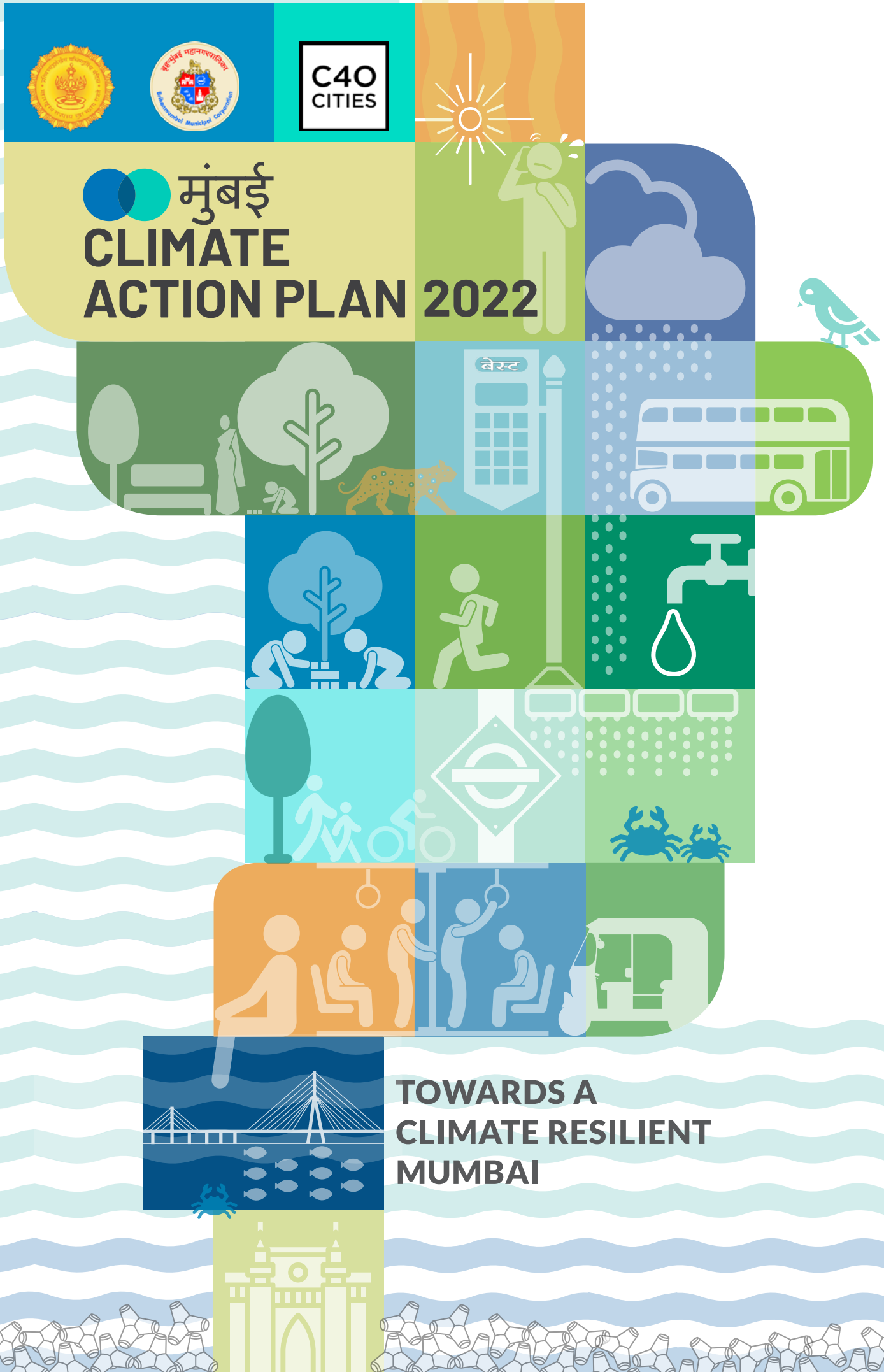
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MUMBAI

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Leaders Pledge for Climate Action in Mumbai

Shri. Uddhav Thackeray
Honourable Chief Minister of Maharashtra

I am pleased to know that the Brihanmumbai Municipal Corporation (BMC) has responded to the climate crisis with the Mumbai Climate Action Plan (MCAP). As extreme weather events unfold across the globe, the climate crisis has reached our doorstep. While India is on track to achieve the Nationally Determined Contributions, Maharashtra is determined to lead India's fight against this impeding crisis by policy-governance reforms and inculcating a climate action culture in the society. At COP26 Maharashtra was the only Indian state to be felicitated with the Inspiring Regional Leadership Award from the Under2 Coalition for Climate Action.

The Government of Maharashtra has been proactive in encouraging sustainable development of the State with various local to global climate action programs such as the Majhi Vasundhara Abhiyan and Maharashtra Electric Vehicle Policy, 2021 to introduction of stringent norms in the Maharashtra (Urban Areas) Protection and Preservation of Trees (Amendment) Act, 2021, and having 43 cities in Maharashtra sign-up to their commitments for the UNFCCC's Race to Zero campaign.

The Mumbai Climate Action Plan is aligned to meet the goals of the Paris Agreement limiting global warming to 1.5°C. The evidence-based policymaking and stakeholder consultations that have led to the shaping of the MCAP will help Mumbai become a climate-resilient city.

I wholeheartedly congratulate BMC for the MCAP and wish them luck in spearheading the climate resilience journey of Mumbai and Maharashtra.

Shri. Aaditya Thackeray

Honourable Cabinet Minister of Environment & Climate Change, Tourism & Protocol, Government of Maharashtra

A day's delay in taking decisive, inclusive climate action is akin to adding months of uncertainty and vulnerability to the lives of our future generations. The climate crisis is no longer an event in the distant future but a reality unfolding in our everyday lives.

At such a critical juncture, I welcome the unveiling of the Mumbai Climate Action Plan (MCAP) by the Brihanmumbai Municipal Corporation(BMC). The Sixth Assessment Report published by United Nations' Intergovernmental Panel on Climate Change has estimated that Mumbai can witness a sea-level rise of around 0.58 metres by 2100, the highest in India. Various recent extreme weather events in Maharashtra such as the Cyclone Tauktae, urban flooding, and untimely rains have shown that developing localised mitigation and resilience strategies is the need of the hour.

Our objective is to encourage climate action at the grassroots level. Achieving climate resilience in an urban body such as Mumbai is to strike the perfect balance between its developmental aspirations and nature conservation. Despite developmental pressures, the citizens of Mumbai successfully protected their city's natural green lungs – The Aarey Forest. More than 5,000 illegal structures on Mumbai's mangrove lands have been removed by the Mangrove Cell. Mumbai has also witnessed a phenomenal rise in the uptake of electric vehicles in public as well as private fleet.

To educate our children about the science behind climate change, we have introduced the Majhi Vasundhara Curriculum in our schools. Mumbai has joined the World Resources Institute's Cities4Forests and C40 Cities' Urban Nature Declaration – both of which aim to protect, preserve and amplify the city's open blue and green spaces to conserve our rich ecological heritage. Mumbai has also joined the C40 Cities Women4Climate program to ensure that women play a pivotal role in Mumbai's fight against Climate Change.

The indomitable spirit of our city has overcome innumerable challenges. It is now time to initiate collective action to safeguard our future. With the launch of the Mumbai Climate Action Plan, Mumbai has set the benchmark for Climate Action in India. As the Guardian Minister of Mumbai Suburban District, I firmly resolve to contribute in every possible manner to make MCAP a success story.

Smt. Kishori Pednekar

Honourable Mayor of Mumbai

It is an honour for me to present the Brihanmumbai Municipal Corporation's Mumbai Climate Action Plan. For a city reeling under climate stress for years now, the MCAP is a path towards a brighter future. The memories of the urban floods of 2005 and 2017 are still fresh in our minds. The increasing frequency of cyclones hitting Mumbai's coast every year is an equally daunting prospect. Between 1991 and 2018, Mumbai has witnessed a 2-degree Celsius rise in average temperature. A well-grounded and scientifically designed strategy is critical to combat the vagaries of climate change.

Even before the formulation of the MCAP, BMC had commenced its journey towards sustainability with active support from the Central and State Government. With the MCAP in hand now, our efforts towards a sustainable city will become even more streamlined.

The MCAP is revolutionary because it provides a holistic roadmap for Mumbai's drive towards sustainable development. Its six focus areas – Energy & Buildings, Integrated Mobility, Sustainable Waste Management, Urban Greening & Biodiversity, Air Quality, and Urban Flooding & Water Resource Management – provide innovative and lasting solutions to Mumbai's climate challenges. The MCAP has truly inspired city leaders like myself to deliver inclusive climate actions and provide equitable solutions for all.

Mumbai stands at the critical juncture, where Mumbaikars can guide the nation by making the MCAP a success and ensuring a safe and sustainable future for our children.

Dr. I.S. Chahal IAS

Municipal Commissioner of Mumbai, BMC

As the Executive Head of the Brihanmumbai Municipal Corporation (BMC), I feel extremely proud and fortunate to present the Mumbai Climate Action Plan (MCAP). Firstly, I would like to thank the Government of Maharashtra and Mumbai for their constant support and commitment towards making the MCAP a reality. Next, I congratulate the Additional Municipal Commissioner (City) and his team for their tireless efforts in drafting the MCAP.

Mumbai is at high risk due to changing weather patterns. Between 1973 and 2020, Mumbai observed a warming trend with an average temperature increase of 0.25°C per decade. Over the years, of all the significant urban floods in India, three major ones have occurred in Mumbai in 2005, 2014 and 2017. Furthermore, as per the data from BMC's Disaster Management Department, 287 locations within Greater Mumbai are landslide-prone.

The MCAP is revolutionary because the solutions that it suggests for Mumbai's climate vulnerabilities are scientifically designed taking into account ground realities after several deliberations with citizens. To begin with, the MCAP team conducted an in-depth vulnerability analysis of the city. Next, a Greenhouse Gas (GHG) inventory was prepared to identify the city's critical sources and sinks of greenhouse gases which then guided action tracks to reduce emissions.

MCAP aims to guide the city towards a net zero future through inclusive, low carbon urban development. I humbly request all Mumbaikars to support the BMC in its efforts to implement the MCAP in an effective manner.

Dr. Sanjeev Kumar IAS

Honourable Additional Municipal Commissioner – City, BMC

At the outset, I would like to thank the political leadership of Maharashtra and Mumbai, for their progressive vision, without which this revolutionary action of the Mumbai Climate Action Plan (MCAP) would not have seen the light of day. I'm humbled to have had the opportunity to lead the Brihanmumbai Municipal Corporation's (BMC) team in preparing the MCAP. I extend my sincere thanks to all departments for their meaningful contributions towards the MCAP. Furthermore, I am deeply grateful to our knowledge partners C40 cities and World Resources Institute India (WRI India) for their technical guidance and support in drafting the MCAP.

South Asian coastal cities like Mumbai are at a high risk and we stand at a crucial precipice where climate disasters can push our developmental aspirations back a few decades. Hence, the MCAP is vital for ensuring climate resilient urban development in Mumbai driven by a people-centric approach. The chosen six focus areas of Mumbai CAP are congruent with India's commitments towards the Sustainable Development Goals (SDG), such as SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) amongst others. With ongoing initiatives like electrifying our bus fleet, developing open blue and green spaces and investing in renewable energy, I am confident that the MCAP would enhance BMC's efforts towards climate change mitigation and adaptation.

Shruti Narayan

Regional Director, South and West Asia
C40 Cities

Mumbai, a C40 city with a population of over 12 million people, has published the Mumbai Climate Action Plan (MCAP). This is the first CAP in the region, aligned to the C40 CAP framework, an important milestone for the region and the Global South. As a signatory to Deadline 2020, Mumbai has committed to reducing carbon emissions by 50% by 2030 and setting a roadmap to becoming carbon neutral by 2050 aligned with the Paris Agreement. Mumbai has led the way in showcasing how political commitment and leadership can result in an ambitious yet implementable plan — which is particularly of importance to the global south, which is home to some of the most polluted, populous and fastest growing cities of the world.

A unique component of the MCAP is around building knowledge systems and common actions to broad base the benefits of this transition, across 42 other cities in the state that joined Cities Race to Zero, with the potential to impact an additional 60 million people. The State Environment and Climate Change Department, the Brihanmumbai Municipal Corporation (BMC) and WRI India led from the front on many of these discussions and helped frame the key priorities and activities that can enable this transition. Beyond the MCAP, the city has also actively engaged on inter-sectional themes like the Women for Climate, Climate Budget Pilot, U20 2022 and Urban Nature Declaration, led and coordinated by the regional C40 Cities team. The next step is to accelerate and mainstream implementation to deliver on Mumbai's transformational climate actions.

At C40, we look forward to working with Mumbai to achieve the targets set out in this plan while acting together, learning from each other, sharing knowledge and building a resilient city that can not only make its citizens prosperous but also achieve a greater quality of life for the future generations of Mumbaikars.

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The development of the Mumbai Climate Action Plan was under the leadership of Shri. Aaditya Thackeray, Hon'ble Minister for Environment and Climate Change, Tourism, Protocol, and Guardian Minister, Mumbai (Suburban), Government of Maharashtra.

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

This report should be referred to as the 'Mumbai Climate Action Plan, March 2022'

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Cover image - Queen's Necklace, Marine Drive; photo credit - Mohammed

Abbreviations

2W	2 Wheeler
A & C	Assessment & Collection Department
A&C	Assessment and Collection
AC	Assistant Commissioner
ADB	Asian Development Bank
AEML	Adani Electricity Mumbai Limited
AI	Artificial Intelligence
ALM	Advanced Locality Management
AMC	Additional Municipal Commissioner
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BAU	Business-as-Usual
BEE	Bureau of Energy Efficiency
BEST	Brihanmumbai Electric Supply and Transport
BKC	Bandra-Kurla Complex
BMC	Brihanmumbai Municipal Corporation
BPCL	Bharat Petroleum Corporation Limited
BRTS	Bus Rapid Transit System
BS	Bharat Stage
C&D	Construction and Demolition
CAAQMS	Continuous Ambient Air Quality Monitoring System
CAC	Climate Action Cell
CAP	Climate Action Plan
CBO	Community Based Organization
CCRA	Climate Change Risk Assessment
CIDCO	City and Industrial Development Corporation
CIRIS	City Inventory Reporting and Information System
CLUA	Climate and Land Use Assesment
CMP	Comprehensive Mobility Plan
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2e	Carbon Dioxide Equivalent

CPCB	Central Pollution Control Board
CRZ	Coastal Regulation Zone
CSCAF	Climate Smart Cities Assessment Framework
CSMIA	Chhatrapati Shivaji Maharaj International Airport
CSO	Civil Society Organization
CSR	Corporate Social Responsibility
D2D	Door-to-Door
DCR	Development Control Regulations
DISCOM	Distribution Companies
DMC	Deputy Municipal Commissioner
DO	Dissolved Oxygen
DP	Development Plan
DRE	Distributed Renewable Energy
DWSC	Dry Waste Segregation Centre
E&P	Existing and Planned
ECBC	Energy Conservation Building Code
ECBC-R	Energy Conservation Building Code For Residential Buildings
EDGE	Excellence in Design in & for Greater Efficiencies
EE	Energy Efficiency
EF	Emission Factor
EIA	Environmental Impact Assessment
ENS	Eco-Niwas Samhita
ERE	Extreme Rainfall Events
ESR	Environment Status Report
EV	Electric Vehicle
EWS	Economically Weaker Section
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
FSSI	Food Safety and Standards Authority of India
FSI	Forest Survey of India
FSSAI	Food Safety and Standards Authority of India
GDP	Gross Domestic Product

GHG	Greenhouse Gas
GHG-i	Greenhouse Gas Inventory
GIS	Geographic Information System
GOI	Government of India
GPC	Global Protocol for Communities
GPS	Global Positioning System
ha	hectare
HDV	Heavy-duty Vehicles
HE	Hydraulic Engineering
HH	Households
HPCL	Hindustan Petroleum Corporation Limited
HPSV	High Pressure Sodium Vapour
ICAP	Inclusive Climate Action Planning
ICCT	International Council on Clean Transportation
ICT	Information and Communications Technology
IDBI	Industrial Development Bank of India
IEC	Information, Education and Communication
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IITM	Indian Institute of Tropical Meteorology
IMC	Indian Merchants Chamber
IMD	Indian Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services
IOCL	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public Transport
ISWM	Integrated Solid Waste Management
IT	Information Technology
ITES	Information Technology Enabled Services
JMC	Joint Municipal Commissioner
JNPT	Jawaharlal Nehru Port Trust
KDMT	Kalyan Dombivali Municipal Transport
Kmph	Kilometer Per Hour
KPI	Key Performance Indicators
KW	Kilowatt
LBSAP	Local Biodiversity Strategies and Action Plan

LIG	Low Income Group
LPCPD	Liters Per Capita Per Day
LPG	Liquefied Petroleum Gas
LST	Land Surface Temperature
MbPT	Mumbai Port Trust
MC	Municipal Commissioner
MCAP	Mumbai Climate Action Plan
MEDA	Maharashtra Energy Development Agency
MER	Monitoring, Evaluation, and Reporting
MERC	Maharashtra Electricity Regulatory Commission
MgC	Megagram Carbon
MGL	Mahanagar Gas Limited
MHADA	Maharashtra Housing and Area Development Authority
MHSEC	Maharashtra State Energy Calculator
ML	Machine Learning
MLD	Million Litres Per Day
MMB	Maharashtra Maritime Board
MMI	Multi Modal Integration
MMR	Mumbai Metropolitan Region
MMRC	Mumbai Metro Rail Corporation
MMRDA	Mumbai Metropolitan Regional Development Authority
MNGL	Maharashtra Natural Gas Limited
MNRE	Ministry of New And Renewable Energy
MoEFCC	Ministry of Environment, Forest And Climate Change
MoP	Ministry of Power
MPCB	Maharashtra Pollution Control Board
MRF	Materials Recovery Facility
MRVC	Mumbai Railway Vikas Corporation
MSDP	Mumbai Sewerage Disposal Projects
MSDRDC	Maharashtra State Road Development Corporation
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSW	Municipal Solid Waste
MU	Million Units of Electricity
MUDRA	Micro Units Development and Refinance Agency
MUTP	Mumbai Urban Transport Project
MVA	Majhi Vasundhara Abhiyan

MW	Megawatt
MWp	Megawatts-peak
NAAQ	National Ambient Air Quality
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Planfor Climate Change
NBS	Nature-based Solutions
NCAP	National Clean Air Programme
NCV	Net Calorific Value
NDC	Nationally Determined Contributions
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NGT	National Green Tribunal
NH3	Ammonia
NIIF	National Investment and Infrastructure Fund
NMMT	Navi Mumbai Municipal Transport
NMT	Non Motorized Transport
NOAA	National Oceanic and Atmospheric Administration
NYC	New York City
NZEB	Net Zero Energy Buildings
OEM	Original Equipment Manufacturer
OWC	Organic Waste Converter
PA	Protected Area
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particluate Matter
PNG	Piped Natural Gas
PPB	Parts Per Billion
PPP	Public–private Partnership
PUC	Pollution Under Control
PV	Photovoltaic
RCP	Representative Concentration Pathways
RE	Renewable Energy
ROPAX	Roll On/Roll Off Passenger Ferry
RTO	Regional Transport Office
RTS	Rooftop Solar
RWA	Resident Welfare Association
RWH	Rainwater Harvesting

SAFAR	System of Air Quality and Weather Forecasting and Research
SAPCC	State Action Plan on Climate Change
SCADA	Supervisory Control and Data Acquisition System
SDA	State Dedicated Agency
SDG	Sustainable Development Goals
SECI	Solar Energy Corporation of India
SGNP	Sanjay Gandhi National Park
SIDBI	Small Industries Development Bank of India
SLR	Sea Level Rise
SMPA	Swachh Mumbai Prabhodhan Abhiyan
SO	Sewerage Operation
SO_2	Sulphur Dioxide
SOM	Soil Organic Matter
SP	Sewerage Projects
SRA	Slum Rehabilitation Authority
SST	Sea Surface Temperature
STP	Sewage Treatment Plants
SWD	Storm Water Drainage
SWH	Solar Water Heaters
SWM	Solid Waste Management
TC	Tropical Cyclones
TCO	Total Cost of Ownership
TMT	Thane Municipal Transport
ToF	Trees Outside Forests
TPD	Tonnes Per Day
UHI	Urban Heat Island
ULB	Urban Local Body
URDPFI	Urban and Regional Development Plans Formulation and Implementation
UT	Union Territory
VOC	Volatile Organic Compound
W2E	Waste To Energy
WASH	Water, Sanitation and Hygiene
WAYU	Wind Augmentation and Purifying Units
WHO	World Health Organization
WPR	Work Participation Rate
WRI	World Resources Institute
WSP	Water Supply Projects
ZCB	Zero Carbon Building

Gateway of India | By Sarang Pande

Vision: Towards a Net Zero & Climate Resilient Mumbai

Mumbai city, home to over 12 million people and thriving on a diverse economy, is increasingly at risk of the impacts of climate change. Increasing temperatures, depleting natural green cover, routine bouts of extreme rainfall events resulting in severe flood conditions incur severe losses to the city's economy and its people. Recent increase in tropical cyclones along the coast and future risks from sea level rise projected over the next 3 decades pose critical challenges to Mumbai's future. In this context, the Brihanmumbai Municipal Corporation have led the process to drafting the first ever, Mumbai Climate Action Plan (MCAP).

The MCAP envisions a city where its communities and citizens are safer, healthier, and thrive even in the context of a changing and uncertain climate. The MCAP is committed to a net zero and climate-resilient Mumbai by 2050. This means ensuring just transitions – towards net zero pathways; big investments – towards inclusive and transformative climate solutions; and coordinated and robust governance – to ensure a targets-based approach. BMC acknowledges that the climate crisis is already affecting us all, although in varying ways, and the *time for action is now* to secure a better future for all by 2050.

> **It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.**
>
> – IPCC, AR6, The Physical Science Basis, 2021

Mindful of these consequences that climate change presents to future generations living in Mumbai and its region, the MCAP recognizes that actions must be taken on priority across six strategic areas - Sustainable waste management, Urban greening & biodiversity, Urban flooding & water resource management, Energy & buildings, Air quality and Sustainable mobility. The actions identified in each strategic area are framed on four pillars of success:

Economy
Economic activity catering to citizens to serve as a 'common good', be sustainable and generate local employment opportunities.

Engagement
Impacted groups and citizens engage in climate action planning and the effective implementation of climate actions.

Environment
City, citizens and stakeholders protect and build natural assets and maintain resources for future generations.

Equity
Improved health and equitable distribution of benefits to address the needs of vulnerable communities and other impacted groups.

Mumbai Samachar | By Ashwin Vaswani

Executive Summary

Mumbai is among the cities most vulnerable to climate change induced hazards, such as sea level rise, storm surge and urban flooding. The 2005 floods, which resulted in 410 deaths and displaced thousands, particularly in the low-income areas, is a case in point of the risks and vulnerabilities the city faces. Mumbai is a C40 member city. In 2020, Mumbai signed C40's Deadline 2020 commitment – aligned with the Paris Agreement – to reduce greenhouse gas (GHG) emissions by 50% by 2030, support the Government of India (GoI) in achieving its Nationally Determined Contributions (NDCs) and become net zero by 2050. In order to meet C40's Leadership Standards, the Brihanmumbai Municipal Corporation (BMC) is developing the city's first ever climate action plan (CAP) aligned to the C40 Climate Action Panning Framework, with technical support from World Resources Institute India (WRI India) that has been engaged as a knowledge partner.

