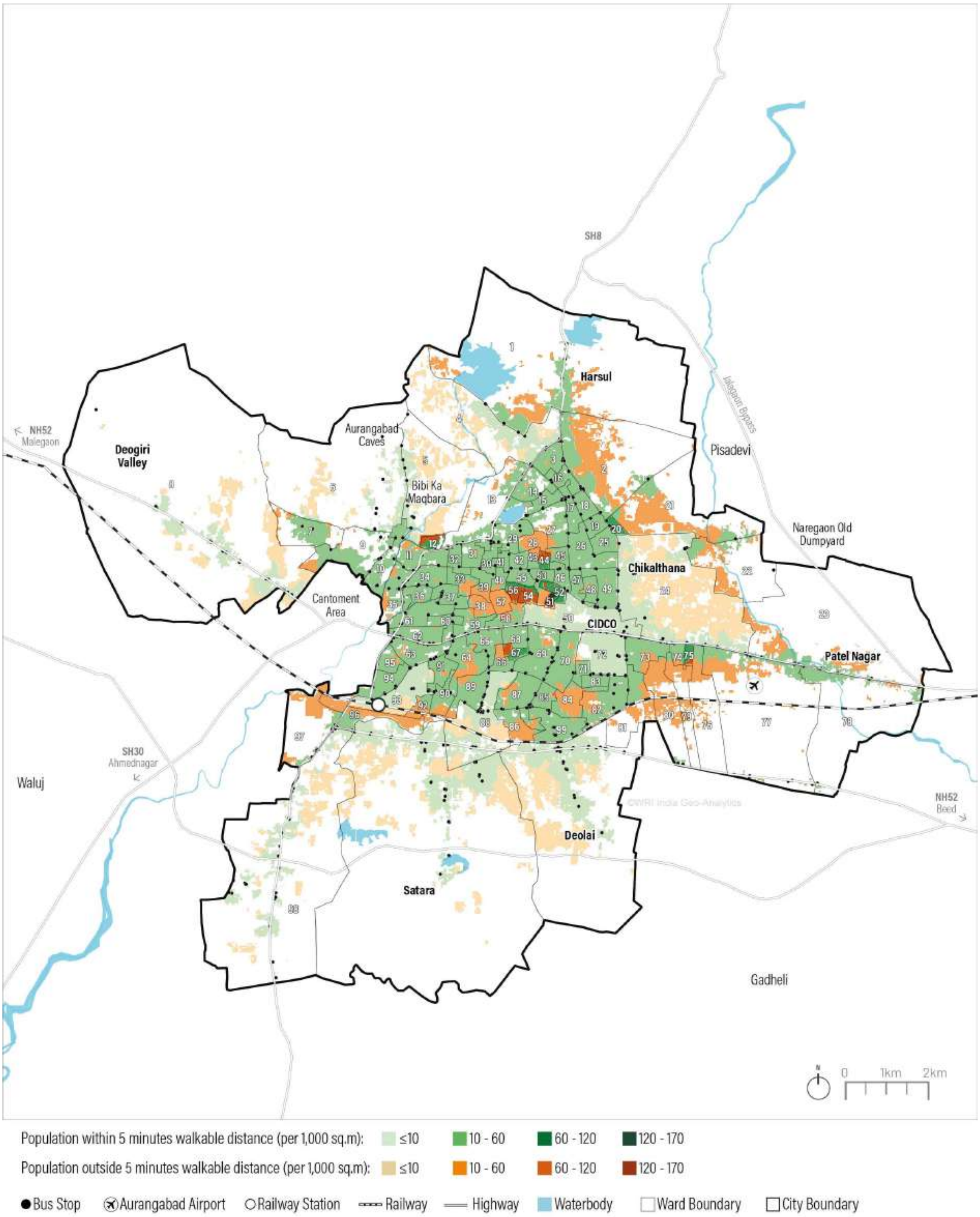
Source: WRI India using Census 2011

Annexure 2-28: Lack of Access to Electricity Grid