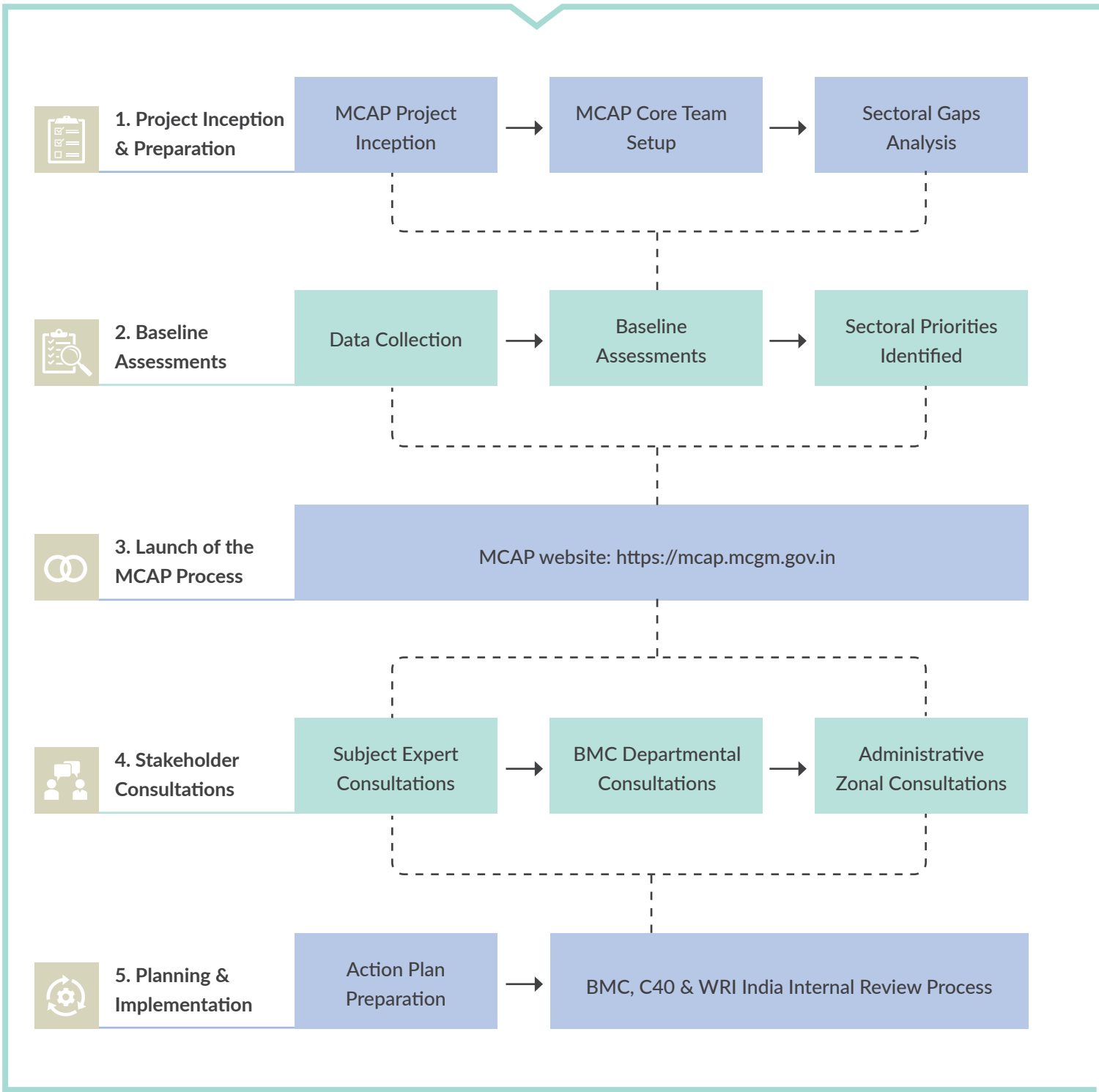
The MCAP will present the city with a robust roadmap in the run-up to 2050, which is the target year for the plan.

The main objective of the plan is to create a comprehensive strategy to tackle the challenges of climate change in the city of Mumbai by adopting inclusive and robust mitigation and adaptation strategies. Mitigation strategies will be adopted for the sectors that have the potential to significantly reduce emissions by adopting cleaner, greener technologies, building materials and land use planning approaches. Adaptation strategies will focus on the sectors that can enhance the city's capacities to manage and recover from growing climate risks and extreme weather events by protecting the city's green and blue systems, keeping the air clean and allowing its natural systems to thrive.

The MCAP is framed as a policy document with an evidence-based approach to planning and mobilizing resources for action plans as well as strategic projects. The process of planning is closely aligned with the Development Plan for Greater Mumbai 2014-34 (DP 2034) and several sector-specific plans and policies to leverage the existing institutional capital towards a unified goal.

The Mumbai Climate Action Planning Process

The MCAP process adopts an inclusive and consultative approach and comprises five stages: **1)** project inception and preparation; **2)** data collection and baseline assessments, including the completion of a Global Protocol for Cities (GPC)-compliant GHG inventory for the city; **3)** launch of the planning process; **4)** stakeholder consultations; **5)** action plan preparation and internal reviews.



Project Inception and Preparation

When Mumbai secured C40 membership in December 2020, the Minister for Environment & Climate Change, Tourism and Protocol in the Government of Maharashtra, Aaditya Thackeray, announced the government's commitment to draft a CAP for the city. The MCAP process has received support from the State government. In the project inception stage, a core team of officers within BMC was created to lead the planning process in collaboration with partners and other consultants. The Additional Municipal Commissioner - City, Dr. Sanjeev Kumar, IAS was designated the leading Nodal Officer, in the project, and Deputy Municipal Commissioner Sunil Godse and his team were assigned the Environment Department. The core team was supported by the Department of Environment & Climate Change, Government of Maharashtra, which assigned Fellows from the Climate Fellows program to coordinate data needs and support inter-agency collaborations. The C40 Cities team provided support in the form of knowledge sharing, especially scientific methodologies and global best practices, through their networks in partner cities. As the knowledge partner, WRI India took the lead in drafting the technical document of MCAP.

As a first step, the team undertook a review of available literature, which included DP 2034, Environment Status Reports and other sectoral plans, to understand the city's urban, ecological, demographic and socio-economic context. This review is presented in Chapter 1 of this report. Sectoral gaps were identified, which threw light on the city's planning challenges.

Baseline Assessments

The climate and air pollution risks and vulnerability baseline assessments for the city were conducted using data from 20 departments of BMC and 26 parastatal, state and national government bodies and private agencies. A GPC-compliant GHG emissions inventory was developed. Mumbai city faces three distinct risks — increasing heat and heat island effect, increasing flood risk as a result of sea level rise and during extreme rainfall events, tropical cyclones and storm surges and increasing air pollution affecting human health. The Intergovernmental Panel on Climate Change (IPCC) Working Group 1 (WG1): Sixth Assessment Report projects an increase in mean precipitation and heavy rainfall events in Mumbai and neighboring regions, resulting in floods and landslides. According to this report, by the end of the 21st century, the mean temperature and number of hot days above 35^{o}C would increase under all Representative Concentration Pathways (RCP) scenarios. Sea level rise and coastal floods are indicated as future risks for several cities in India. In South Asia, particularly in coastal cities such as Mumbai, the number of "internal climate migrants", i.e., those migrating due to climate change and associated impacts such as water scarcity, crop failure, sea level rise and storm surges, is expected to increase between 2020 and 2050, amplifying rural-urban migration.

Mumbai's total GHG emissions for the base year 2019

23.42 million tons CO_2e

1.8 tons CO_2e per capita

The transport sector **20%**

The stationary energy sector accounts for **72%** of the total emissions

The waste sector **8%**

Based on the C40 Cities Pathways Model, three types of emission reduction scenarios were developed — *existing and planned actions scenario*, *ambitious actions scenario* and *extended scenario*. These are presented in detail in Chapter 3 of this report. These scenarios have been applied to structure the analysis, document Mumbai's current strategies, identify new strategies for the short and medium terms and assess the barriers in implementation. In order to arrive at its overarching mitigation target of net-zero emissions by 2050, Mumbai has committed to achieving 30% reduction by 2030, 44% by 2040 and net zero[1] by 2050.

[1] Residual emissions will amount to a 30% gap in meeting the 2050 target of net-zero emissions. Residual emissions will be reduced by energy efficiency initiatives in the building sector and low/zero carbon technologies in wastewater treatment.

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CLIMATE
ACTION PLAN

Launch of the Planning Process

The process of planning the MCAP was initiated on 27 August 2021 under the auspices of the Honourable Minister, Shri. Aaditya Thackerayji, Minister of State, Shri. Sanjay Bansodeji, Mayor of Mumbai, Smt. Kishori Pednekarji, Municipal Commissioner of Mumbai, Dr. I.S. Chahal IAS, MMRDA Commissioner Shri. S.V.R. Srinivasji and Additional Municipal Commissioner - City, Dr. Sanjeev Kumar IAS. The citizens of Mumbai were invited to participate in the planning process through the MCAP website[2] that was launched by Shri. Aaditya Thackerayji. The website presents information about the MCAP, the six sectoral priorities and links to relevant blogs and presentations. Citizens' inputs in the form of more than 300 recommendations were received on the Talk to Us page of the website, thus strengthening public participation and awareness about the CAP. Of the citizens who shared recommendations, 60% were male and 40% female. Most of the recommendations (65%) pertained to the adaptation sectors of flooding, greening and air quality, with the latter two being of primary concern to the citizens, while 35% was focused on mitigation, particularly on waste management.

Stakeholder Consultations

The first round of consultations was held with experts from NGOs, research organizations, citizens' forums, international development agencies and municipal service providers such as BEST and private companies. Six consultations were held in the first round, one for each sector. In each consultation, 5-7 subject experts shared specific recommendations, which formed the basis of the initial approach, goals and actions for each sectoral priority. These consultations were widely attended by climate enthusiasts, subject experts, students and citizens, with an average participation of 80-100 people. These consultations highlighted the key priorities and impact groups for each sector, with a focus on ensuring inclusivity in the planning process and representation of the needs of vulnerable citizens.

The second round of consultations was hosted with various departments within BMC, external agencies such as Brinhanmumbai Electric Supply & Transport (BEST), Mumbai Port Trust (MbPT), Mumbai Metropolitan Region Development Authority (MMRDA), Maharashtra Pollution Control Board (MPCB) and DISCOMS such as TATA Power and Adani Electricity Mumbai Ltd. In this round, the overarching goals and actions were discussed and the participants shared their feedback and recommendations on priority actions proposed in the MCAP. This process helped assess the relevance and feasibility of actions, the status of projects underway and the key barriers to timely implementation.

The third round of consultations was held at the ward level for seven administrative zones across three divisions - City, Western Suburbs and Eastern Suburbs. During these consultations, Assistant Commissioners (ACs) and zonal DMCs of the divisions were familiarized with the MCAP and the proposed actions. The officials shared their perspectives with respect to the challenges and priorities at the grassroots and offered their support and commitment for the implementation of MCAP at the ward level. The ACs' recommendations for increased capacities to monitor progress, track projects and ensure timely collaboration is reflected in the form of the Climate Action Cell (CAC) proposed for the city. The complete list of stakeholders who participated in the three rounds of consultations is presented in Annex 3.

[2] The weblink https://mcap.mcgm.gov.in can be used to access the MCAP website, and the weblink https://mcap.mcgm.gov.in/talk-to-us/ can be used to access the citizens' feedback form.

Planning and Implementation

Based on the literature review, analysis of the primary data and climate profile, inputs from stakeholder consultations and experts' review, the goals and actions for each sector were revised and strengthened. The sectoral action plans were then prepared. These are summarized in Table 1. The action plans present information about the key stakeholders, outcome and output indicators, timeframes and revenue sources for each action. To ensure timely implementation of the MCAP, BMC will create a CAC as part of its Environment Department that will report to the AMC City on progress made. Mumbai is also part of the C40 Cities Climate Budget Pilot. The City of Oslo, which is leading the pilot, is supporting Mumbai to develop its first climate budget. The budget will be developed and monitored by the CAC. A Monitoring-Evaluation-Reporting-Learning (MERL) cell within the CAC will track budget allocations, expenditures, implementation and progress of the MCAP. A climate budget will help operationalize the plan, build on existing emission scenario analysis, targets, goals and actions and organize actions into prescriptive implementable tasks for relevant stakeholders. The climate budget will also help the city plan and secure financial resources.

Energy & Buildings

Table 1: Sector-wise action tracks and rationale

Sectoral Action Track	Rationale
Decarbonizing Mumbai's electricity generation mix	The city's electricity mix presents the biggest mitigation opportunity through phasing out fossil fuel-based power and tapping into the decentralized renewable energy (RE) potential, while simultaneously reducing transmission losses.
Transition to clean fuels and resource efficiency in buildings	Reducing energy demand through energy efficiency improvements is the most time- and cost-effective way to reduce emissions. Electrification of cooking coupled with a clean grid will reduce emissions from buildings and avoid carbon lock-in.
Low carbon buildings	Decarbonizing buildings is a smart and sustainable way of promoting urban development by mitigating emissions, avoiding future carbon lock-in of inefficient infastructure and reducing urban heat island effect.
Passive design strategies to improve resilience in buildings	Better ventilation and cooling in different building typologies, coupled with low carbon and heat-resistant material in construction is essential to mitigate increasing heat risk, especially in low-income communities with limited access to cooling equipment.

Integrated Mobility

Sectoral Action Track	Rationale
Improve public transport ridership	Improving reliability, interconnectivity, accessibility, safety and information delivery of public transport services would reduce private vehicle usage, thereby reducing congestion, road fatalities, air pollution and GHG emissions. It will also help increase safety and accessibility for all, especially women, children and the elderly.
Access to non-motorized transport (NMT) and infrastructure	Currently, only 22% of the roads in Mumbai are walkable. Increasing pedestrian and NMT infrastructure will increase walkability, enable modal shift and reduce GHG emissions, air pollution and congestion. It will also lead to improved health benefits due to physical activity.
100% municipal and private zero emission vehicles by 2050	Increasing the share of alternative fuels and improving fuel efficiency, along with an increase in the share of renewable energy in the grid through increased access to finance, policy enablers and incentives, will reduce GHG emissions and air pollution.
Zero emission freight	There is an urgent need to decarbonize freight through policies, route management and incentives as logistics contributes to about 7% of total emissions in India. Also, the current Comprehensive Mobility Plan lacks any freight-related strategies, governance mechanisms, data and targets.

Sustainable Waste Management

Sectoral Action Track	Rationale
Reducing landfilled waste	At source reduction and reuse is the most preferred way of managing waste through waste minimization, sustainable use/multi use of products and awareness, thereby reducing overall emissions.
Decentralized waste management	Setting up decentralized infrastructure helps reduce costs and emissions related to collection and transportation and facilitates the overall uptake of recycling and composting.
Remediation and scientific management of landfills	Landfilling is the least preferred mode of managing solid waste as it generates the least amount of value. Remediation of legacy sites and scientific management of existing landfills is crucial to reduce GHG emissions, pollution and health risks due to unscientific solid waste management (SWM).

Urban Greening & Biodiversity

Sectoral Action Track	Rationale
Increase vegetation cover and permeable surface	Increasing vegetation cover and applying scientific knowledge in tree planting and maintenance will help reduce heat and flood risk, increase permeable surfaces in the city and secure other co-benefits in terms of health and air quality.
Reduce urban heat island effect	Reducing urban heat island effect and increasing permeable surfaces along the city streetscape to manage vulnerability to heat and floods through tree banking system, streetside landscape guidelines and usage of permeable/cooling materials.
Equitable access to green open spaces	There is a gap in demand for and available open spaces, and BMC aims to increase per capita open space from 1.8 square meters to 6 square metres. This will increase flood and heat resilience, make space available for physical activity and improve public health as co-benefits. Increased green spaces will also increase the city's carbon sequestration potential.
Restore and enhance biodiversity in the city	Protecting, restoring and enhancing Mumbai's diverse natural habitats is essential for maintaining and preserving hotspots for biodiversity. This will enhance urban resilience, improve public health, build healthier ecosystems and increase carbon sequestration in line with Mumbai's commitments to the C40 Urban Nature Declaration and the Cities4Forests partnership.

Air Quality

Sectoral Action Track	Rationale
Curb the pollution concentration level by 20-30% by 2030	Mumbai has higher concentrations of PM2.5, PM10 and NO2 than the CPCB permissible limit (Refer Table 1 of Chapter 2), and the concentration of these air pollutants in the city is extremely localized. Improving air quality by curbing pollution levels will help reduce health risks.
Increase information availability through monitoring	Improving stationary and dynamic monitoring systems to increase information access, lending to accurate trend and hotspots analyses and forecasting mechanisms will help issue timely warnings in local areas, or by times of day, where/when people are more at risk, and help reduce personal exposure.
Community health resilience through decentralized planning and awareness	Ward-wise analysis of the city reveals that certain wards are very critical in terms of concentrations of NO2, SO2, CO, PM2.5, and PM10 and have become gas chambers from toxic emissions and fires at landfill site. This action track will help tackle acute health issues and respiratory risks among people living in these areas.

Urban Flooding & Water Resource Management

Sectoral Action Track	Rationale
Build flood resilient systems and infrastructure	The existing Storm Water Drainage (SWD) network is due to concretization of open spaces in discharging the surface flow. Thus, large-scale nature-based solutions would go a long way in reducing annual instances of waterlogging and flooding.
Localized water conservation and efficiency	Ensuring that up to 50% of the city's water demand is met through localized water conservation and efficient use initiatives will help increase water security for all, meet the city's daily water demand and reduce the extreme dependency on catchments and lakes located far from the city.
Reducing pollution and restoring aquatic ecosystems	Reducing pollution by improving sanitation through strict enforcement and introducing nature-based solutions will help reduce pollution and waste disposal at the outfalls and maintain and restore riparian zones and green cover.
Safe and affordable drinking water	Improving availability and accessibility to water will lead to health and socioeconomic benefits for all and reduce the risk of contamination while sourcing water from informal sources. Understanding the energy consumption in water supply and treatment will help make these systems energy efficient and reduce GHG emissions.
Clean, safe and accessible toilets	Sanitation has been recognized as a human right and, hence, all citizens must be provided with toilet facilities. Real-time monitoring and GIS systems in sewage disposal coupled with sanitation data generation and management systems can be developed and utilized to expand sewage network in the underserved areas.
Disaster risk and impact reduction	Ensuring disaster risk and impact reduction by strengthening early warning systems, data monitoring and integration, and community engagement would make the city better prepared and reduce human, financial, infrastructural losses.

How to Read the MCAP?

Chapter Title
Chapter Overview

Key Elements of the Chapter

What is the city like?

City Context
Understanding Mumbai

Urban Context
Ecological Context
Demographic Context
Socio-economic Context

What is the current climate like?

Baseline Assessment
Conducting an assessment of climate and air pollution risks and vulnerability, and developing a GPC-compliant GHG inventory for Mumbai

Climate Risks


Urban Heat


Urban Flooding


Landslides


Coastal Risks


Air Pollution

Critical Sources


Stationary Energy


Transport

Waste

Carbon Sinks


AFOLU

What are the future trajectories?

Pathways to a 1.5°C Warming Scenario
Understanding future emissions in the business-as-usual scenario and assessing future emission reduction scenarios to make Mumbai net-zero by 2050

Future Emission Scenarios

Business as Usual Scenario

Existing & Planned Scenario

Ambitious Scenario

How do we make Mumbai climate resilient?

Sectoral Priorities and Plans
Establishing overall priorities across sectors and conducting a detailed assessment of every sector in terms of sectoral overview, gaps, approach, ongoing initiatives and implementation strategies for priority and long-term actions

Six Sectors – Priorities and Plans


Energy & Buildings

Sustainable Waste Management


Air Quality


Sustainable Mobility


Urban Greening & Biodiversity


Urban Flooding & Water Resource Management

How do we achieve this vision and ensure we are on track?

Governance & Institutional Structures

Proposing governance mechanisms to support implementation of the CAP

- Update the GHG inventory and climate & air pollution risks and vulnerability assessment every two years.
- Revise the Climate Action Plan every five years

Existing Governance Structure

Proposed Department of Environment & Climate Change (CAC)

Climate Budget

MER Cell to monitor, evaluate and report progress

- Environment Protection & Pollution Control
- Knowledge Management
- Innovations and Green Finance
- Sustainable Urban Landscapes
- Vulnerable Communities
- Climate Resilient Buildings
- Integrated Mobility

Shot in Lower Parel | By Joel Steevan

Shot at Fort | By Victor Jiang

Chapter 1:
City Context

Mumbai is the most populous city in India, the seventh most populous in the world and projected as the sixth most populous by 2030 (UNDESA, 2018), despite its growth rates declining since 1991 (MMRDA, 2003). Located in the southwestern part of India, it is the state capital of Maharashtra and the financial capital of the country. The city of Mumbai, also known as Greater Mumbai, comprises the two districts of Mumbai City and Mumbai Suburban and is part of the Mumbai Metropolitan Region (MMR) that includes three more districts — Palghar, Thane and Raigad. The MMR covers an area of 6,328 square km and is governed by various Municipal Corporations and ULBs; and the Mumbai Metropolitan Development Authority (MMRDA) is the planning and infrastructure development authority for the MMR. The Mumbai Climate Action Plan (MCAP) has been developed for Greater Mumbai. As per Development Plan for Greater Mumbai 2034 (DP 2034), Greater Mumbai covers an area of 458.28 sq km and is managed and governed by the Brihanmumbai Municipal Corporation (BMC). For the purpose of administration, the BMC is divided into 7 zones and 24 wards. The three geographic divisions are Mumbai city, western suburbs, and eastern suburbs. The BMC is led by the Municipal Commissioner and four senior IAS officers as Additional Municipal Commissioners (AMC), one for each division and one for spearheading special projects across the city. Detailed information is presented in Chapter 6.

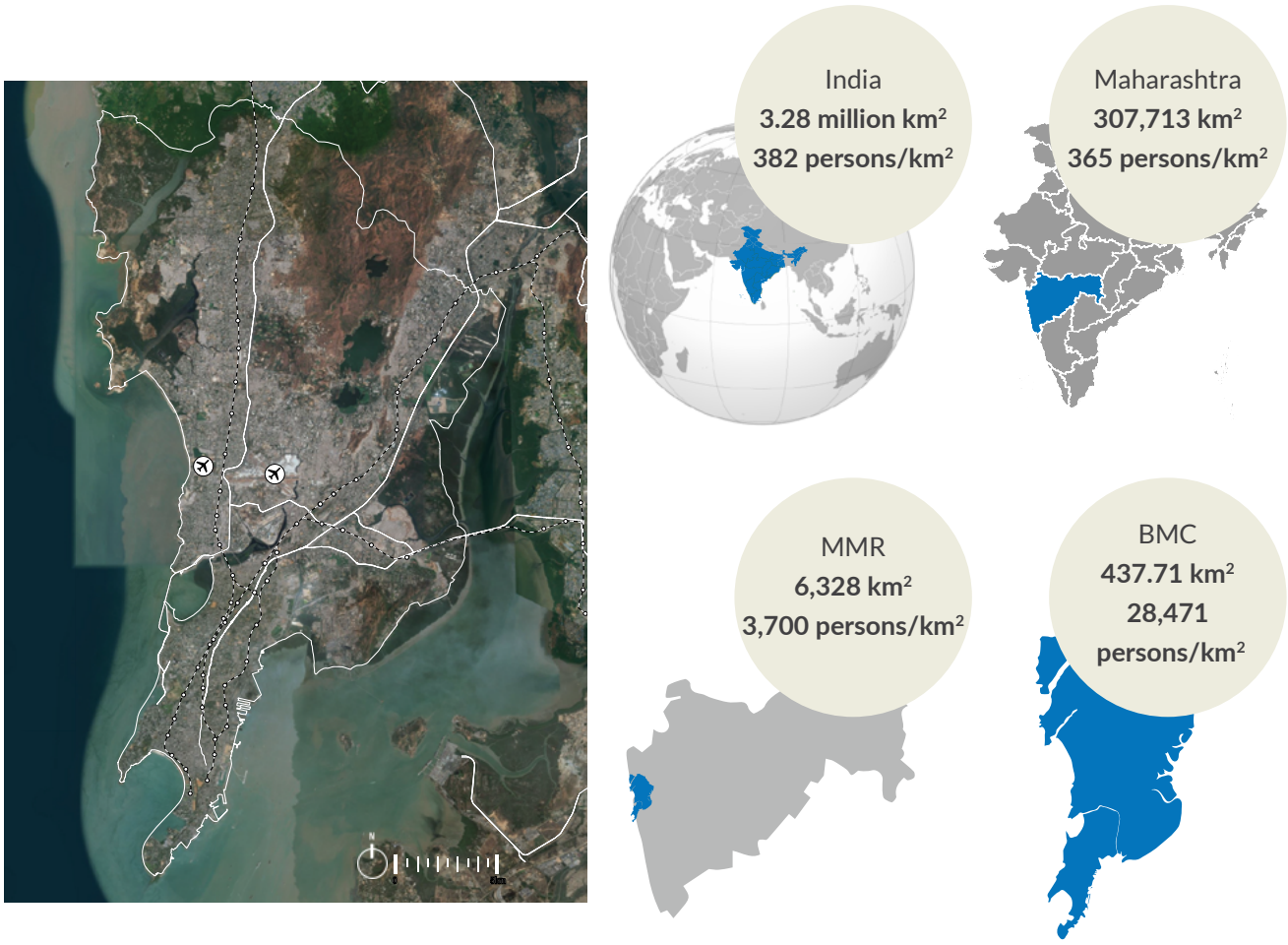


Figure 1 : *Location of the Mumbai Metropolitan Region and Mumbai city in the State of Maharashtra in India (Source: WRI India, Contains Modified Copernicus Sentinel Data [2022])*

1.1 Ecological Landscape

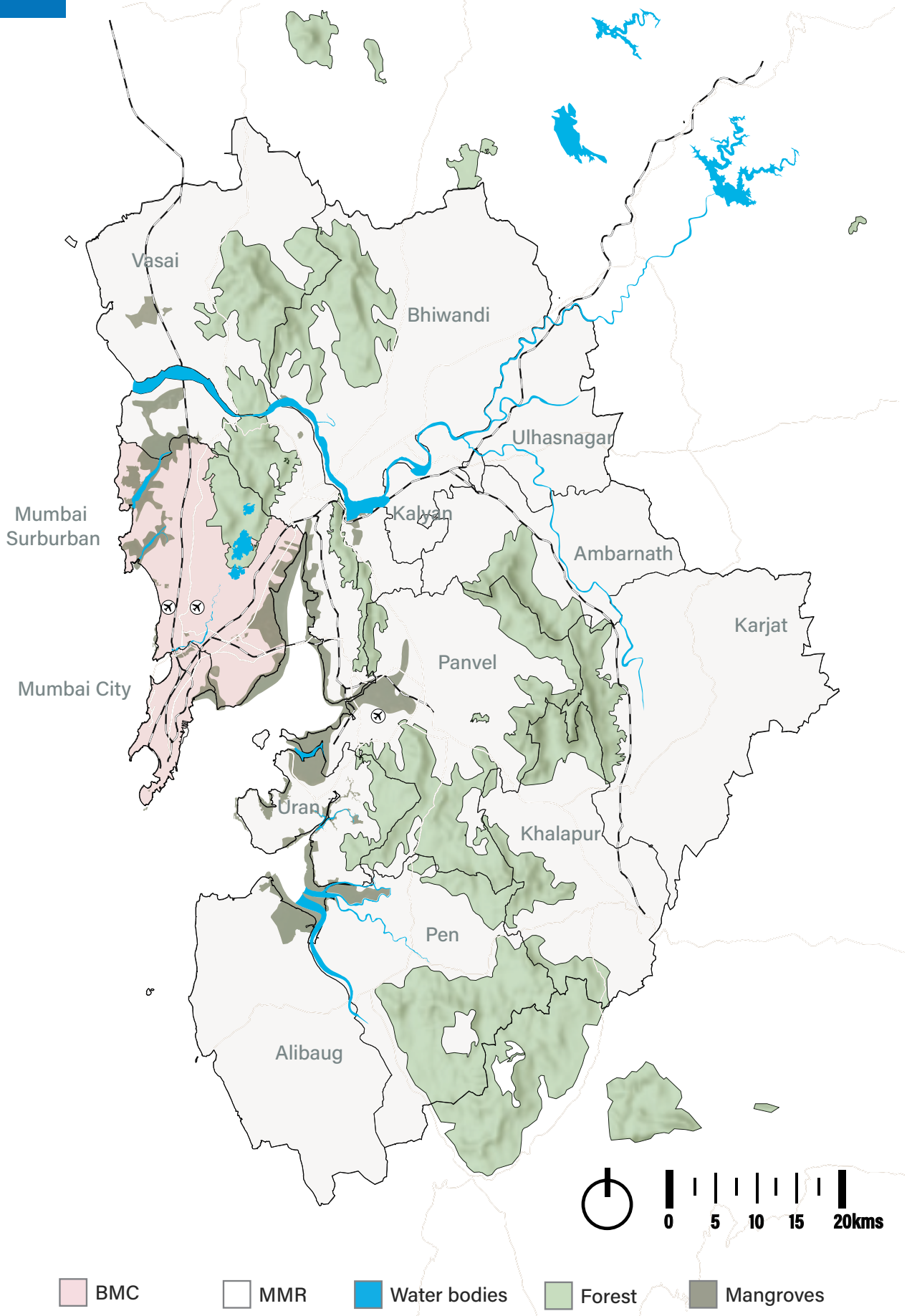


Figure 2: *Greater Mumbai's ecological and urban landscape (Source: Map by WRI India)*

The Mumbai region is located on the windward side of the Sahyadri range, also known as the Western Ghats. Greater Mumbai is a coastal estuary that lies south of the Ulhas river and is drained by four rivers into the Arabian sea – Mithi, Dahisar, Poisar and Oshiwara. These rivers originate from the Powai-Kanheri ranges in Sanjay Gandhi National Park, a protected area in the northeast of the city (Disaster Management Department of BMC, 2019). Mumbai's coastline of 146 kms is indented with numerous creeks and bays, stretching from the Thane creek on the eastern coast to Madh and Marve on the western coast. The eastern coast is characterized by large mangrove swamps, rich in their biodiversity, while the western coast is mostly sandy and rocky with few mangroves and wetlands closer to the creeks. These mangrove forests guard the city against tidal erosion, support an ecosystem of flora and fauna and prevent urban flooding, besides performing the function of productive carbon sinks. The DP 2034 has demarcated these ecologically sensitive areas, such as forests, mangroves, water bodies and areas under the Coastal Regulation Zone (CRZ)-I, as Natural Areas where no (built) development is permitted.

Mumbai city, commonly known as the island city, is the older part of the city that is marked by Mahim creek and the Mithi river on the north and extends up to the Backbay reclamation in the south. As the name suggests, the island city of Mumbai was built through a process of reclamation, connecting seven islands south of Salsette island or present-day Bandra. This has resulted in several "low-lying" areas that are just above the mean sea level and chronically challenged by monsoon and tidal flooding. Northern Mumbai is hilly, with the highest point in the city at 450 m in the Powai-Kanheri ranges. The forest in Sanjay Gandhi National Park further subdivides Mumbai's suburbs into western and eastern. It is the only mega city in the world that has a forest within its boundaries. The city's landscape is dotted with three lakes — Vihar, Tulsi and Powai — and several small ponds, comprising 0.2% of the total area.

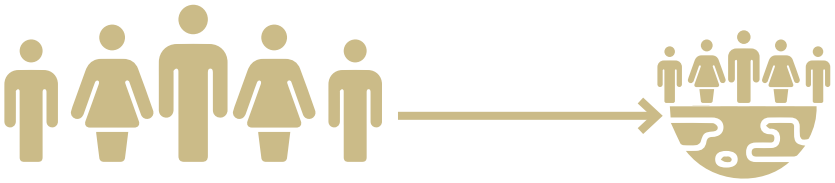
1.2 Urban Landscape

The land use survey for Mumbai conducted as part of DP 2034 revealed that while 65% of the planning area (area under the jurisdiction of BMC) is developed, 35% lies undeveloped. The undeveloped areas comprise natural areas, vacant land, plantations, and salt pans. Mumbai's land use distribution is 38% residential, 8% industrial, 3% commercial and 1% office. In addition, 33.43% is used for amenities, open spaces, public utilities and transport, while 14% comprises roads. The city's existing housing stock of 3.1 million units includes a mix of 2.6 million residential and mixed-use units, with 0.5 million vacant homes. Of the total housing stock, approximately 38,000 units are identified as "dilapidated" or structurally unstable and approximately 23,000 units are "non-serviceable"; these are largely located in the older precincts of south and central Mumbai. In addition, 42% of the city's residents live in slum settlements. Ageing buildings, small homes and underserviced slum units have led to a demand of 1.1 million new units in the city that are affordable and dignified. The planning institutions Maharashtra Housing and Area Development Authority (MHADA) and Slum Rehabilitation Authority (SRA) build affordable housing and develop policy and regulatory instruments to address housing shortage. There is immense scope for the MCAP to introduce energy-efficiency and climate-resilience in this sector. Chapter 5 presents more details.

Mumbai's spatial development is largely concentrated around mass-transit stations along the vast suburban railway network, and the city's transport modal share includes a high share (76%) of public transport usage. This includes trips on the suburban railway, metro, monorail, and the public bus system Brihanmumbai Electric Supply and Transport Undertaking (BEST). Mumbai's BEST bus network is one of the oldest and largest in the country, with a fleet strength of 4,128 buses (as of 2021), operating on 507 routes. The suburban rail services carry an estimated 7 million passengers every day while the public bus transport system accounts for 5.5 million passengers. As of 2015, suburban rail had the highest modal share (62%) within public transport, followed by the BEST bus network (34%). The metro and monorail comprised a total of 4% MoHUA, 2016). To improve regional transportation corridors, the MMRDA has conceived a series of trans-harbor links, connecting Greater Mumbai to the MMR along the eastern coast.

1.3 Social and Economic Context

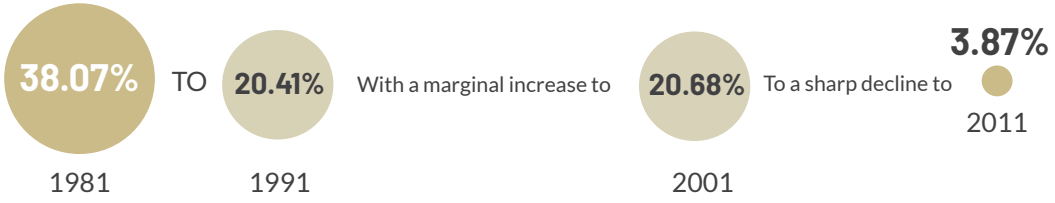
Mumbai is one of the densest mega cities in the world

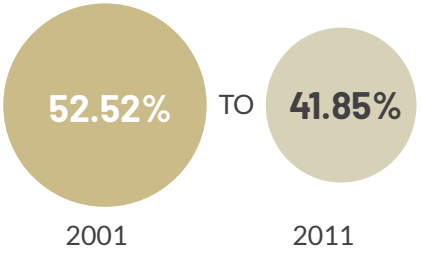


With a population of **12.44** million (as per Census 2011)

Population density of **28,426** persons/sq.km.

The Growth Rate Percentage of Slum Residents in Mumbai from 2001-2011





Though spatial coverage of slum areas has increased as per satellite images, population projections (based on academic research models) estimate that the Mumbai Metropolitan Region (MMR) will be the world's largest urban agglomeration by 2050, at 42.4 million people (Hoornweg & Pope, 2014).

The sex ratio of Greater Mumbai stands at 853 per 1000 males, which is lower than the state average of 925 and the national average of 940. The lowest sex ratio of 695 is observed in C-ward in south Mumbai. The district of Greater Mumbai has the highest literacy rate (81%) and highest female literacy rate (77.7%) in the MMR. M/E Ward has the lowest effective literacy rate, of 83%, and the lowest effective female literacy rate, of 78%. Despite the relatively high literacy rates in the region, in 2019, only one-fifth of women in Greater Mumbai were employed and only 17% of their trips were for work as compared with 80% for men, according to a World Bank (2021) study. Findings from the survey revealed that women were seen accessing fewer economic opportunities even though they were commuting for an equal duration of time as men, with a majority of them identifying commuting as a barrier. Systems that do not explicitly recognize gender differences in access and usage can exacerbate gender inequalities. The dependency percentage, which is the percentage of the elderly and children that is not in the labor force, for Greater Mumbai is 37.5%. Data reveals that the city areas falling in the BMC jurisdiction have a lower population of persons belonging to the Scheduled Castes and Scheduled Tribes as compared with that in the MMR. Data on asset ownership across the city reveals that 85% households own a television, 61.7% households own a mobile phone, and 20.1% households own a computer with access to the Internet, indicating the extent of socio-economic stability as well as access to information and telecommunication systems that is critical during disasters.

Mumbai has an estimated GDP of $310 billion and contributes to more than 6% of the nation's GDP (Disaster Management Department of BMC, 2019). The key sectors contributing to the city's economy are finance, IT & ITES, textiles, entertainment, gems and jewellery and leather processing. Over the years, the economy of the city has transformed from being a major trading port to a manufacturing hub to a services and financial center (BMC, n.d.). The employment data clearly reveals the shift from manufacturing to services. The total service sector employment increased from 55% in 1961 to 64% in 2001 (BMC, n.d.). Similarly, factory employment reduced from 4.47 lakhs in 1991 to 3.39 lakhs in 2001 to only 2.59 lakhs in 2011 (MMRDA, 2021). Despite the increase in service sector employment in Greater Mumbai, the city recorded a negative growth over the last two Census periods, from 88.2% in 1998 to 78.89% in 2005.

The work participation rate (WPR) in Mumbai has remained consistent since 1961, between 35% and 40%. While male WPR hovers between 55% and 61%, female WPR has doubled, from 8.81% in 1961 to 16.38% in 2011. Despite this, the gender participation gap in the city is wide. The Census of India 2011 identifies 44.2% of Mumbai's population as "migrants", of which 62.7% have migrated from outside Maharashtra and 30.4% migrated for employment. Of the migrant population, 55.8% are male. A 2021 IIED study (Bharadwaj et.al., 2021) states that recurrent climate disasters, such as floods and droughts, have a tremendous impact on livelihoods, forcing people to migrate to other cities and work in the informal sector. Approximately 65% of the city's workforce is employed in the informal sector (Bhowmik, 2010), exacerbating the negative impacts of climate-induced hazards among these vulnerable communities. This also suggests that exposure to and experience of climate risks are highly varied across the city and across different socio-economic groups.

By Zeber 2010

Shot at Shivaji Park | By Saikiran Kesari

Chapter 2:
Mumbai's Baseline Assessment

Mumbai's Baseline Assessments include Three Parts

1. The Climate & Air Pollution Risks and Vulnerability Assessment that places the issues of increasing risks and vulnerability in Mumbai city in the global context of climate change

2. The GHG inventory that summarizes the key sources responsible for GHG emissions

3. An inventory of natural green cover in the city that will help sequester carbon dioxide (CO_2)

Adaptation strategies help reduce the city's (including people, communities, infrastructure, systems, and services) vulnerability to climate change, while mitigation strategies are those that enable GHG emission reduction. The link between GHG emissions and increases in the frequency and intensity of extreme weather events is unequivocal. This calls for cities to take immediate steps to adapt to climate risks and ensure that new investments are not detrimental to the city's climate in the future.

2.1 Assessment of Climate Risks and Vulnerabilities in Mumbai

Mumbai city faces two major climate challenges – rising temperatures and increasing number of extreme rainfall events (ERE). The city has been routinely experiencing higher temperatures and variable heat stress in areas with higher urban heat island[3] (UHI) effects. The total rainfall per season has also increased, with a fewer number of rain days. Flood prone areas — areas that are either low-lying or marked by poor storm water drainage— are routinely waterlogged during the monsoons and remain submerged for several hours during EREs.

Landslide prone areas too experience heavy loss and damages as a result of EREs, especially if the retaining walls are weak or fail. In recent years, there has been an upward trend of cyclonic events in the Arabian Sea due to warming seas, thereby increasing coastal risks for the city. Coastal communities in fishing villages or slum settlements close to the east or west coast face coastal inundation even during non-monsoon days., with Often high tides bring in sea water, causing localized flooding which only retreat with the low tide.

[3] UHI effect is a heat accumulation phenomenon within an urban area that is a consequence of urban construction and human activities. It has been recognized as the most evident characteristic of urban climate (L. Yang et.al., 2016).

Projections made as part of recent research by Climate Central projects indicate that a large part of Mumbai city is at risk of being submerged by 2050 (Kulp & Strauss, 2019) and that by 2080, the likelihood of urban floods, such as the 2005 event, is more than double (Ranger et al., 2010). Based on a report by Patankar et al (2010), the Indian Merchants Chamber (IMC) has estimated the financial losses of the 2005 deluge to the tune of USD 1,100 million, of which around USD 245 million could be the value of the losses borne by the marginalized population and the informal economy alone (Patankar, 2015). If the potential risk of such events reoccurring doubles over a period of time, the likelihood of potential financial losses will also double. Several impacts of climate change – sea level rise, extreme rainfall events and storm surge – can compound the impacts, resulting in more days of inundation (or submergence) during which low-lying and vulnerable parts of the city may be cut off and residents may need to relocate temporarily. Anthropogenic activities have been neglectful of the estuary nature, landscape ecology and diverse demography of the city, exacerbating vulnerabilities (TERI, 2014). **It is projected that by the 2070s, Mumbai will be among the top Asian cities in terms of population exposed (including all environmental and socioeconomic factors) to coastal flooding** along with Kolkata, Shanghai, Bangkok and some other cities (Hijioka et al., 2014).

Along with climate-induced risks, the increasing air pollution caused by the increasing traffic congestion, unregulated construction activities and mismanaged solid waste adds to the city's risk exposure, leaving vulnerable communities more exposed to adverse health impacts. These risks impact different communities to varying degrees. Communities living in informal settlements, residing in weak structures, with poor access to services or in areas with poor vegetation or lack of open spaces remain more exposed or sensitive to risks. This section of the baseline assessment focuses on analyzing climate risk and air pollution trends in the city and understanding differential vulnerabilities based on socio-economic aspects and access to infrastructure or essential services. The Maharashtra State Adaption Action Plan on Climate Change (SAPCC) 2014 (TERI, 2014) provides the context for climate vulnerability at state, regional and city levels.

In Maharashtra, 40% of the geographic area is drought-prone and 7% is flood-prone, with deficient rainfall reported every once in five years. The state experienced severe and successive years of drought during 1970-1974 and 2000-2004. Severe drought conditions occur once in 8-9 years. According to a recent study on India's vulnerability to climate change, projects that Maharashtra is the third most vulnerable state in the country and Mumbai is one of five districts in Maharashtra most vulnerable to the compounded impacts of climate change (CEEW, 2021). Climate risks, such as severe droughts, extreme heat waves, and unseasonal riverine flooding, in the State of Maharashtra indirectly impact Mumbai and other cities, in the form of climate-induced migration (Vitthal et al., 2021) and food insecurity (Chakrabarty, 2016).

Methodologies Applied in Analysis of Risks and Vulnerabilities

The Climate and Air Pollution Risks and Vulnerability Assessment framework used to develop the MCAP was aligned with the C40 Cities' Climate Change Risk Assessment (CCRA) framework through its screening parameters related to past climatic trends and future projections based on global models and assessment reports such as the IPCC, state and national plans. The climate and air pollution risks were assessed spatially and temporally and by exploring the relationship between the parameters that increase a community's exposure or sensitivity to climate risks and potentially decrease or restrict their adaptive capacities during extreme events.

The spatial analysis was carried out using GIS and remote sensing-based technologies to identify the areas that are more exposed to climate or air pollution risks. Monitored weather and air pollution data was used to map decadal, inter-annual and temporal (monthly, daily and hourly) trends, present associated impacts and project potential future trends. Socio-economic sensitivities were mapped using Census of India 2011 data by visualizing and overlaying risk layers at the ward level to identify the potentially vulnerable wards in the city. BMC's services and amenities data was visualized spatially to identify the underserved neighborhoods with poorer adaptive capacities[4]. Finally, these different data sets were correlated to present the interlinkages between climate risks, air pollution risks, socio-economic sensitivities and compromised access to infrastructure and services.

Shot in Kurla | By Manoej Paateel

[4] Socio-economic indicators, including access to information, education, housing and access to essential services such as water, sanitation and electricity, enhance people's ability to manage or withstand climate stresses and shocks, often characterized as "adaptive capacities".

Assessment of Climate-Induced Risks in Mumbai

Urban Heat

Mumbai presents a warming trend over a period of 47 years (1973-2020), with an increase of 0.25°C per decade observed between 1973 and 2020.

An increase in frequency of warmer years has been observed with three out of the last five years

Indicating a departure of more than 1°C from the baseline average air temperature (1973-2020)

Between 1973 and 2020, 10 heatwave and 2 extreme heatwave events were observed.

Since the mid-'90s, a transition from caution[5] to extreme caution events has been observed, with over 200 days annually classified as extreme caution events.