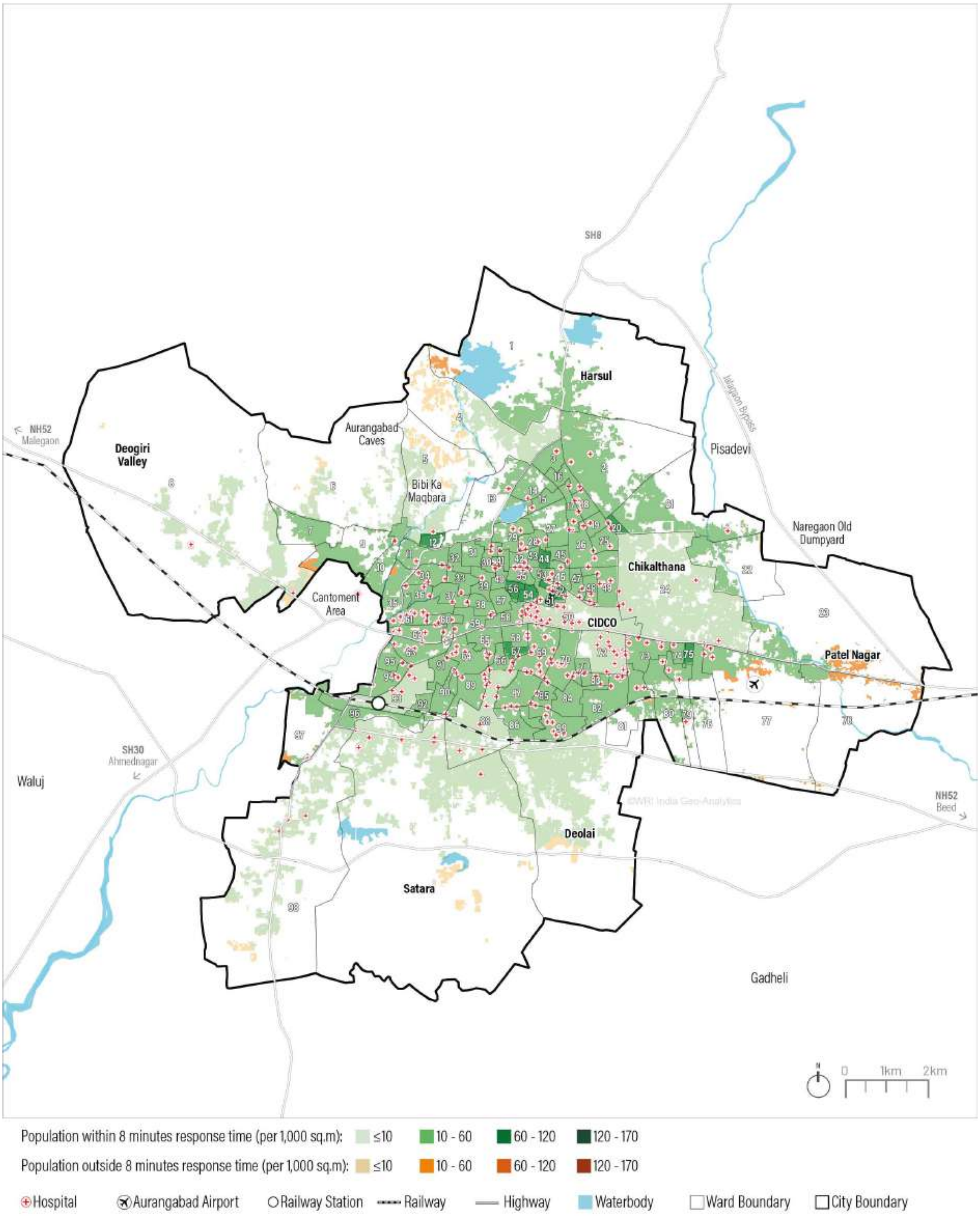
Source: WRI India using Census 2011

Annexure 2-29: Access to Bus Stops