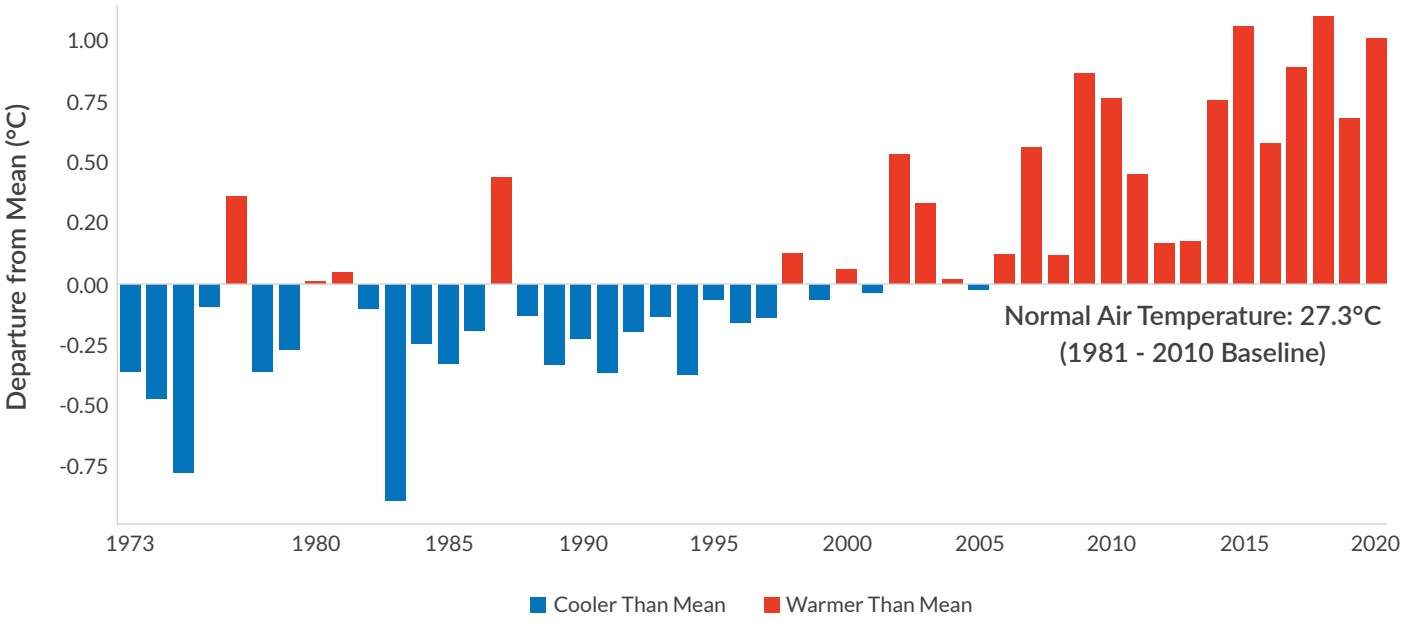


Figure 3: *Annual air temperature anomalies between 1973 and 2020*
(Source: Meteorological data from IMD Santacruz station (1973 - 2020))

Land Surface Temperature (LST) data was analyzed to identify the heat islands in the city, where increased heat exposure is caused by certain land use types (such as industrial and commercial), poor vegetation cover, or high exposure to heat-conductive or reflective building materials, such as metal roofs, glass and steel structures. Mumbai airport recorded a temperature of over 35°C owing to the nature of land use, a large footprint, extensive use of concrete and asphalt and very low vegetation cover. On the contrary, the areas adjacent to the mangroves and Sanjay Gandhi National Park recorded temperatures in the 25-30°C range due to the large area and density of vegetation cover that helps reduce the surface temperature. LST indicates a negative relationship with green cover (NDVI), with higher temperatures observed in areas with lower green cover. Higher LSTs result in increased UHIs in the city, resulting in areas that are more exposed to heat than others.

[5] National Weather Service under NOAA has classified heat index into four categories — Caution (26-32°C), Extreme Caution (32-41°C), Danger (41-54°C) and Extreme Danger (above 54°C) — to identify its differential adverse impact on human body. The phenomenon of heatwaves was determined based on the thresholds set by the IMD and the definition of heatwaves.

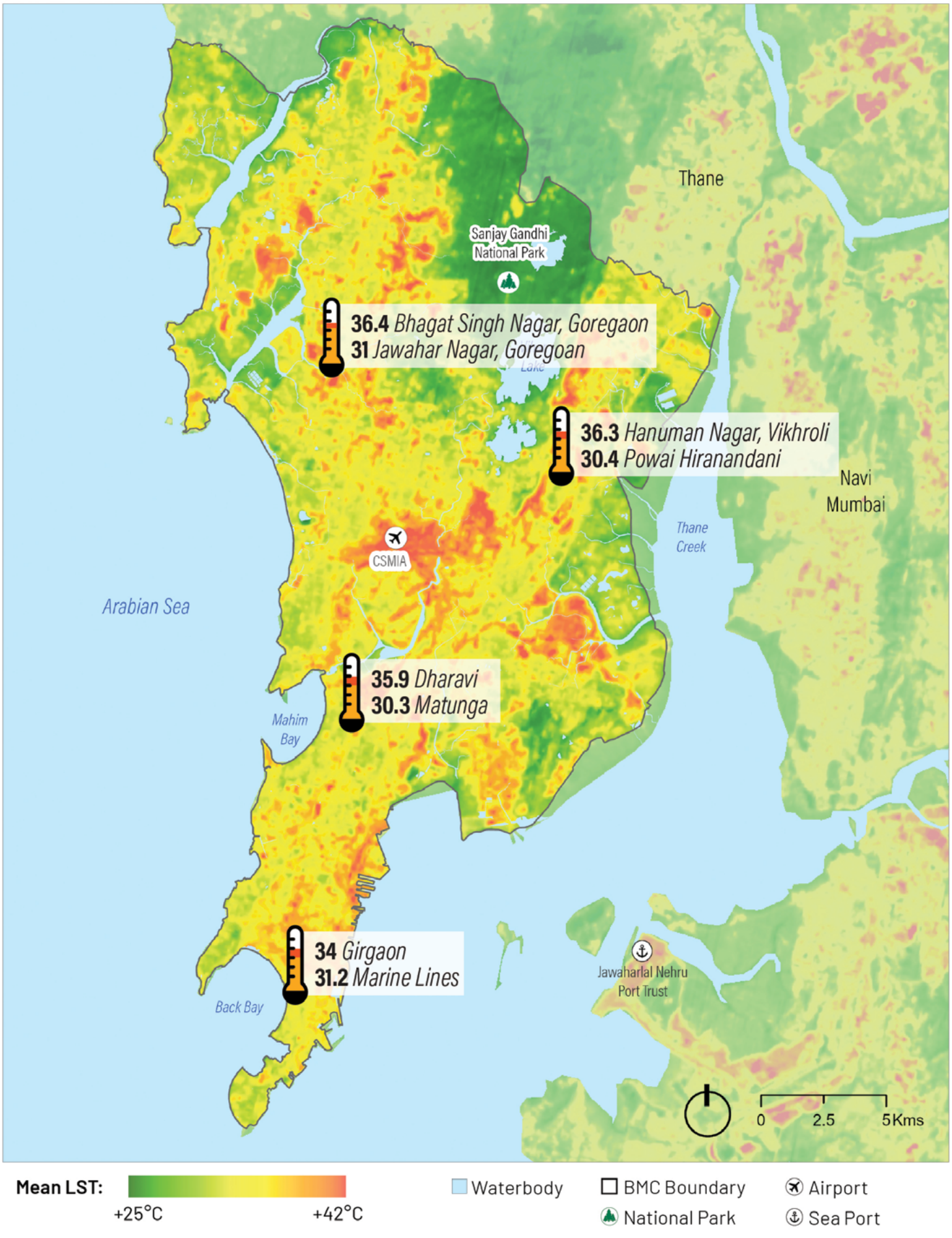


Figure 4: *LST map for Mumbai*
(Source: WRI India, LandSat 8 (USGS)

Mumbai also experiences high temperatures in the post-monsoon period, when humidity levels increase heat stress at relatively lower air temperatures. Low-income households and informal settlements are at a higher risk of indoor heat exposure (Mehrotra et al., 2018) due to poor light and ventilation inside the homes. A ward-level analysis of heat exposure of the population in Mumbai indicates that 40% of the population residing in the M-East ward are exposed to heat stress as opposed to 0.9% of those in A Ward. In higher density informal settlements with very low vegetation cover, temperatures were observed to be 6-8 degrees warmer than in the neighboring residential areas. This can be understood as a function of the high-density morphology of built form, choice of roofing material, which is majority metal or asbestos, and very low vegetation cover. Industrial and commercial land uses with large built-up footprints, such as the airport, industrial estates and malls, have a significantly higher surface temperature than blue-green areas (forests, lakes, mangroves), as shown in Figure 5.

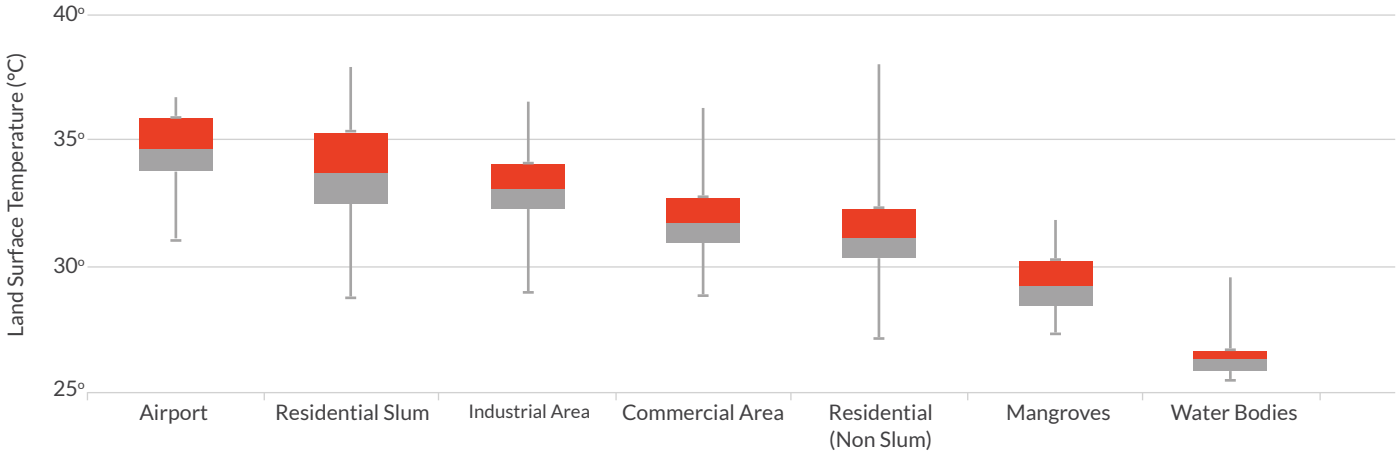


Figure 5: *Difference in surface temperature by land use and land cover in Mumbai (Source: WRI India using LandSat 8 (USGS), October (2017-2019))*

Future Heat Risk

As per the IPCC Fifth Assessment Report (Hijioka, et al., 2014), Asia is projected to experience more frequent and intense heat waves and an intensified heat island effect, resulting in a very high risk of heat-related mortalities in the long term (2080-2100), especially among vulnerable groups, such as outdoor workers, residents of informal settlements, children and the elderly. The IPCC A6 Atlas (IPCC 2021) projections for the Mumbai region are as follow:

By the end of the century, the mean temperatures are expected to increase by 1.5-2°C under RCP 2.6 and by 4.5-5°C under RP 8.5.

The maximum temperatures, specifically the total days above 35°C per annum, are expected to increase by 20-30 days under RCP 2.6 and by more than 40 days under RCP 8.5.

By 2050, India has a 10% likelihood of experiencing a lethal heat wave in climate-exposed regions that would lead to reduced productivity due to loss of working hours (McKinsey Global Institute, 2020). According to NOAA and Climate Lab projections, by 2040, in Mumbai, 60% of the days in a year will comprise high heat days, i.e., those days when temperatures could exceed 32°C. This, along with high-humidity days, would increase heat exhaustion and result in a sudden spike in heat-related deaths and illnesses.

Urban Flooding

Decadal data (2011-2020) accessed from 37 weather stations show that Mumbai experiences an average of 6 heavy, 5 very heavy and 4 extremely heavy[6] rain events per year. Between 2017 and 2020, there has been a steady increase in extremely heavy rainfall events. Spatially, most EREs tend to occur as localized clusters in western and central areas, such as Worli-Dadar, Kurla and Andheri. The analysis also shows that most EREs tend to last only a single day while 17% of very heavy and 21% of extremely heavy EREs last more than a day. Between 2004 and 2007, Mumbai experienced flooding annually causing heavy losses and damages (Kuruppu et al., 2018). The worst flooding in the city's history took place in July 2005 (Gupta, 2007), causing huge damages of over INR 450 crores and more than 900 deaths (TERI, 2014) (Hallegatte et al., 2010).

The low-lying areas of the island city have a history of flooding 5-6 times in a year, generally for a few hours, when high-intensity rainfall is coupled with high tides. In areas such as Sant Gadge Maharaj Chowk (Sat rasta) Rasta, Lower Parel and Grant Road, the land level is below the high-tide level. In these areas, the low-tide periods (about 10-12 hours in a day, below the mean sea level) provide relief during the storm when the accumulated surface waters are drained out (TERI, 2014). The Disaster Management Department in the BMC catalogues data on the flooding "hotspots" in the city, where waterlogging and flood incidents are common. Figure 6 shows the 699 hotspots marked across the city. These hotspots are also monitored by the Storm Water Drainage Department in order to help with infrastructural arrangements.

Wards F-north, H-east, H-west, K-west, L and M-west have over 40 hotspots each, making the population within these wards more vulnerable to the risk of flooding. This shows that about 35% of Mumbai's population is exposed to the risk of flooding[7] and wards H-east, H-west, and F-north are the most vulnerable, with more than 60% of their population exposed to risk. Wards P/N and S have the highest percentage of population living in informal settlements and a high number of flooding hotspots, making these wards the most vulnerable. These areas are particularly at risk during storm surge or cyclonic events when the sea level rises and coastal inundation takes place. Recurring waterlogging events create challenges in accessing places of work, thus impacting businesses, jobs and the economy as whole (UNICEF, 2021). Based on our analysis using DoE data (Source: MOSPI, 2013) and using a 500m buffer around flooding hotspots, every year, in Mumbai, 73% of small and large industrial and commercial establishments are affected during floods. Of the employees who work at these establishments, 69% experience limited access.

Mumbai ranks 5th among the world's cities most at risk of flooding, recording annual losses amounting to USD 284 million (Hallegatte et al., 2013). The catastrophic flood events of 2005 killed around 5,000 people and caused economic damages of up to USD 690 million (Nagendra, 2017). Several studies have projected that by 2050, such annual losses from flooding and heavy rain events will increase up to USD 6.1 billion per year (Picciariello et al., 2021). Most of these losses are uninsured and borne by individuals or small businesses (Patankar & Patwardhan, 2016), leading to devastating impacts on livelihoods and household incomes

Future Flood Risk

The IPCC AR6 predicts that South Asia will witness increased annual and summer monsoon precipitation during the 21st century, with enhanced inter-annual variability. Climate projections for Mumbai estimate that by 2080, the likelihood of a 2005-like event will more than double, under an "upper bound"[8] climate scenario (Ranger et al., 2010).The IPCC A6 Atlas (IPCC, 2021) indicates that owing to an increase in intense rainfall events, there is medium confidence that the region will be exposed to increased fluvial and pluvial flood events.

The analysis also points to the importance of adaptation actions, such as strengthening the city's storm water drainage network that can reduce losses due to a 100-year flood event by 70%. Other flood resilience solutions are described in Chapter 6.

[6] The IMD has categorized events on the basis of the intensity of rainfall. –An event is categorized as "heavy rain" when the amount of rainfall realized in a day is between 64.5 and 124.4 mm, "very heavy rain" when the amount of rainfall realized in a day is between 124.5 and 244.4 mm and "'extremely heavy rain" when the amount of rainfall realized in a day is more than or equal to 244.5 mm. More information can be accessed from the weblink https://www.imdpune.gov.in/Weather/Reports/glossary.pdf.

[7] Exposure to flooding is calculated by assuming a 250m radius buffer around each flooding hotpot and overlaying it with the population density.

[8] IPCC Special Report on Emissions Scenario (SRES) A2 estimates a projection of 3.4°C warming by 2100.

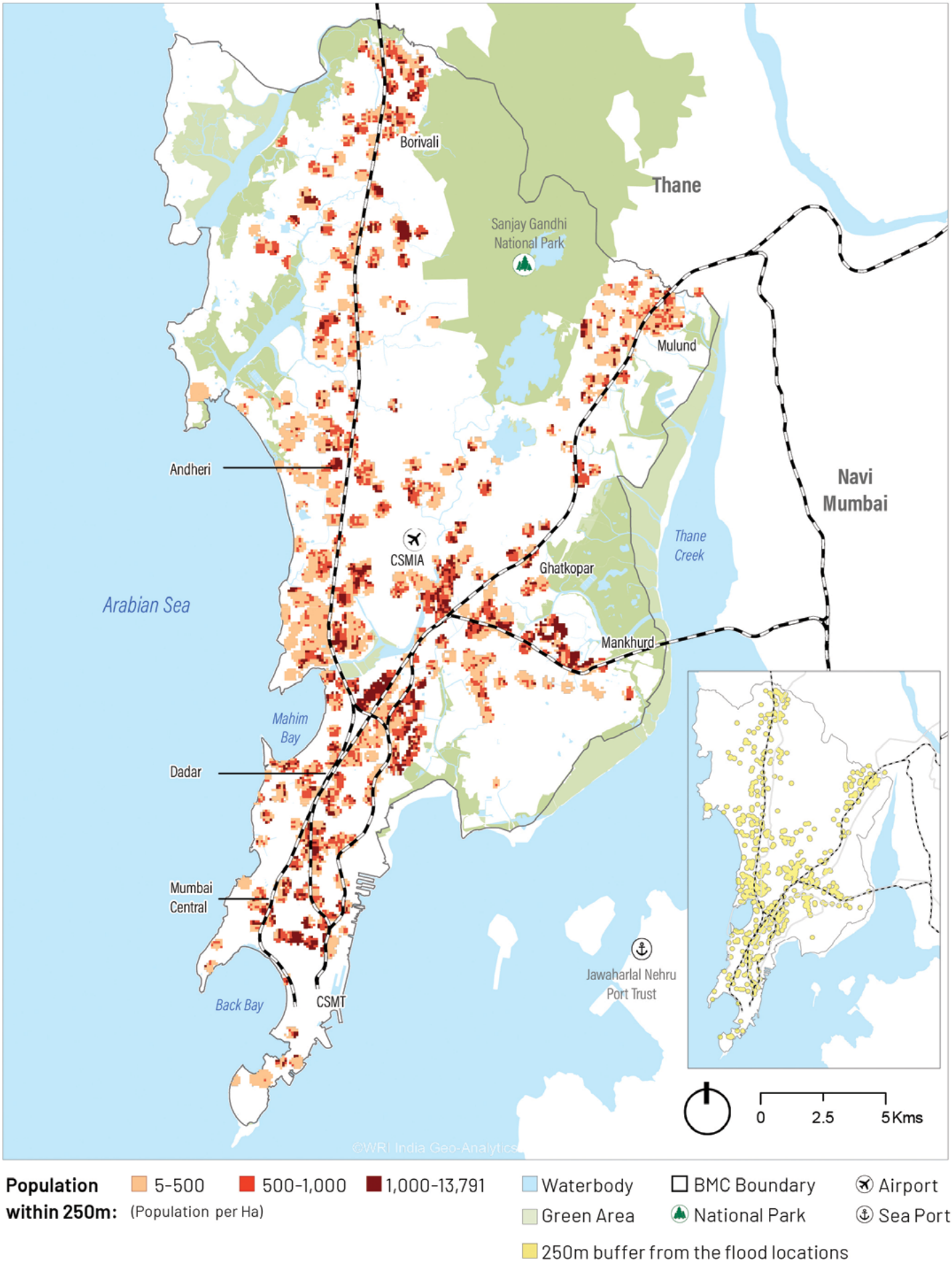


Figure 6: *Map showing BMC waterlogging hotspots and population density exposed within 250m risk area around each spot (Source: BMC and WRI India)*

Landslides

According to projections made in the IPCC report (2012), the settlements on unstable slopes or landslide-prone areas, which are common in some coastal cities in Asia, face increased prospects of rainfall-induced landslides. A majority of the locations that are prone to the risk of landslides are concentrated along the flanks of hill slopes and foothill regions in Mumbai towards the north, around Sanjay Gandhi National Park, in central Mumbai, around the Ghatkopar area and in the southwestern coastal areas around Malabar Hills.
As per the data recorded by the Disaster Management Department, BMC, there are 287 locations within Greater Mumbai that are landslide-prone, of which 209 fall in the extent of informal settlements (figure 7), exacerbating vulnerability, given the temporary nature and poor condition of built environment within these settlements. S-ward, with the highest slum population in BMC, is the most vulnerable with 160 landslide prone locations out of which 147 overlap with informal settlements.

The slums that are located along the slopes of the hills/ hillocks or foothill regions are prone to landslide events. These are majorly located towards the north, near Borivali and western flanks of Sanjay Gandhi National Park, and to the northeastern part of the city, near Mulund and Kanjurmarg, along the eastern flank of the National Park. The slums in the central part of the city, around Ghatkopar and the airport, are also highly prone to landslide events caused by sudden heavy rainfall episodes or slope failures. The slum pockets near Andheri and some south-eastern parts are affected by landslides.

Future Landslide Risk

The IPCC A6 Atlas (2021) indicates that there is medium confidence that the risk of landslides in India will increase. Given the projected trends for extreme rainfall for Mumbai, there is a strong likelihood that landslides will become an increasing risk for the city if adequate investments on adaptation are not made, especially in the vulnerable slum settlements located on/ in close proximity of hilly terrains.

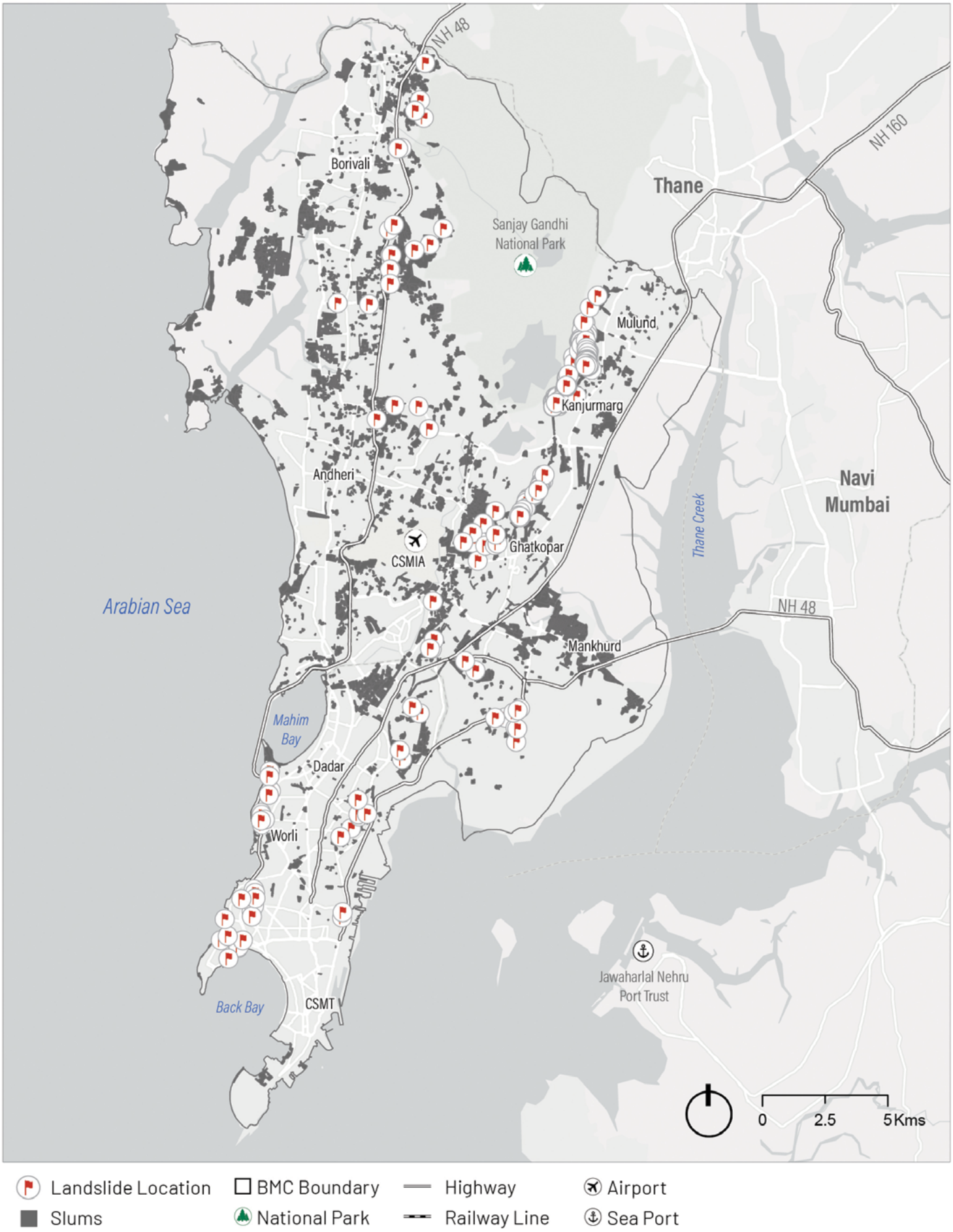


Figure 7: *Landslide-prone locations and informal settlements (Source: BMC and WRI India)*

Coastal Risk

Coastal risk assessment in Mumbai is made by examining sea surface temperature (SST) patterns along with measurements from tidal gauges, to understand the temporal patterns in tides and short-term effects such as storm surges. Analyzing storm surges is critical as a heated sea surface can create more cyclonic storms and the ability of the city's stormwater drainage to move water would be affected by the increased height of the sea. Coastal risk assessment also includes long-term coastline change analysis at different tidal phases (1990-2020), and the transformation in mangrove areas that act as a natural cushion against violent storm surges.