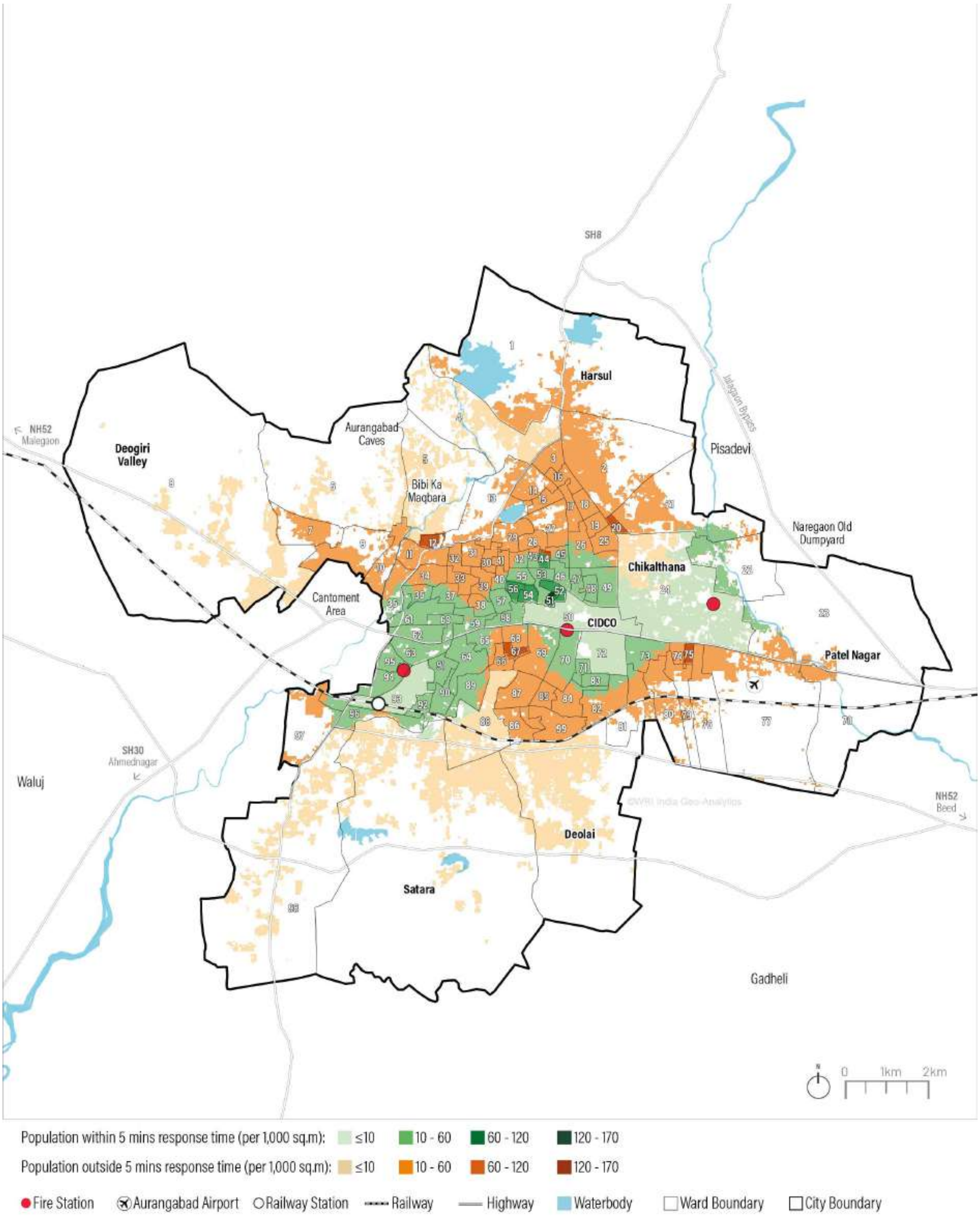
Source: WRI India using Census of India 2011, World Settlement Footprint 2019, Chhatrapati Sambhajinagar