SST is an important physical property that impacts the biological processes and flora and fauna in coastal regions. SST is one of the key factors in the formation of tropical cyclones (TC) and must be at least 26°C (Dare & McBride, 2011) for TCs to develop. While various factors are required for TC development, SST is widely considered as a leading factor for examining the TC climatology, especially the maximum intensity that a TC can attain in a given environment (Thanh et al., 2019). As observed in several studies, the surface temperature of the Arabian Sea has increased (Bharti et al., 2020; Kumari et al., 2021; Nandkeolyar et al., 2013), over the last two decades, which can also be a tentative cause for the increase in cyclone events in the Arabian Sea. While the analysis of annual mean SST between 2003 and 2020 shows an absence of a statistically significant trend in sea level variations, as illustrated in Figure 8, a slight steady increase of 0.025°C per year for daytime SST and 0.019°C per year for night time SST has been observed.

Day Time Annual SST Trend in Arabian Sea

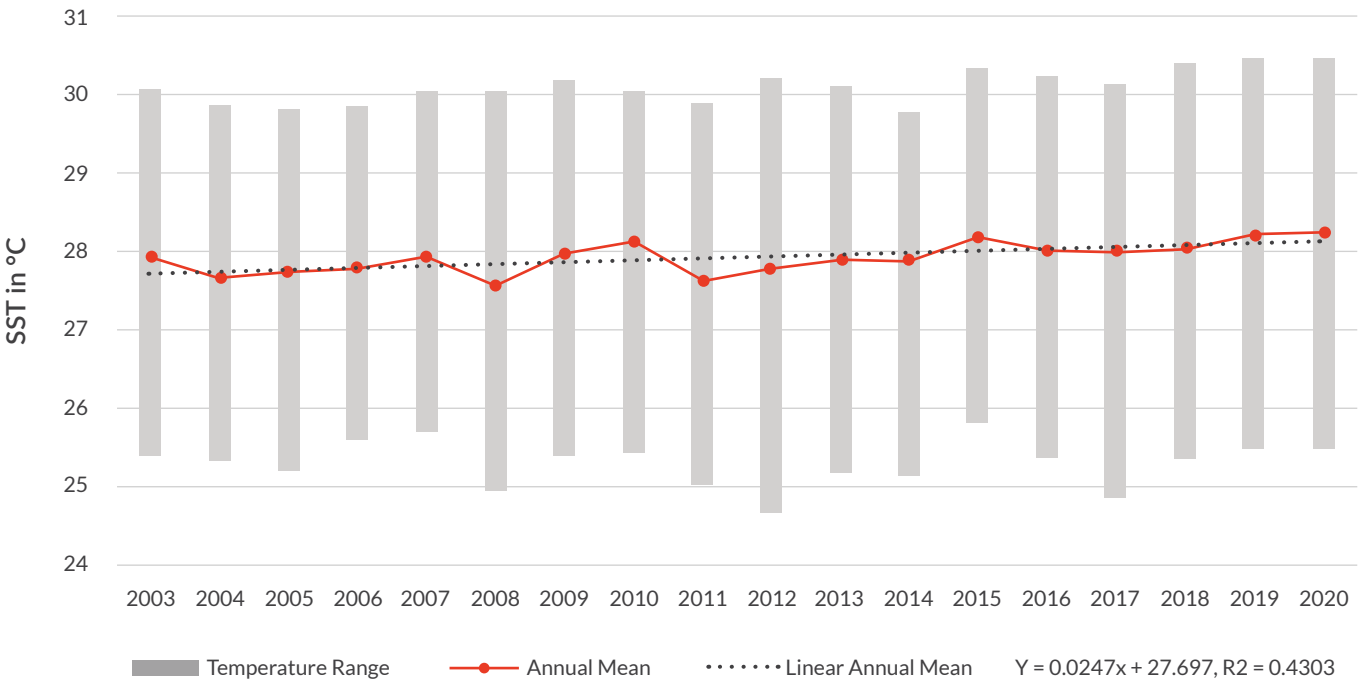
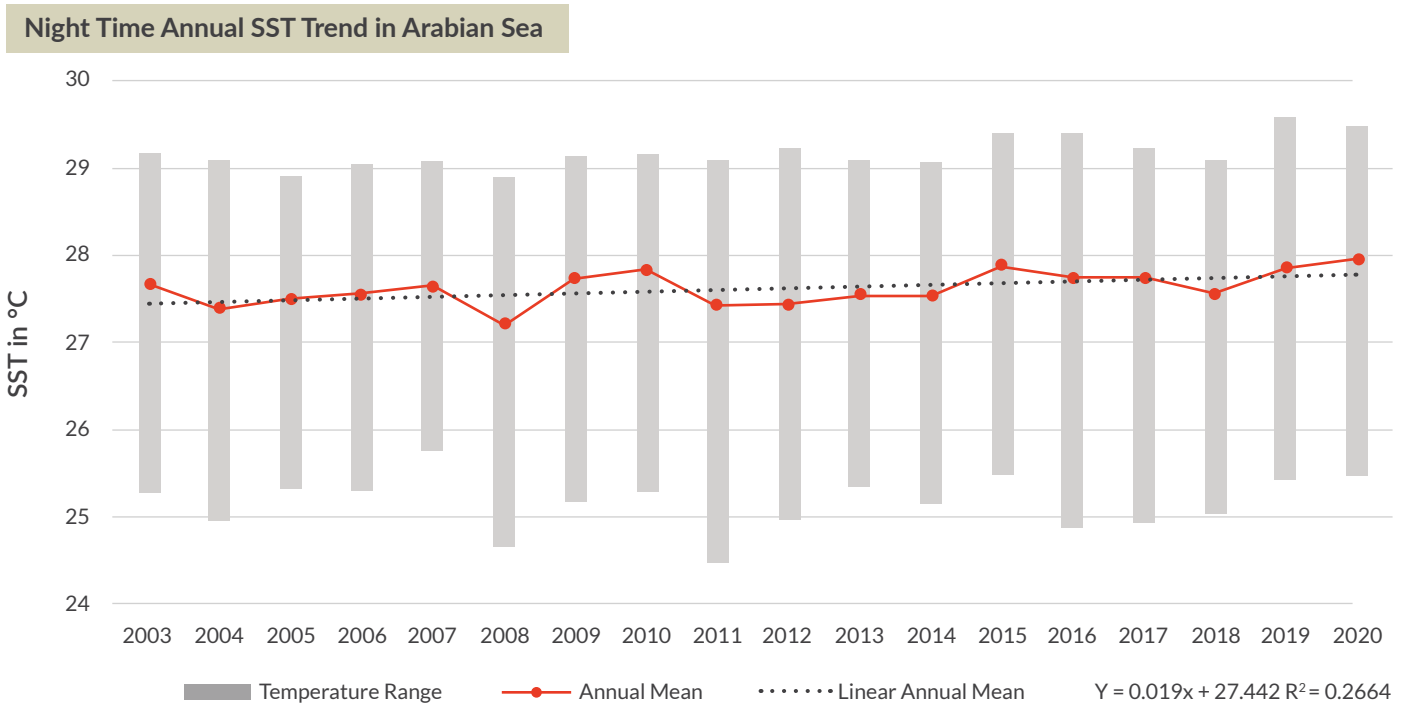


Figure 8: *Average annual sea surface temperature, 2003-2020 (a) Daytime (b) Nighttime, (Source: INCOIS Radar tide gauge data)*



(Source: INCOIS radar tide gauge data)

The annual sea level trend analysis (measured at the JNPT tide gauge, Mumbai coast) for the period between 2011 and 2021 shows an absence of a statistically significant trend in sea level variations. A storm surge event results in an exceptional rise of water level due to the impact of the strong winds associated with a storm. As per the India Meteorological Department (IMD), between January 2011 and June 2021, Mumbai and other areas along the Arabian Sea were subjected to 18 cyclone events. During this period, when the storm is active, the maximum sea level variation is used as an indicator of the amount of sea level change or surge due to the storm event. The year 2019 saw the highest number of cyclones occur in the region. This is highlighted by Cyclone Kyarr (2019) and Cyclone Tauktae (2021), both of which reached their highest potential during a high tide. Storms surge events that coincide with high tide formation are more likely to contribute to higher sea level increase. Figure 9 illustrates the sea level rise (SLR) associated with Cyclone Tauktae at 0.93 m. Projections of SLR for Mumbai city show that by 2050, the Arabian Sea could begin flooding most of Mumbai at least once every year, estimating the at-risk population to be three times more in the coming decades than was previously estimated (Goswami, 2019).

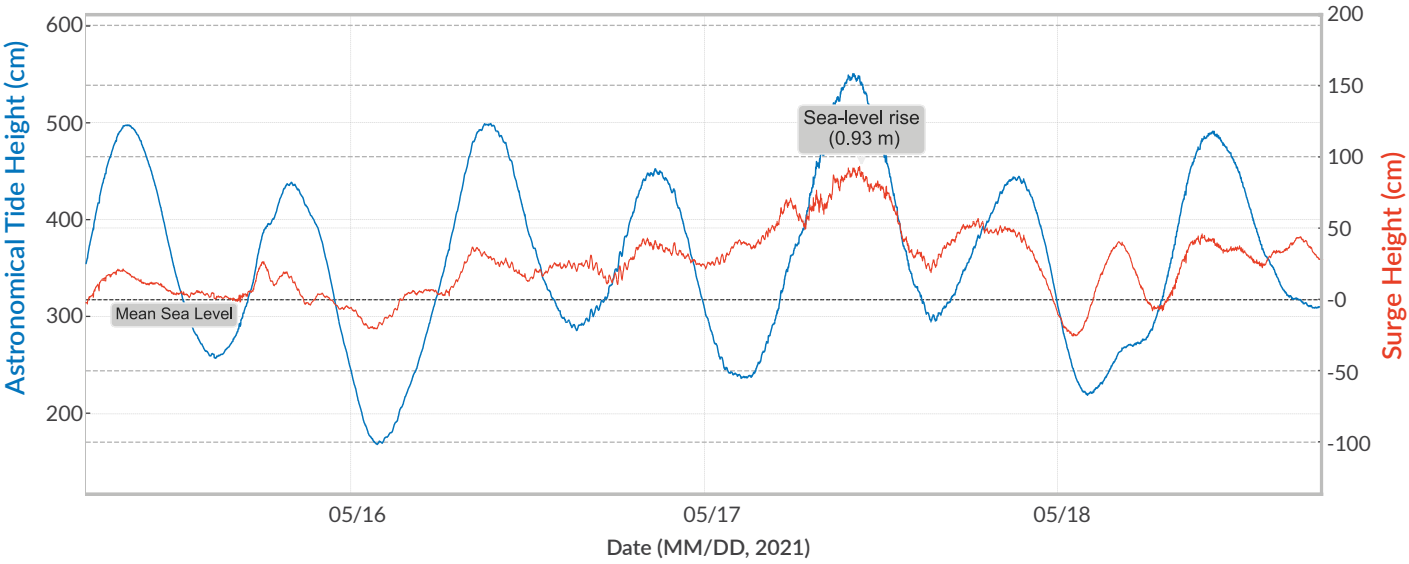


Figure 9: *Storm surge associated with cyclone tauktae, May 2021*
(Source: INCOIS Radar tide gauge data)

The overall coastline in Southern Mumbai has not changed much owing to the tetrapods stone blocks which line the sea. As illustrated in Figure 10, the coastlines in 2020 and 1990 reconcile for most of the shoreline length. The comparison between 1990 and 2020 shows that Thane Creek on the eastern side of Mumbai has been shrinking. This has also been observed by the Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra (2021). Parts of the creek have turned into mudflats and mangroves over the last three decades, with more than 14 sq.km of coastline witnessing mud deposition. The smaller creeks, led by Malad Creek, are shrinking due to the extension of mangroves and mud flats such as those in Thane Creek. On the northwestern coast, which is not protected and where there are no cases of land reclamation, in areas such as Versova and Juhu beach, the sea has been eroding and accreting. Ceaseless shoreline erosion poses threats in the form of loss of infrastructure, displacement of communities living near the shore and impact on the livelihood of communities dependent on coastal activities.

Increasing storm surges and sea intrusion can only be addressed by conserving mangrove forests and mudflats to protect coastal communities from routine inundation. However, there has been a significant transformation of mangroves since the year 2008, which can be attributed to the efforts made by the state Forest Department (Prasad et al., 2010) to protect the mangrove areas.

Based on the satellite imagery analysis, from the year 2008 to 2021, 325 ha of dense mangrove cover changed to sparse mangrove cover or has been converted to intertidal mudflats due to excessive erosion and sedimentation, as illustrated in Figure 11, and for around 305 ha of mangroves, the density has increased.

Future Coastal Risk

The IPCC A6 Atlas (IPCC, 2021) indicates that there is high confidence that the sea levels in India will increase. In addition, there is high confidence of coastal floods, coastal erosion and marine heatwaves. In addition, the IPCC AR6 regional factsheet for Asia states that relative sea level around Asia has increased faster than the global average, with coastal area loss and shoreline retreat. It states with high confidence that regional mean sea level will continue to rise, warning that Mumbai along with 11 other Indian coastal cities will witness sea level rise of 0.1-0.3 m over the next three decades due to climate change. Due to a lack of coastal data for the Mumbai coast, it is tough to establish SLR as a current risk for the city. The global projections are a warning to the city to pay heed to coastal adaptation strategies and plan for future risks.

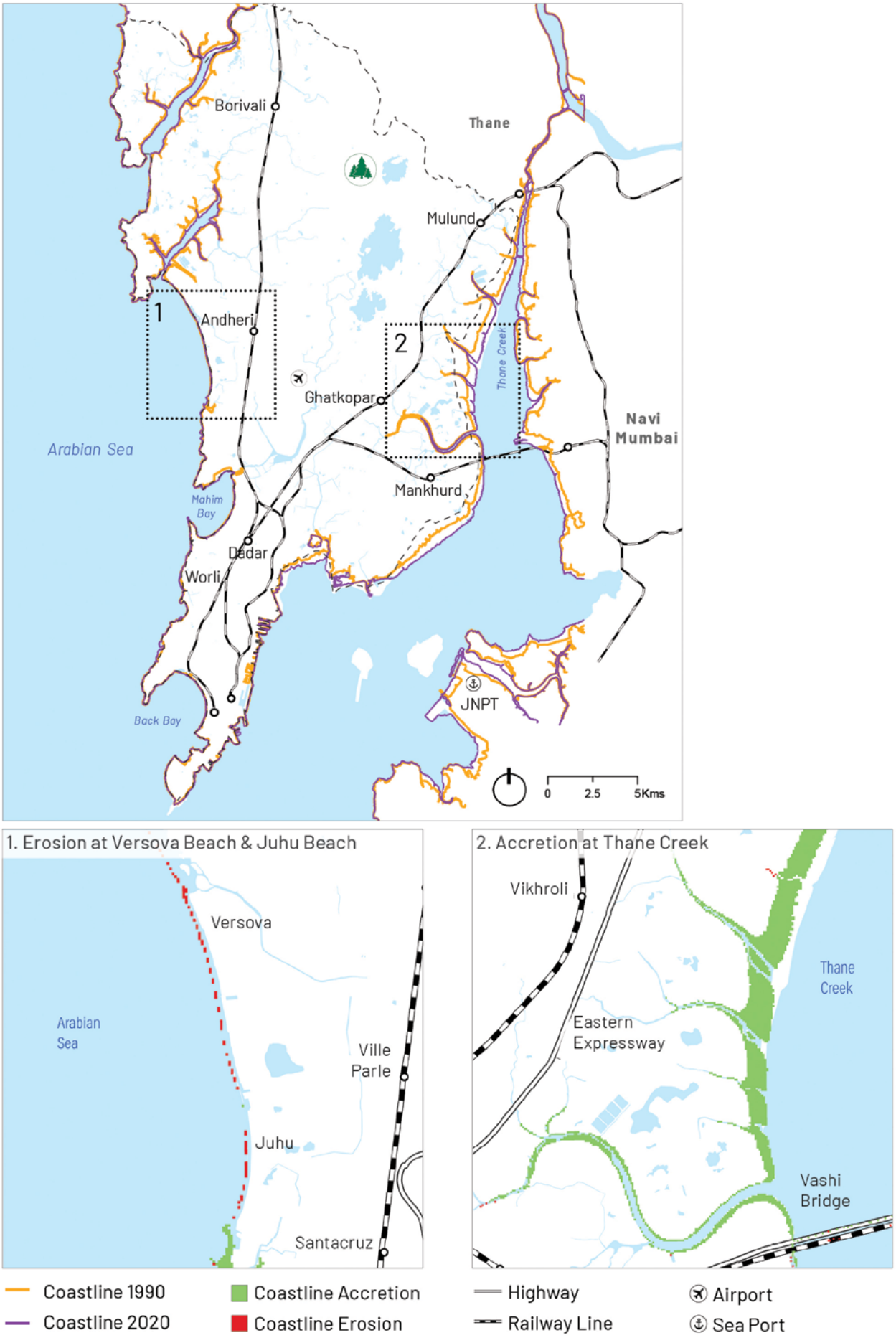


Figure 10: *Mumbai coastline change, 1990 vs 2020 (Source: WRI India, LandSat 5 & LandSat 8 (USGS))*

Figure 11: *Mumbai mangrove area assessment, 2008-2010 vs 2018-2021 (Source: WRI India, LandSat 5 & LandSat 8) (USGS))*

Assessment of Air Pollution-Induced Risks in Mumbai

In 2017, outdoor air pollution caused around 670,000 premature deaths in the country, a six-fold increase since 2000 (The World Bank Group, 2021). The air pollution risk analysis was done using data from seven Fixed Monitoring Stations of BMC for the period from April 2010 to March 2021, nine stations of SAFAR Mumbai for the period from July 2015 to March 2021 and CAAQMS data for the period from May 2019 to June 2021, which helped identify the temporal (annual) trends of various pollutants. The monthly and hourly variations in PM2.5 have been computed using hourly mean PM2.5 data recorded at nine CAAQMS monitoring stations in Mumbai for the period from June 2019 to May 2021. Monthly variation using mean weekday and weekend of PM2.5 concentrations has been derived using daily averages for PM2.5. Similarly, the spatial distribution of the pollutants was mapped for the period from June 2019 to May 2020 using the annual average value of Copernicus Sentinel 5P (TROPOMI) data. For PM2.5, the critical hotspots have been identified for the period from June 2019 to May 2021 using the data from CAAQMS monitoring stations.

The air pollution risk assessment includes the temporal and spatial concentration patterns and the distribution across various hotspots by pollutant type, highlighting certain times of day and particular areas that are more exposed. However, the scope and expanse of the analysis is hampered by critical data gaps that inhibit the ability to project correct past and future trends. Hence, this analysis helps identify those areas and concentration variations that show up as extreme but may exclude some others for which data is lacking.

PM10 and PM2.5: The air pollution assessment includes a trend analysis based on monitored data from monitoring stations of BMC and SAFAR to identify pollutant concentration trends at city level and around specific monitoring stations. The pollutants assessed for the trend analysis include particulate matter (PM 2.5 and PM10), nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (CO) and ammonia (NH3). Along with the annual trend analysis, the concentration of these pollutants with reference to their individual CPCB permissible limits was also assessed. The CPCB permissible limits of each of these pollutants are listed in Table 2.

Table 2: Critical pollutants by pollution control permissible limits

Pollutants	CPCB Permissible Limit	WHO Standards
Particulate Matter (PM) 2.5	40 (µg/m3)	5 µg/m^3
Particulate Matter (PM) 10	60 (µg/m3)	15 µg/m^3
Nitrogen Dioxide (NO2)	40 (µg/m3)	10 µg/m^3
Carbon Monoxide (CO)	1.78 (8 hrs) (ppm)	4 µg/m^3 (24-hour mean)
Sulphur Dioxide (SO2)	50 (µg/m3)	40 µg/m^3 (24-hour mean)
Ammonia (NH3)	100 (µg/m3)	NA

Although average annual concentrations of PM2.5 and PM10 have declined over the years (2015-2020), they continue to remain above the National Ambient Air Quality (NAAQ) standards. Areas with high concentration have emerged in Bandra Kurla Complex, Mazgaon, Andheri and Malad, as per SAFAR Mumbai data. In 2019, major concentration of PM2.5 was observed in the central part of the city around the airport, Kurla, Andheri and Sion. PM10 and PM2.5, being critical pollutants for the city, are majorly generated from construction and roadside dust and in traces from traffic congestion and vehicular emission.

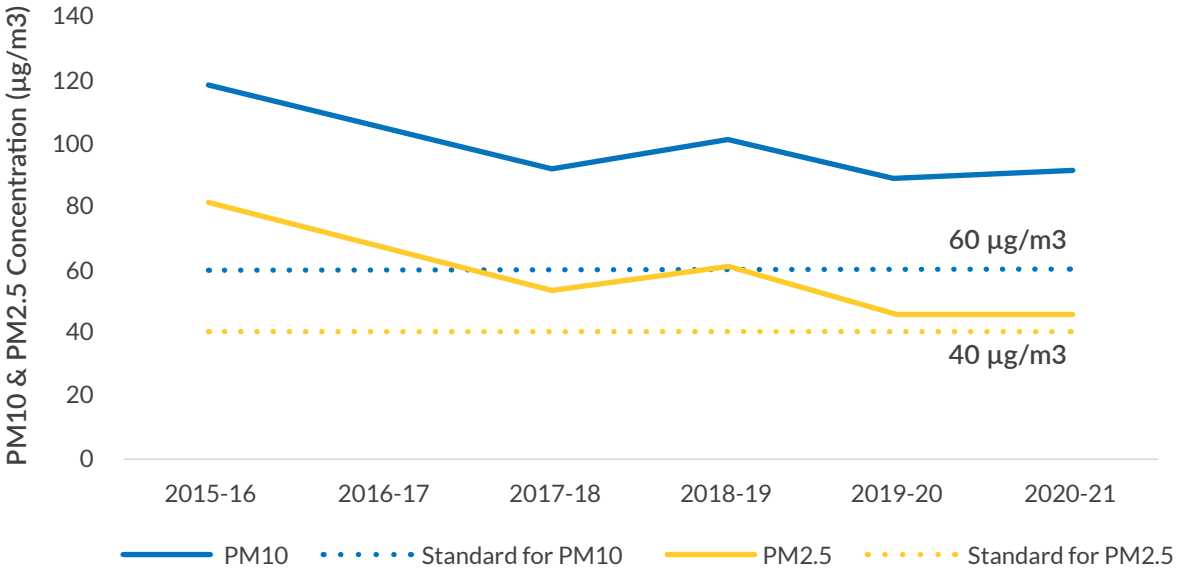


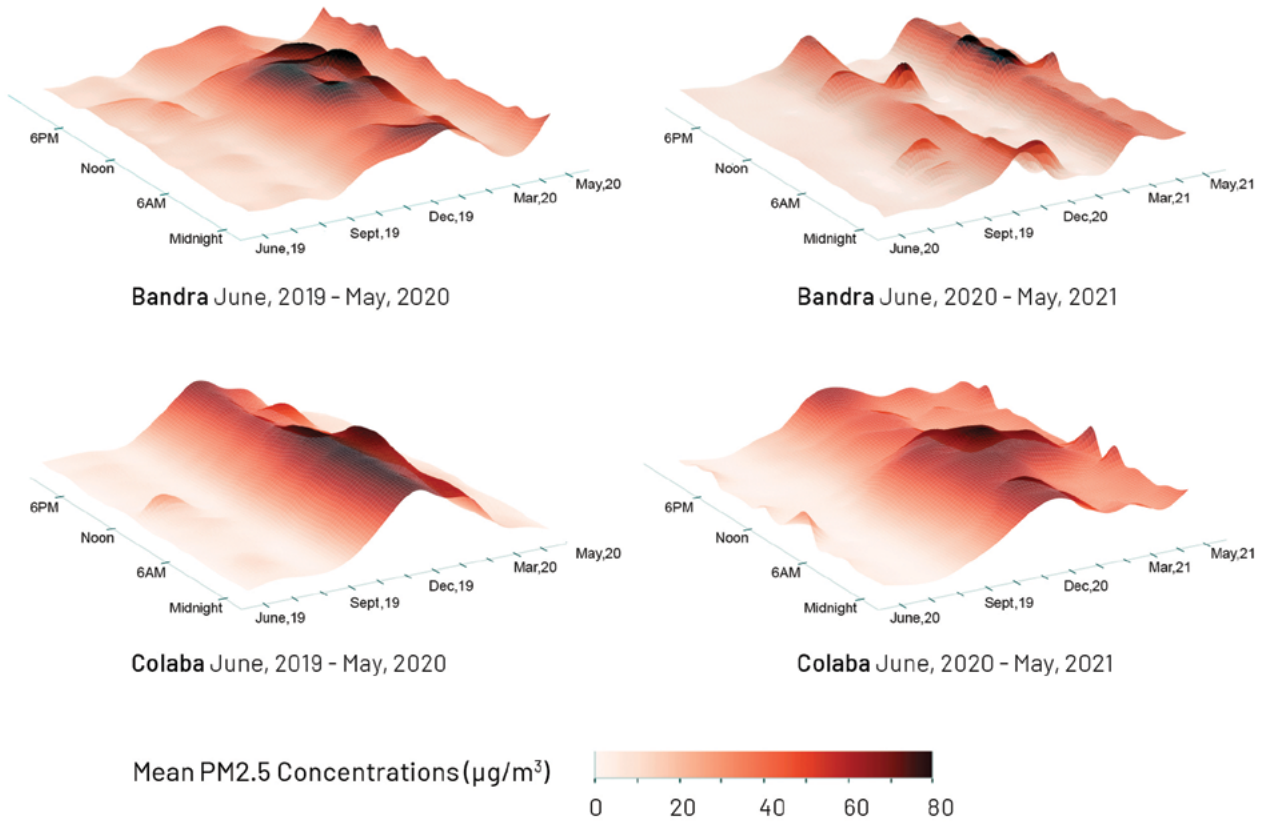
Figure 12: *Concentrations of PM10 and PM2.5 (July 2015 - March 2021) (Source: SAFAR - Mumbai,NAAQ)*

Figure 13 shows higher concentrations of PM2.5 were observed during the winter months than the rest of the year. Relatively lower concentrations were observed during monsoons, whereas the values start increasing after the monsoon period, reaching a peak during the winter months. PM2.5 values are higher on weekdays than on weekends, with some winter months recording higher concentrations on weekends due to festivities in that season. On average, peak morning and evening office hours show higher concentrations as compared with the other times of the day and a spike is seen past midnight due to high freight movement. On average, the maximum daily mean concentration for weekdays and weekends stands 2-3 times higher than the permissible limit of 60µg/m3[7], except in Kurla, Colaba and Ville Parle, where the weekdays and weekend peaks have reached levels that are 10 times higher than the permissible limit in 2019. In conclusion, areas in central Mumbai and traces in the southern part of the city show high concentration of particulate matter (especially PM2.5) mostly during the weekdays of the winter months, in the morning and evening office hours and after midnight.

NO_2

NO2 is a major pollutant in Mumbai, and most of the monitoring stations have recorded a high concentration of this for the years 2010-2020, beyond the annual permissible limit of 40 µg/m3. The pollutant is majorly concentrated in the central and south-eastern parts of the city [see Annex A 3.2] near the Tata Thermal Power Plant, the refineries in Trombay, the Deonar landfill site and in areas such as Khar, Andheri and Maravli. Widespread small- and medium-scale industries, petroleum refineries and dumpsites are major polluters of nitrogen dioxide. The trend analysis for the years 2010-20 reveals that concentrations of the pollutant showed a steady upward rise from 2010 to 2018, which later declined in 2020 during the pandemic and lockdown restrictions.

[7] The daily permissible standard for PM2.5 as per NAAQ CPCB is 60(µg/m3) and annual is 40(µg/m3)



Note: Both hourly-monthly 3D timeseries and weekly-monthly 2D timeseries for PM2.5 concentrations are to be read in tandem to understand the variations in PM2.5 levels.

Figure 13: *3D timeseries of hourly average concentration of PM2.5 for Bandra and Colaba monitoring stations, Mumbai, June 2019 - May 2021*
(Source: Two monitoring stations, CAAQMS; CPCB, June 2019 - May 2021)

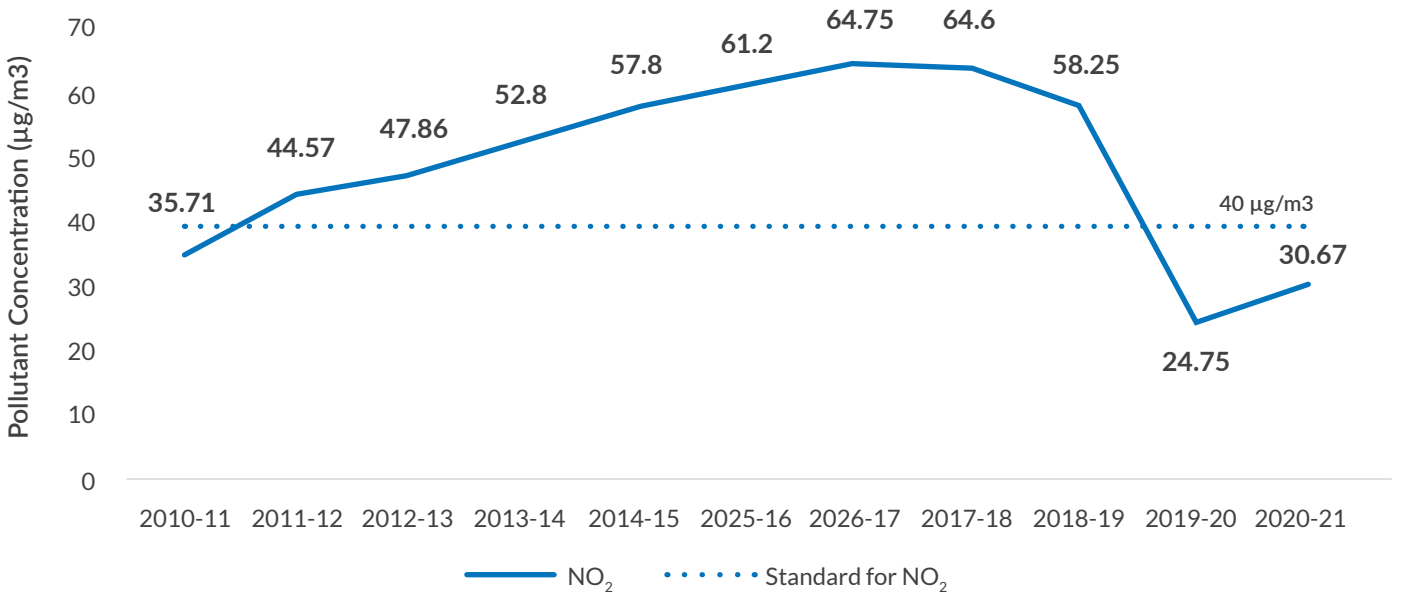


Figure 14: *Concentration of NO_2 levels in Mumbai April 2010– March 2021 (Annual Average)*
(Source: 7 BMC monitoring stations, Mumbai; NAAQ Standards, CPCB)

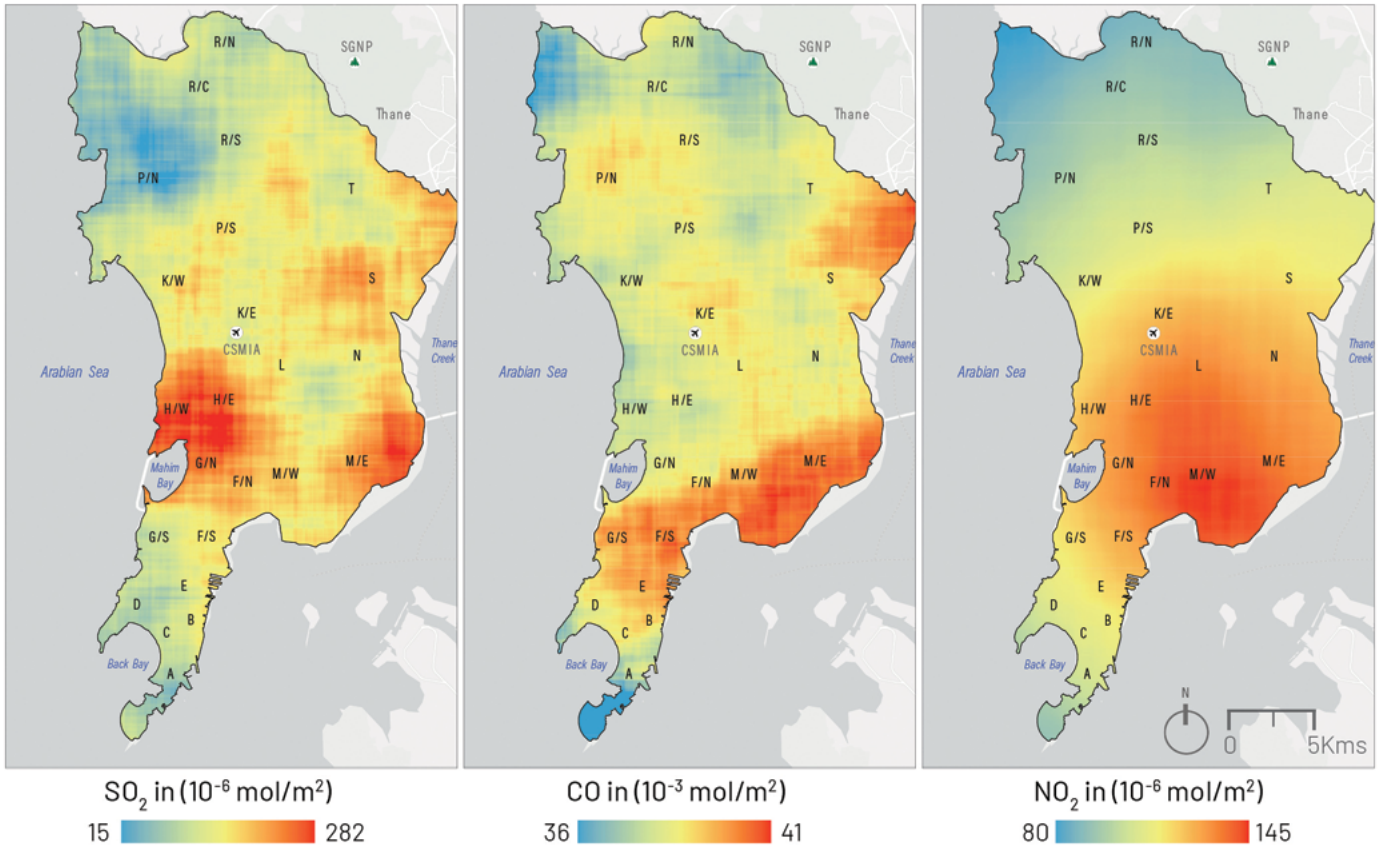


Figure 15: *Total vertical column density of SO_2 and CO and NO_2, June 2019 - May 2020*
WRI India, Contains Modified Copernicus Sentinel Data (2022)

SO_2, CO and NH_3

The mean concentration levels of these three pollutants have been below the NAAQ permissible limits. Higher concentration of CO can be found in the eastern suburbs (around Mulund and Mankhurd); it is observed that the M/E and M/W wards are exposed to CO pollution due to the Deonar landfill site. Traces of CO have also been found in the south in the G/S, G/N, F/N and F/S wards.

Higher concentrations of SO2 are observed in the east (around Mankhurd) and west (around Bandra and BKC), contributed mostly by the activities around the airport. NH3 also showed lower concentration levels, below the CPCB permissible limit, except in the years 2012 and 2015. [see figure 14].

Ozone

Ozone (O3) also exhibited a gradual decreasing trend in annual concentration from 2015 to 2020, much below the CPCB permissible level of 51 (8hrs) ppb[8], with comparatively higher concentration in Colaba, Worli and Bhandup. Colaba had recorded a strikingly high concentration of 62ppb in 2015-16, much above the concentrations of other monitoring stations.

In conclusion, the wards M/E (Deonar, Govandi, Mankhurd and Trombay), M/W (Mahul and Chembur), F/N (Antop Hill and Sion) and N (Ghatkopar and Vikhroli) are highly exposed to the risks of air pollution. The other hotspots include the airport complex, Andheri, Kurla, Worli and Colaba. Some extreme locations, such as Mahul, Ambapada and Chembur, are commonly described as "gas chambers" of the city due to their proximity to the refineries and petroleum industries (Saigal, 2020). A respiratory morbidity survey undertaken by KEM Hospital, Mumbai, in 2013 observed that 67% of Mahul's residents complained of routine breathlessness and 84.5% complained of choking sensations.

Indoor Air Pollution

The impact of indoor air pollution is a poorly studied area of vulnerability to air pollution. The major contributor is the burning of fossil fuels and domestic activities such as cooking and heating water. Exposure to the burning of fossil fuels causes 4.5 million premature deaths worldwide every year. In 2018, fossil fuel burning caused over 1 million deaths in South Asia (The World Bank Group, 2021). Data from Census of India 2011 suggests that firewood is consumed by only 2% of the households in Mumbai in comparison to kerosene and LPG. However, based on an analysis conducted by WRI in 2021, these 2% households are exposed to maximum indoor concentration of PM2.5 from the kitchen area, which is twice the exposure of PM2.5 concentration levels from kitchens fueled by kerosene and LPG.

Vulnerability Assessment Framework

Vulnerability assessment to climate and air pollution-induced risks is carried out across three aspects: socio-economic sensitivities, physical environment, and access to infrastructure and essential services. The overall demographic context provides a background to understand how vulnerabilities are experienced differentially, even within a neighborhood (that is equally exposed geographically) or a household (that is equally impacted), based on demographic differences such as age, gender, occupation and education. Climate-induced risks, such as urban heat, flooding, landslides, coastal risks and increasing exposure to various air pollutants in the city are jointly seen as hazards or drivers of vulnerability. The different aspects of socio-economic, physical, infrastructural and service access contribute differently to increasing vulnerability. Figure 16 illustrates the vulnerability assessment framework which uses climate and air pollution risk indicators against indicators under the three aspects to understand, spatialise and quantify differential vulnerabilities.

[8] The permissible limit of ozone is 51 parts per billion, which is obtained as an average of 8 hourly observation in a day.

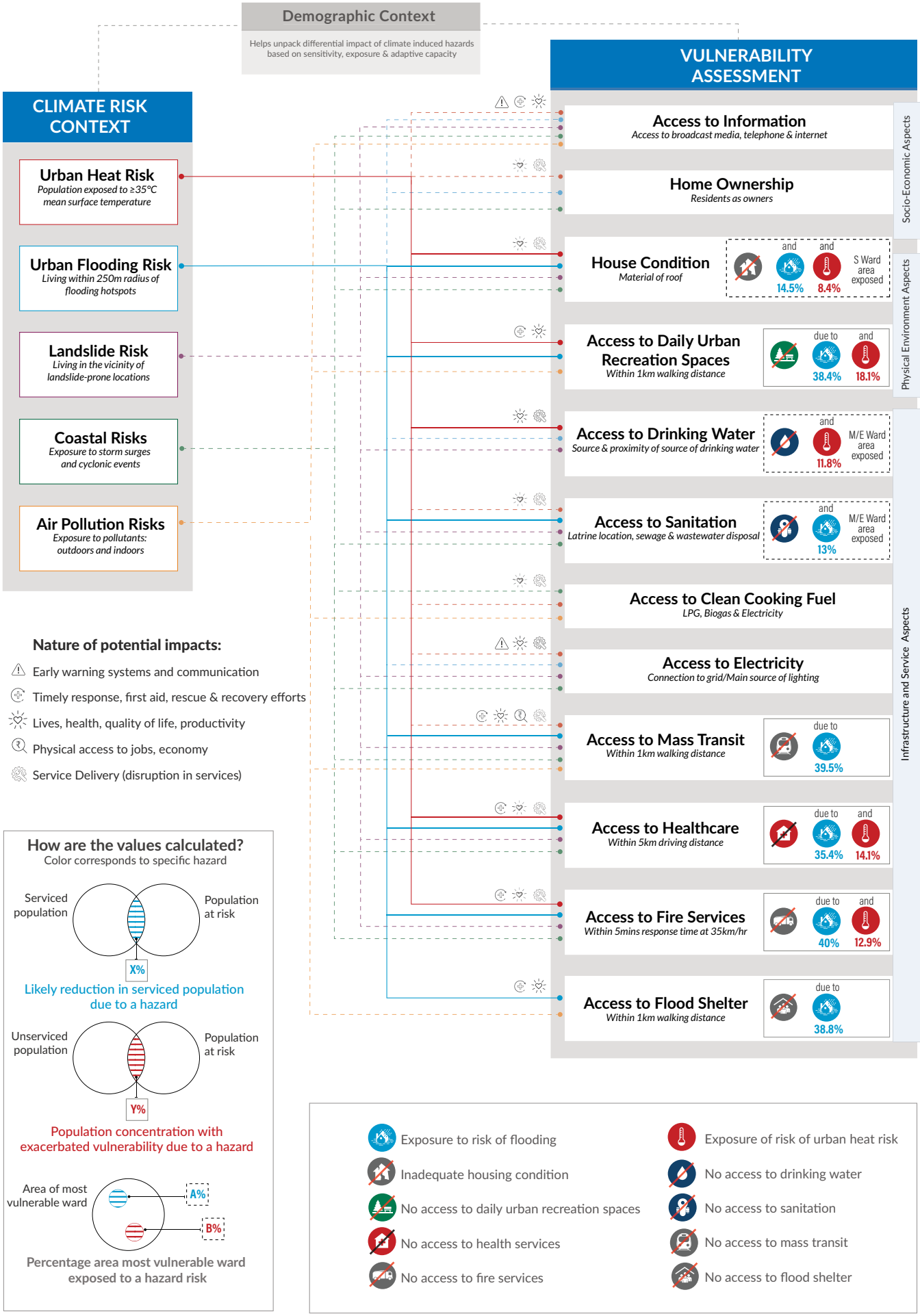


Figure 16: Climate and air pollution risks and vulnerability assessment framework
(Source: WRI India)

Mumbai's Vulnerability Assessment

Key Least vulnerable Moderate Most vulnerable

A. Table 3: Socio-economicaspects[9]

Literacy

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Effective literacy Greater Mumbai: 89.7% Low rank ward: M/E 83.3% Top rank ward: T 93.2%	Higher literacy increases adaptive capacity, thereby reducing sensitivity to shocks and stresses.	Mumbai city has an overall high population of literate people; however, female literacy is slightly lower. Literacy increases one's ability to access information, absorb early warnings and respond faster during a crisis or disaster event. Higher literacy increases socio-economic stability and decreases one's sensitivity to shocks and strains; access to stable jobs, knowledge of saving mechanisms, etc. are observed to be better in educated individuals/ families.
Effective female literacy Greater Mumbai: 86.4% Low rank ward: M/E 78% Top rank ward: R/C 91.3%		
Access to education - Population having no access to schools within 1km walking distance Greater Mumbai: 3.2% Low rank ward: G/S 6.4% Top rank ward: C 0% [access map in the Annex A]	For poor families, proximity to educational institutions ensures enrolment, especially for girls. Access to education improves literacy, thereby improving adaptive capacity and reducing vulnerability.	Most people in Mumbai have access to educational institutes within walking distance of 1km. Schools and higher educational institutions can help build community resilience capacities, among the youth as well as climate consciousness and disaster preparedness, especially for those living in vulnerable communities.

[9] The parameters listed for each indicator are represented using a visual code: red - most vulnerable, orange - moderate, and green - least vulnerable.

Access to Information

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households owning radio Greater Mumbai: 36.2% Low rank ward: B 17.5% Top rank ward: R/C 55.7%	Information access enables better adaptive capacity and reduces sensitivity to shocks and stresses.	Information and telecommunication devices increase one's access to warning alerts and climate risk and preparedness information. The ownership of these devices offers the opportunity to access regular live news updates, weather broadcasts and awareness campaigns, as well as timely updates, such as warnings and evacuation instructions, in the event of a disaster. Greater access to information increases adaptive capacities and reduces vulnerability to disasters and slow onset events. A larger percentage of the population with whom communication is possible before and during such events can help authorities and communities prepare better, efficiently manage evacuation plans and effectively carry out rescue operations.
Households owning TV Greater Mumbai: 85.3% Low rank ward: M/E 75.3% Top rank ward: R/C 92.4%		
Households owning PC with Internet Greater Mumbai: 20.1% Low rank ward: M/E 7.7% Top rank ward: H/W 39.8%		
Households owning landline connections only Greater Mumbai: 9.3% Low rank ward: M/E 6.2% Top rank ward: H/W 14.6%		
Households owning mobile phones only Greater Mumbai: 61.7% Low rank ward: D 40.2% Top rank ward: L 75.7%		
Households owning landline connections and mobile phones Greater Mumbai: 24% Low rank ward: M/E 8.6% Top rank ward: D 44.7%		

Home Ownership

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households residing in a house owned by them Greater Mumbai: 73.7% Low rank ward: C 54.1% Top rank ward: R/C 82.7%	Owning a house enables better financial security, thereby reducing vulnerability.	Approximately, 74% of Mumbai's households live in houses owned by them. Home ownership increases one's willingness to invest in improvements to increase safety (to increasing climate risks such as heat and extreme rainfall events) and resilience of property and associated assets.
		In case of other associated losses, such as job loss, income loss due to health impacts and asset losses (such as vehicles or electronics), having a safe living space is critical to retaining a sense of social security and decreased vulnerability.