Annexure 2-30: Access to Hospitals



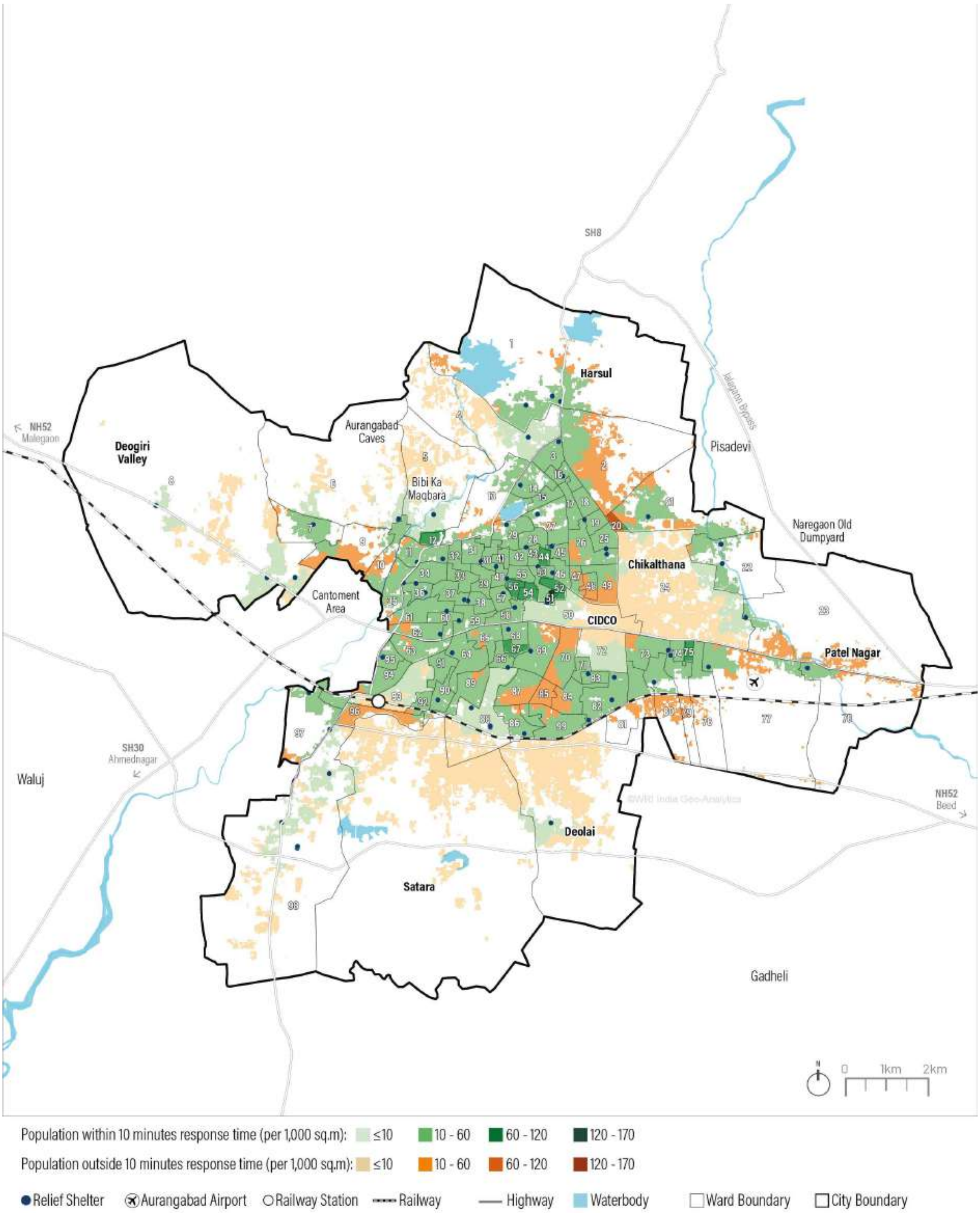
Source: WRI India using Census 2011, World Settlement Footprint 2019, Chhatrapati Sambhajinagar Municipal Corporation 2020

Annexure 2-31: Access to fire stations



Source: WRI India using Census 2011, World Settlement Footprint 2019, Chhatrapati Sambhajinagar Municipal Corporation 2021

Annexure 2-32: Access to Relief Shelters



Source: WRI India using Census 2011, World Settlement Footprint 2019, Chhatrapati Sambhajinagar Municipal Corporation 2021

ANNEXURE 3: VULNERABILITY ASSESSMENT (VA) PROCESS – DATA REQUIREMENT

Annexure 3-1: Type of data required

What is city exposed to?

CLIMATE HAZARD

RISK

Urban heat

Air Pollution

Rainfall & Lightning

Droughts

Satellite Imagery
IMD
Disaster Management Dept.
Fire Dept.
MPCB & CPCB
Town Planning Dept

Who's sensitive to the risk?

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 Envirnoment 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.

Who needs to adjust to the potential risk?

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 required data

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

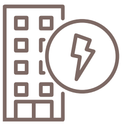
Impact on livelihood
- Potential impactr on employment hubs
  - Economic Census
  - ELU
- Migrant workforce due to flood and heat

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

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*

- Residential buildings
- Commercial buildings and institutional buildings
- Manufacturing industries and construction
- Utility and streetlights

Transportation

- Road Transport: 4W, 3W, 2W, Buses

Waste

- Municipal Solid Waste Management
- Wastewater treatment

Note: ****Excluded:** coal and fuelwood consumption, emissions from industries outside city boundary*

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 describes climate action planning in five 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 emissions 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 sectoral targets achieved. It also allows users to compare the impacts of different scenarios.