B. Table 4: Physical environment aspects

Access to Daily Urban Recreation Spaces [Access Map in the Annex A]

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Population having limited access to daily urban recreation spaces Greater Mumbai: 40.2% Low rank ward: T 61% Top rank ward: M/W 21 %	Access to a recreational open space enhances overall quality of life and increases community health, thereby reducing vulnerability.	Approximately 60% of Mumbai's population live within walking distance of 1km from a daily urban recreation space. Open spaces are critical for physical and mental health. During disaster events, open spaces serve as grounds for evacuation, rescue and recovery. During slow onset events, such as extreme summers or heat waves, well-shaded open spaces can offer poor and more exposed communities (such as those living in informal settlements) essential respite from extreme indoor heat stress. The populations with limited access to open spaces are at higher risk and more vulnerable.

House Condition

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Populations living in houses with temporary roofing material Greater Mumbai: 45.7% Low rank ward: S 63.6% Top rank ward: C 10.8%	Living in structurally stable houses reduces the risk of life loss and asset losses. Hence, those living in poor housing conditions are more sensitive to shocks and stresses.	A high percentage of Mumbai residents live in structurally unstable/compromised houses. The roof is the largest exposed area of a house. As compared with walls and floors, constructing a structurally stable and safe roof built of concrete, burnt brick or machine-made tiles costs more. Hence, houses with roofs made of material such as thatch, mud, polythene and asbestos are more vulnerable to extreme weather conditions (such as heavy rainfall, strong winds and heat waves), thereby exposing the residents to a greater risk to climate-induced hazards. Poor housing conditions result in increased risk and vulnerability.

C. Table 5: Infrastructure and services aspects

Access to Drinking Water

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households with access to treated tap water Greater Mumbai: 94.4% Low rank ward: M/E 82.8% Top rank ward: C & D 98.3%	Access to reliable and potable water is crucial for public health. Limited access to drinking water increases health hazards and exacerbates vulnerabilities during climate-induced disasters.	In Mumbai, 94% of households have access to treated piped water and 79% have a tap in their premises. However, access is largely restricted or unavailable in informal settlements. During or after a disaster, the households dependent on alternate water sources, such as tankers or community taps, face vulnerability since physical access via roads is impacted. During a heat wave or days of extreme heat, the households with limited access to piped water are vulnerable to health impacts. In times of water cuts, these households may not be able to access alternate sources such as water tankers on account of affordability thereby restricting their access and increasing vulnerability.
Households with tap within premises Greater Mumbai: 79.2% Low rank ward: M/E 53.6% Top rank ward: C 98.4%		

Access to Sanitation

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households with latrine within premises Greater Mumbai: 58.3% Low rank ward: M/E 35.8% Top rank ward: C 93.4%	Access to safe sanitation within the premises at all times reduces dependency on public toilets, curtails the risk of public health hazards and ensures access even during disaster events when physical access to toilets may be limited or blocked; this, in turn, reduces vulnerabilities.	Only 58% of the households in the city have access to toilets within their homes. This has led to greater dependency on public toilets, exposing people to health risks and safety and ease-of-use issues, especially for women, children and persons with special needs. These conditions increase vulnerabilities during extreme events when physical access is hindered. Unhygienic methods of sewage and wastewater disposal can pose serious health hazards, pollute surface water and groundwater, exacerbate air pollution, worsening the impact in case of a climate-induced hazard, such as flooding.
Households relying on unhygienic sewage disposal methods Greater Mumbai: 2.8% Low rank ward: M/E 4.06% Top rank ward: F/N 1.7%		
Households relying on unhygienic wastewater disposal methods Greater Mumbai: 18% Low rank ward: M/E 47.9% Top rank ward: C 1.26%		

Access to Electricity

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households with electricity as source of lighting Greater Mumbai: 97.3% Low rank ward: M/E 95.3% Top rank ward: C 99.7%	Electricity as the main source of lighting represents a connection to a safe and stable grid, which improves the adaptive capacity of households and reduces vulnerability.	Most households in the city have access to a metered electricity connection, which reduces the risks of illegal connections, and ensures connectivity when the grid is restored after disasters. Hence, the lack of power/electricity is not a source of vulnerability for most households in Mumbai.

Access to Mass Transit [Access Map in Annex A]

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Population having no access to mass transit within 1km Greater Mumbai: 39.5% Low rank ward: M/E 74.6% Top rank ward: B 0.8%	Access to mass transit enables access to jobs and resources, which can help improve household incomes. Women and children have access to safe and affordable networks for better access to jobs and education, thereby increasing their adaptive capacity and reducing vulnerability.	More than 60% of Mumbai's population lives within walking distance of 1km from mass transit stations and has good access to sustainable mobility options. (This analysis takes into consideration the completion of the Metro network, planned for the next decade). During flood events, waterlogged streets hinder physical access to mass transit stations, disrupting regular access to mobility networks. During a flooding event, the population having access to a mass transit station within 1km potentially declines to 36.6%, as compared with 60.5% on normal days. The populations that are dependent on mass transit to access jobs and for personal needs are deeply impacted due to loss of working hours, reduced productivity, loss of income and the inability to access basic needs or access health and emergency services. The vulnerability of poor households is exacerbated during such events.

Access to Healthcare [Access Map in Annex A]

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Population having limited access to any healthcare facilities Greater Mumbai: 1.1% Low rank ward: P/N 4.2% Top rank ward: F/N & C 0%	Healthcare is an essential service, critical to the wellbeing of city residents. Limited access to healthcare reduces adaptive capacities and increases vulnerability during shocks and stresses.	Timely access to medical care is crucial for everyday life as well as during a disaster event. The vulnerability of population concentrations with limited access to health services is exacerbated during heat waves, flooding and landslides, which may lead to higher mortalities or long-term health risks. During a flood event, the population with access to a healthcare facility potentially declines to 63.9%, as compared to 98.9% on normal days.

Access to Fire Services [Access Map in Annex A]

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Population with limited access to emergency fire rescue services Greater Mumbai: 21.4% Low ranking ward: S 61.1 % Top rank ward: C 0 %	Higher access to fire services implies low response time, which decreases vulnerability.	Majority of Mumbai's residents are well covered by emergency fire services and are within a five-minute response time, ensuring timely emergency and rescue operations. Residents of high-density, informal settlements are most at risk during fire emergencies (higher the density, higher is the risk of fires spreading and challenges in physical access for rescue operations). The population having access to fire services within the standard response time potentially declines, from 78.6% on a regular day to 47.2% during a flood event.

Access to Clean Cooking Fuel [Access Map in Annex A]

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Households with access to clean cooking fuel Greater Mumbai: 78.6% Low rank ward: M/E 54.3 % Top rank ward: R/C 91.3%	The usage of non-polluting cooking fuels, such as LPG, electricity and biogas, reduces exposure to indoor air pollution and decreases vulnerability.	Although 79% of Mumbai's households have access to LPG (cleaner cooking fuel), several low-income households continue to rely on firewood and kerosene for cooking purposes. Indoor air pollution is as critical as outdoor air quality. The current trends of deteriorating air quality coupled with indoor air pollution increase health risks and make populations more vulnerable. Those living in smaller houses, with kitchens not separated from the living quarters are the most vulnerable.

Access to Flood Shelters

Mumbai Context	Vulnerability Rationale	Vulnerability Analysis
Population having no access to any flood shelters within 1km walking distance Greater Mumbai: 24.1% Low rank ward: M/E 68.5% Top rank ward: C 0.1%	Proximity and easy access to flood shelters reduces vulnerability.	In flood-prone cities, such as Mumbai, access to flood shelters is pivotal to ensure the safety of lives, effective evacuation and emergency response measures. Underserved populations living far from flood shelters are more vulnerable during flood events when road access is compromised. The population having a flood shelter within 1km of walking distance potentially declines, from 75.9% on a regular day to 46.5% during a flood event. People living in temporary structures in dense informal settlements are more vulnerable owing to the high likelihood of the structure collapsing, giving lesser time to react.

Conclusion

The geography and scale, rate and pattern of its urbanization exposes Mumbai to the risks of several climate-induced hazards. Analysis reveals changing and uncertain patterns of rainfall, deteriorating coastal ecology and development choices that have made flooding a recurrent major challenge. More than 35% of the city's population lives within the influence zone (250m radius buffer around a hotspot) of BMC-reported flooding hotspots. Ward F/N has the highest number of flooding hotspots (54), and more than 65% of the population here is potentially exposed to the risk of flooding, making it the most vulnerable area to the hazards of flooding. Also, only 50% of the households in this ward have a latrine within the premises, hindering access to safe and hygienic sanitation services during a flood event.

Urban heat not only in summer but also post-monsoon, is another major challenge for Mumbai owing to the rise in relative humidity at that time, the increasing built density, the choice of building materials and the reducing green cover in the city. M/E is the ward most vulnerable to heat stress, with over 40% of its population potentially exposed to a surface temperature greater than 35°C. This ward also has the highest percentage (more than 45%) of households depending on polluting cooking fuels, is among the top three wards with the highest number of houses with a temporary roof made of polythene or asbestos, has over 45% of households without a drinking water source within their premises and only about 35% households with a latrine within their premises, intensifying the risk. Further, across different aspects and indicators, a potential reduction of more than 30% in services (access to mass transit, healthcare, daily urban recreation space, fire services and flood shelter) has been observed during flood events and between 10% and 15% of Mumbai's underserved population, i.e., those who have limited or no access to daily urban recreation spaces, healthcare and fire services based on defined thresholds, is exposed to an overlapping risk of heat stress, exacerbating the vulnerabilities.

With a large section of Mumbai's population living in underserved neighbourhoods, climate and air pollution-related risks can be catastrophic for the city. The demographic and socio-economic study to assess Mumbai's vulnerability is largely based on Census of India 2011 data, which is outdated and may not adequately represent the city's vulnerability to climate-induced disasters. Among the 24 administrative wards in Mumbai, the M-East ward ranks lowest across most socio-economic and infrastructure parameters, pointing to the possibility of greater vulnerability in that area. A deeper assessment of vulnerability parameters and community resilience capacities is recommended to bridge capacity gaps and ensure access to infrastructure and services, thereby reducing vulnerability for all residents of Mumbai.

2.2 GHG Inventory: Critical Sources and Sinks

The GHG inventory for Mumbai includes an analysis of all the sectors/sources that emit GHGs into the atmosphere and all the sectors/land uses that absorb (or sequester) GHGs from the atmosphere.

A citywide GHG inventory forms a critical piece of any climate action plan as it establishes the sources/sinks of GHGs. This allows cities to formulate evidence-based mitigation actions and policies and is a powerful tool for monitoring progress towards climate goals.

Critical Sources

In 2019, Mumbai's GHG emissions were 23.42 million tonnes of CO2e, or 1.8 tonnes of CO_2e per person. The emissions inventory complies with the Global Protocol for Communities (GPC) BASIC standards using the City Inventory Reporting and Information System (CIRIS) tool of C40. Most of the city's emissions are from energy use in residential buildings, followed by commercial buildings and transport. Electricity consumption contributes significantly to the total emissions (64.3%) due to the predominantly coal-based grid in the city.

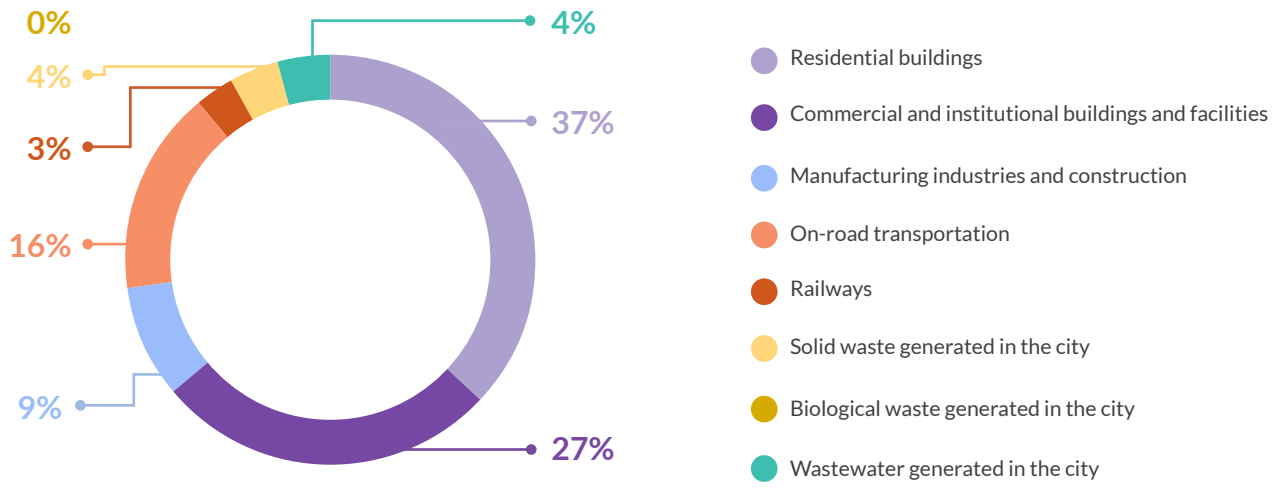


Figure 17 Emissions from sub-sectors
(Source: BMC & Service providers)
Analysis by WRI India

Mumbai's GHG emissions inventory includes three GHGs —CO_2, methane (CH_4), and nitrous oxide (N_2O). The inventory boundary spans an area of 603 km^2, with a population of 12.8 million people. The stationary energy sector is responsible for 16.9 million tonnes of CO_2e, which is 72% of Mumbai's total emissions, followed by the transportation sector at 4.56 million tonnes of CO_2e, which is 20% of the city's total emission and the waste sector at 1.94 million tonnes of CO_2e, which is 8% of the city's total emissions. This is illustrated in Figure 18.

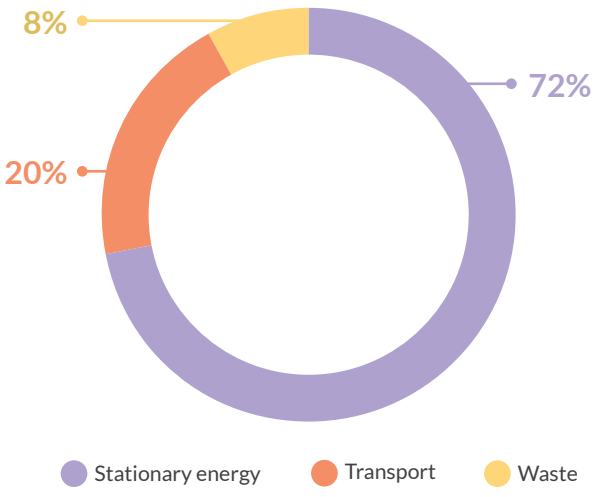


Figure 18: GHG emissions by sector for Mumbai (million tonnes CO_2e)
(Source: BMC & Service providers)
Analysis by WRI India

Stationary energy: The stationary energy sector comprises electricity and fuel consumption from **(i)** residential buildings, **(ii)** commercial and institutional buildings, **(iii)** manufacturing industries and construction and **(iv)** energy industries. This sector accounts for 72% of the total GHG emissions in the city. Of this, the emissions from electricity consumption make up 89% of the total emissions from stationary energy. The remaining are from the consumption of PNG, LPG, coal, fuelwood and kerosene. Residential buildings are responsible for 8.68 million tonnes of CO_2e (51% of total stationary energy emissions), while commercial and institutional buildings account for 37%, as illustrated in Figure 19. This is mainly because the source of a significant amount of the electricity consumed is a predominantly coal-based grid. Furthermore, 50% of the lighting in residential buildings and 44% in commercial buildings are derived from incandescent technologies, which have the least energy efficiency. In commercial and residential sectors, 60% of the heating demand is also met using electricity.

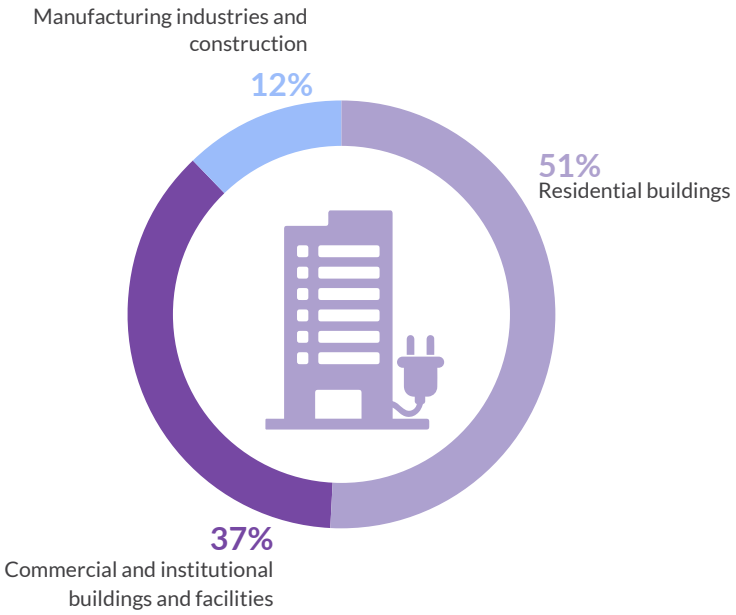


Figure 19: Stationary energy emissions - Total GHGs (metric tonnes CO_2e)
(Source: BMC & Service providers)
Analysis by WRI India

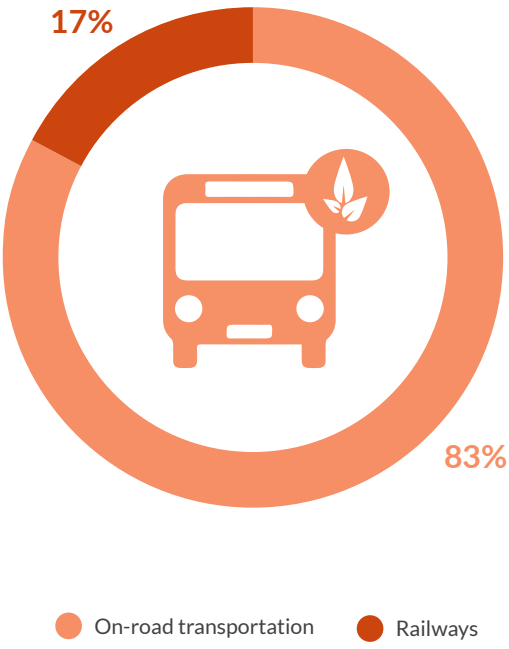


Figure 20: Transportation (SCOPE 1 & 2) - Total GHGs (metric tonnes CO_2e)
(Source: BMC & Service providers)
Analysis by WRI India

Transportation: The transport sector comprises **(i)** on-road transport, **(ii)** railways and **(iii)** aviation. Within the BMC boundary, the transportation sector is responsible for 4.56 million tonnes of CO_2e, of which on-road transportation is responsible for 83%, as illustrated in Figure 20. This is because of high fossil fuel consumption across passenger and freight sub-segments (65% of cars, 85% of freight and 100% of two wheelers run on petrol, while 27% of buses run on diesel). Despite being a low-carbon alternative, 40% of the emissions also result from CNG consumption by intermediate public transport fleets (three-wheelers and taxis). Railways are responsible for 17% of the emissions. Although all trains operate on electricity, the emissions can be attributed to the coal-dominated grid. Aviation, which is responsible for 3.7 million tonnes of CO_2e , falls in the Scope 3 category as these are emissions mostly occurring outside the boundary as a result of the activities within the boundary and is therefore not included in the "BASIC" total emissions.

Waste: Waste is responsible for 1.93 million tonnes of CO_2e, of which solid waste disposal is responsible for 0.96 million tonnes, or 50%, as illustrated in Figure 21. This is mainly due to CH_4 emissions from landfills, with the city landfilling 75% of its dry waste and 90% of wet. The biological treatment of waste in the city is responsible for 0.04 million tonnes of CO_2e, mainly due to composting, with 9% of the total wet waste being composted. Wastewater is responsible for 0.92 million tonnes of CO_2e. This is because 53% of wastewater is treated using facultative methods without biogas capture and 47% is released without treatment.

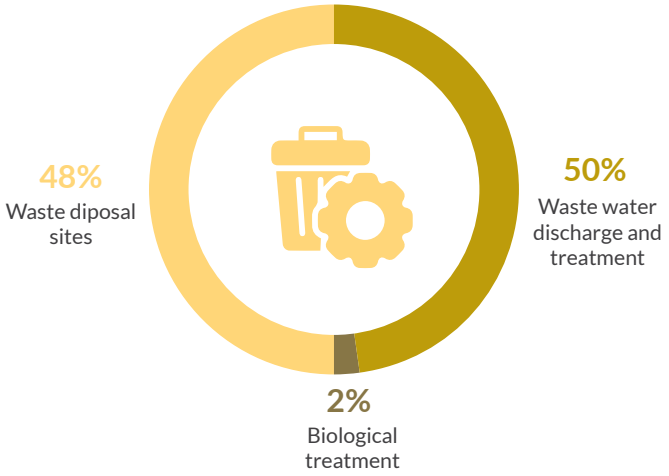


Figure 21: Waste sector emissions - Total GHGs (metric tonnes CO_2e)
(Source: BMC & Service providers)
Analysis by WRI India

Carbon Sinks

Natural ecosystems, such as forests, wetland and mudflats, play an important role in sequestering carbon and modulating the overall climate. The GHG inventories for lands are reported in six "land use" categories — forest land, grassland, cropland, wetland, settlement and other land (barren, snow, ice). In the case of Mumbai, cropland and grassland are extremely small. Settlement comprises the largest land area, followed by wetland. The two protected areas (PAs) in the city — the Sanjay Gandhi National Park and the Aarey forest — are the forested area.

As part of the Cities4Forests Initiative, the BMC conducted a climate and land use assessment to quantify the role of forests, mangroves and trees in influencing Mumbai's net GHG flux. Unlike other sectors, forests, mangroves and trees not only emit GHGs, they also remove CO_2 from the atmosphere. To develop baseline data for Mumbai, the periods 2010-2016 and 2016-2020 were analyzed for changes in forests, mangroves and Trees outside Forest (ToF). GHG values were estimated for **(i)** the PAs of Sanjay Gandhi National Park and Arrey forest, **(ii)** mangrove forests and **(iii)** ToF in Mumbai city and Mumbai suburbs separately.