ANNEXURE 6: STAKEHOLDER CONSULTATIONS

Date	Objective	Key agencies/stakeholder consulted and other details
21 December 2021	Launch and signing of 'Letter of Intent' with CSMC	The Letter of Intent (LoI) for the Chhatrapati Sambhajinagar Climate Action Plan was signed by the then Municipal Commissioner, Shri Astik Kumar Pandey (IAS).
16 Feb 2022	2nd Kickoff meeting	The meeting was to familiarize the stakeholders with the framework of a climate action plan and collect relevant data from the departments. A few site visits were done. Commissioner, Additional Municipal Commissioner, Deputy Municipal Commissioner (DMC)- Environment and Solid Waste, PHE, City Engineer, Fuel agency, Gardens Department Health Department, Zonal representatives, Fire Department, Water supply Department, MSEDCL, DDMA, IMD, RTO, Officials from Smart Bus Division, ASCDCL, and Civil Society Organizations working with CSMC.
30 May 2022	Consultative meeting with Government stakeholders on CAP process, heat hotspot and water logging hotspot mapping	Data collection, validation and site visits. DMC- Environment and Solid Waste, PHE, City Engineer, Fuel agency, Gardens Department Health Department, Zonal representatives, Fire Department, Water supply Department, MSEDCL, DDMA, IMD, RTO, Officials from Smart Bus Division, and Civil Society Organizations working with CSMC.
29 May -3 June 2022	Data Collection and Stakeholders meeting	DMC- Environment and Solid Waste, Mechanical Department, Town Planning Department, DP unit, Officials from Smart Bus Division, GIS teams of ASCDCL.
4 August 2022	Capacity Building Workshop on Vulnerability Assessment and GHG Emissions Inventory	Around 20+ officials from 11 key departments and parastatal agencies such as Town Planning, DP Unit, Gardens, Fire, and a few stakeholders representing independent agencies such as IOCL, IGBC were in attendance.
23 August 2023	Stakeholder Consultation and workshop on presentation of the draft Climate Action Plan of Chhatrapati Sambhajinagar city.	Around 15+ participants from CSMC, ASCDCL, MSEDCL, IGBC, sectoral experts attended the meeting which discussed the draft CAP in detail. The workshop was presided over by Hon'ble Commissioner CSMC.

CAPACITY BUILDING WORKSHOPS WITH CSMC

ANNEXURE 7: NOTES ON CLIMATE PROJECTIONS USING RCP SCENARIO

i. 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.

ii. 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

iii. 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

iv. 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.

v. 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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9 Normalized Difference Vegetation Index (NDVI) is an indicator to signify presence of live green vegetation. The universal range of NDVI is from -1 to +1, where positive values from 0.2 generally indicate vegetation, which may vary according to the study area under consideration (Reference). The current assessment has used a threshold of 0.18, based on trial and error, to calculate the vegetation cover.

10 Tier-2 cities are defined as the cities with population between 50,000 and 99,999 as per RBI (Reference)

11 https://agricoop.nic.in/sites/default/files/Aurangabad.pdf

12 The quality of vegetation has not been considered in the current assessment.

13 Correlation coefficient measures the statistical relationship between two variables. The range of this coefficient is between -1 and +1, where -1 indicates strong negative correlation (inverse relationship), while +1 indicates strong positive correlation (direct relationship) (Reference)

14 https://agricoop.nic.in/sites/default/files/Aurangabad.pdf

15 Source: http://cpcbenvis.nic.in/airpollution/finding.htm Note : RSPM is the same as PM10

16 Except for the station at Waluj MIDC, all the other stations have been collecting data only twice a week. In the event of the availability of daily data points, the numbers shown in this figure may differ.

17 Source: https://www.unep.org/interactive/air-pollution-note/?gclid=Cj0KCQjwguGYBhDRARIsAHgRm4_R9fXSOlloTv_NXLdX8A2pSNfS04XxftN0RCoNZIV_o2_yg4Sf9vwaApgmEALw_wcB

18 Source: https://www.epa.gov/sciencematters/linking-air-pollution-and-heart-disease#:~:text=This%20study%20found%20 that%20long,calcium%20in%20the%20coronary%20artery.

19 Administrative wards from city corporation could not be used due to their non overlapping nature with census wards and non-availability of information regarding the proportion of population and area of each census

ward to be considered in each of the administrative wards, especially where a census ward is getting divided into two administrative wards.

20 The LST heat threshold value is a calculated value. An average LST image was derived from average of all cloud free LST images from Landsat 8 data between 2019-2021. The average LST image was used to calculate mean value for entire built area which is defined as Heat Threshold. This value is variable for each of the city.

21 The DoE data consists of sample data of formal jobs and does not include informal jobs.

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