The assessments from the three typologies of vegetation (as in figure 22) in Mumbai for the 2016-2021 period shows that ***in the PAs*, 3448.74 tonnes of CO_2/year** is removed from the forest remaining as forest category, **308.80 tonnes of CO_2/year** is removed because of the net gain of forest and **1067.99 tonnes of CO_2/year** is emitted due to loss of forest. ***In mangroves*, 87622.08 tonnes of CO_2/year** is removed from the mangroves remaining as mangroves, **4569.95 tonnes of CO_2/year** is removed because of the net gain of mangroves and 1572.06 tonnes of CO_2/year is emitted due to loss of mangroves. ***In ToFs*,** for the 24 wards in Mumbai (as in Figure 23), the annual ***carbon emission*** amounts to **19640.899 tonnes of CO_2/year** and the annual ***carbon removed*** is **76991.35 tonnes of CO_2/year**. Map in Figure 24 shows the changes in mangrove areas and protected forest cover in Mumbai for the period 2016-2021

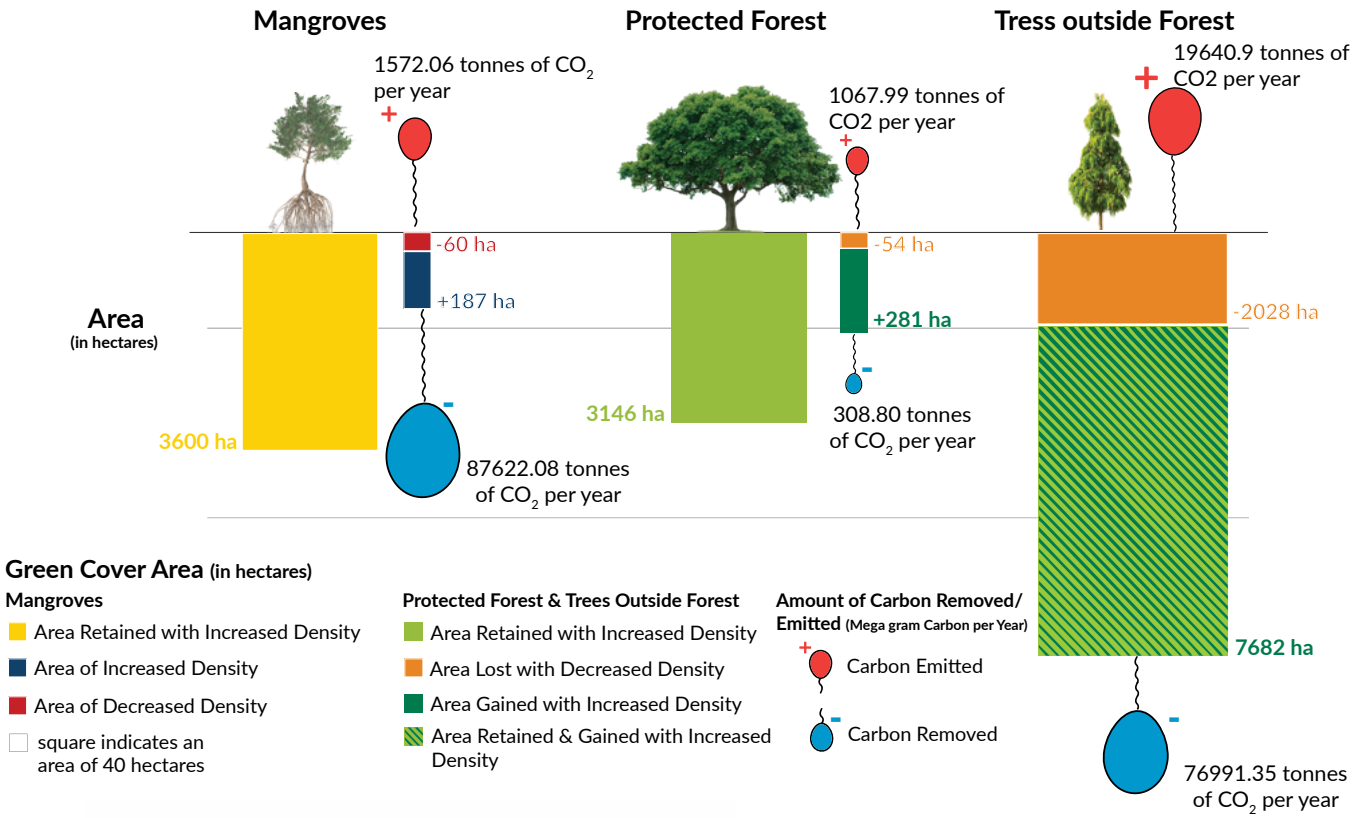


Figure 22: Carbon sequestration from different vegetation types in Mumbai from 2016 to 2021 (Source: Google Earth Engine; i- Tree Canopy Cover, 2021)

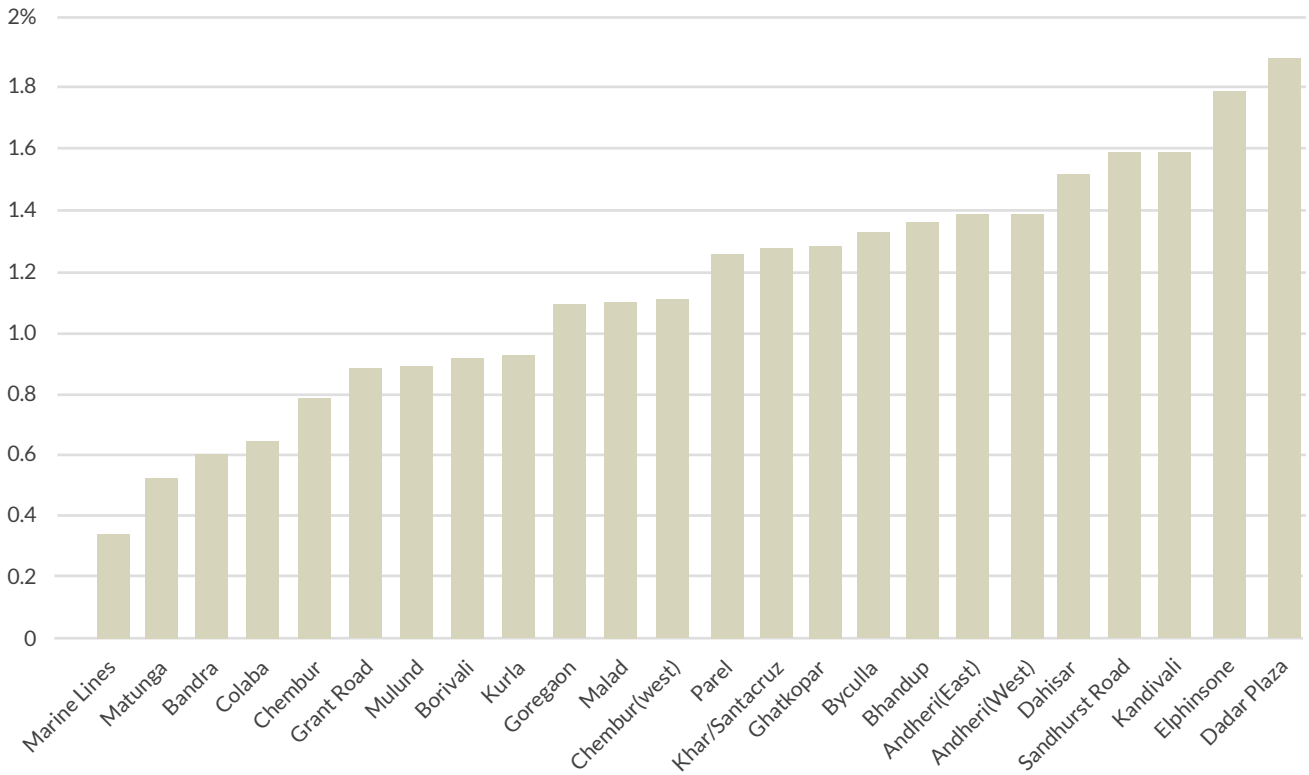


Figure 23: % Loss in tree cover density in Mumbai, 2016-2021 (Source: WRI India, iTree Canopy)

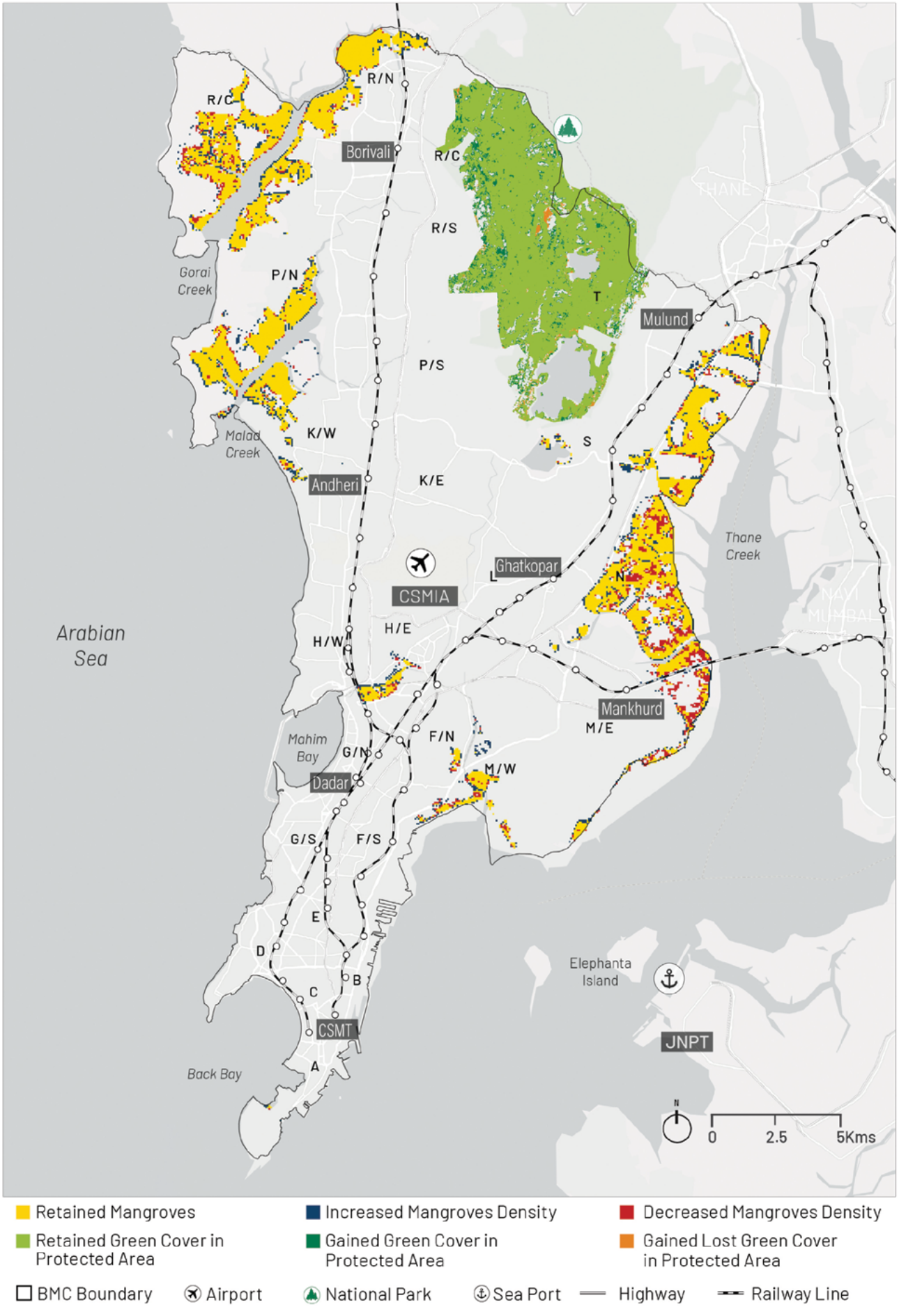


Figure 24: Change in mangrove and protected forest density in Mumbai for 2016-2021 (Source: WRI India, Contains Modified Copernicus Sentinel Data (2022))

2.3 Conclusion from Baseline Assessment

The climate and air pollution risks and vulnerability assessment points to three key risk areas that impact the city:

Increasing heat stress, with an increase in heat island effect in areas that have depleted green cover

Increasing monsoon flooding during extreme rainfall days, tropical cyclones resulting in increased storm surges, and increasing risk of landslides in informal settlements

Increasing air pollution impacting public health, especially among those who are more exposed (due to location or occupational exposure)

The vulnerability assessment helps identify areas and communities that are more at risk/sensitive or have poorer adaptive capacities to endure these risks.

The GHG emissions inventory points to three key sectors:

The waste sector contributes 1.93m tonnes of CO_2e, which is 8.2% of the city's total emissions.

The stationary energy sector is responsible for 16.9m tonnes of CO_2e, which is 72.2% of Mumbai's total emissions.

The transportation sector is the second-largest contributor, emitting 4.5m tonnes of CO_2e, which is 19% of the city's total emissions.

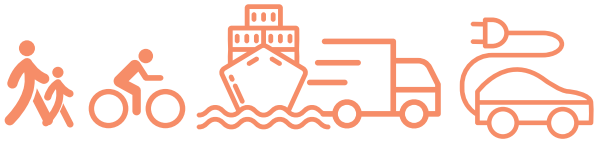
A majority of the emissions originate from electricity consumption, since electricity is predominantly generated from high-emitting fossil fuels, such as coal, oil and gas.

While the climate and land use assessment helps calculate the carbon removal factor from forests, mangroves and trees outside forests in the city, the adaptation benefits of increasing the green cover in Mumbai are higher than the mitigation potential.

Based on these assessments, six priority strategies, where adaptation and mitigation actions can be developed as part of the MCAP, are suggested below and discussed further in Chapter 4.

Energy and Buildings

Decarbonizing Mumbai's energy grid and building energy efficient and climate resilient infrastructure.

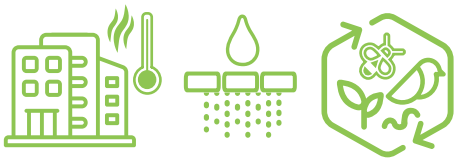


Sustainable Mobility

Promoting low-carbon mobility solutions, with a strong focus on non-motorized transport infrastructure and zero emission fuels.

Sustainable Waste Management

Adopting an inclusive and zero landfill waste management strategy.



Urban Greening and Biodiversity

Increasing the urban green cover to reduce heat risk and increase the city's resilience to flood events.

Urban Flooding & Water Resource Management

Increasing resilience by reducing water-sanitation inequity and adopting nature-based solutions for water conservation and flood risk management.

Air Quality

Reducing air pollution by improved monitoring, effective regulations and a shift to cleaner technologies.

By Atharva Tulsi

Mumbai Traffic | By sladkozaponi

Chapter 3:
Pathways to a 1.5°C Warming Scenario for Mumbai

The objective of the pathways scenario exercise is to establish an evidence base that could be used to set emissions reduction targets for Mumbai's energy, transport and waste sectors in line with the fair-share 1.5 degree scenario and identify the strategies to achieve these.

In the MCAP, these scenarios have been used to structure the climate action planning analysis, document Mumbai's current strategies, identify new strategies that could be implemented in the near and medium terms and assess the barriers in implementing ambitious action.

3.1 City-wide Mitigation Targets

Mumbai has an overarching mitigation target of achieving net zero emissions by 2050. Interim and long-term targets include a 30% emissions reduction by 2030, 44% by 2040 and net zero by 2050 against the base year emissions of 2019. These targets are based on the pathways scenarios developed as part of the MCAP. These actions would help reduce about 27% emissions in 2030 and 71% emissions in 2050 against the base year emissions of 2019. The definitions of the modelled GHG scenarios are presented in Figure 25.

Business-as-usual (BAU)
No action scenario excluding the effects of ongoing or planned policies

Existing and planned (E&P)
Considers effects of existing or planned city actions along with regional and national policies

Ambitious
Includes the most ambitious yet achievable strategies for the city

Figure 25: Scenarios modeled

The Pathways Methodology

C40's landmark research 'Deadline 2020' describes the fair-share 1.5 degree warming scenario trajectory of cities, depending on their specific contexts. The scenarios presented in Figure 21 are based on the pathways model developed by C40. These have been developed to model a trajectory that could keep emissions within the limits established in the Paris Agreement. The scenarios, were developed over a period of five months, primarily through desk-based research, and provide an evidence-based roadmap to a fair-share 1.5 degree warming scenario for Mumbai.

The pathways scenarios were developed in consultation with key city departments and external stakeholders to gain inputs on feasibility and priorities. Most of the data was provided by different agencies with whom BMC coordinated. For example, SWM data was received from the SWM, Water Supply, Gardens and Storm Water Drainage Departments, energy data from DISCOMS within BMC and Mahanagar Gas Limited (MGL), and transport data from fuel companies, MMRDA, BEST, Regional Transport Offices (RTOs) and Western and Central Railways. Gaps in data were filled using secondary sources.

3.2 GHG Scenarios for Mumbai

1. Business-as-Usual Scenario

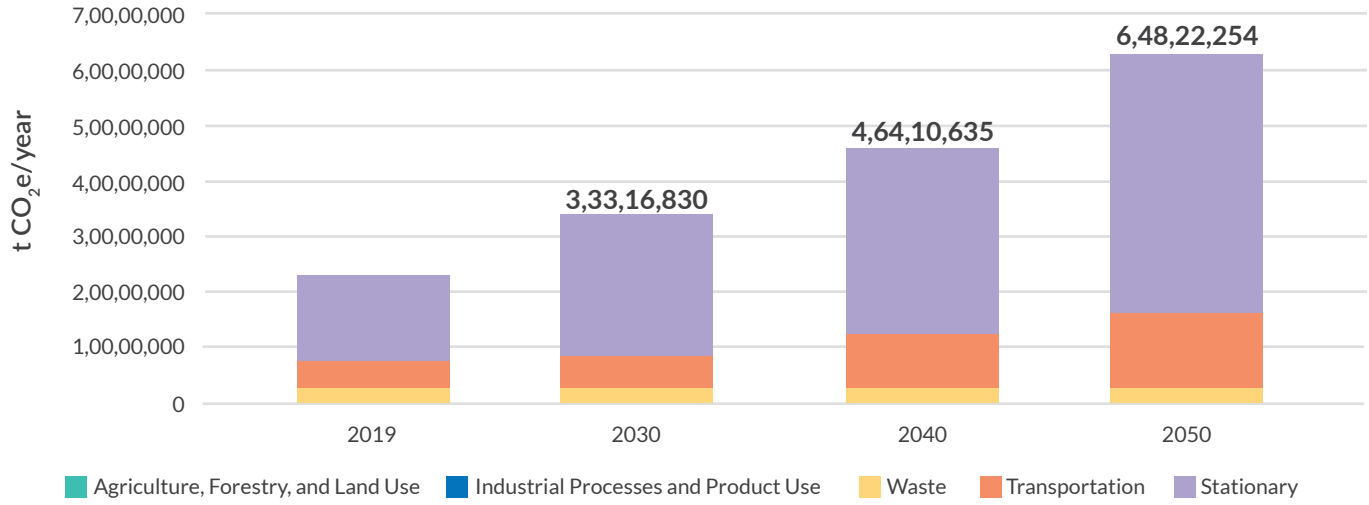


Figure 26: Business-as-usual scenario emission estimate (Source: Analysis by WRI India)

As the graph in Figure 26 indicates, if no action is taken, the emissions are expected to reach 64.8 million tonnes CO2e/year by 2050, increasing 2.7 times between 2019 and 2050. This is slightly higher than the Indian level Business-as-usual (BAU) trajectory of 2.5 times (Ge et al., 2020).

2. Existing and Planned Scenario

The Existing and Planned (E&P) scenario uses existing or planned city, regional and national actions, policies and programs to demonstrate the emissions reductions trajectory for Mumbai before the implementation of the climate action plan. Existing policies and commitments including 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), MMRDA's Metro Plan, Maharashtra Electric Vehicle Policy 2021, Mumbai's Comprehensive Mobility Plan 2017, Waste or Wastewater Master plans at city level and DP 2034 were reviewed in order to develop this scenario.

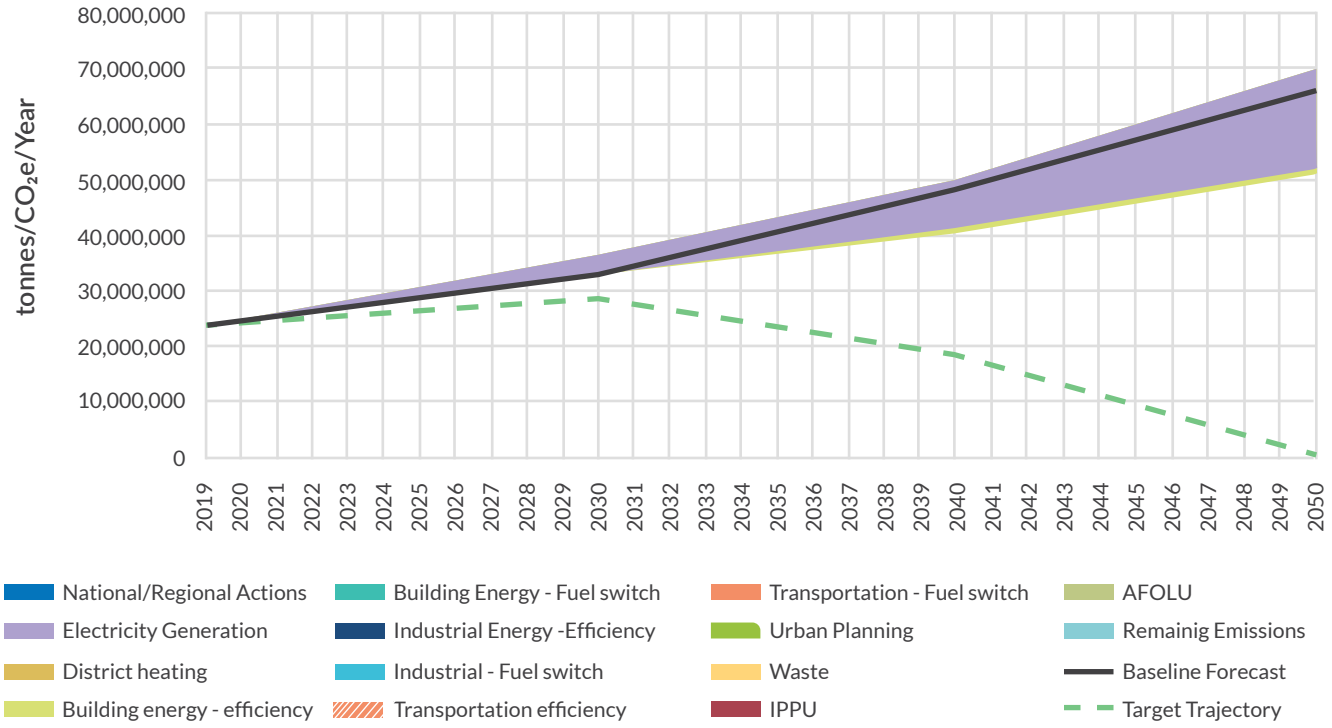


Figure 27: Emission reduction potential of actions in the E&P scenario (Source: Analysis by C40 & WRI India)

As per this scenario, the emissions are expected to reach 51.3 million tons CO2e/year by 2050, an increase of 119.4% in comparison to the base year emissions (see Table X). Mumbai can achieve a 30% share of renewables in the electricity grid by 2050 under this scenario through solar photo voltaic (PV) initiatives by Maharashtra State Electricity Development Company Limited (MSEDCL) and hydro power projects of 732 MW proposed by Maharashtra Energy Development Agency (MEDA) and BMC's Water Resources Department. This scenario also estimates that 28% of passenger cars and 32% of buses in the city will be electric by 2050, thereby progressing towards Maharashtra's electric vehicle (EV) policy targets. The emissions trends are not aligned with the 1.5°C Paris Agreement and Deadline 2020 emission trajectories.

3. Ambitious Scenario

The existing and planned policies leave a significant gap in meeting the 1.5°C Paris Agreement goals and the Deadline 2020 trajectory, indicating that more aggressive action would be required for Mumbai to meet a fair-share 1.5°C warming scenario. The Ambitious scenario was modelled as the most "ambitious yet achievable" trajectory for Mumbai to identify the strategies to achieve it. This scenario forms the basis of city-wide GHG targets and mitigation actions within the MCAP.

The scenario also takes into account India's recent commitments at the 26th session of the Conference of the Parties (COP26) in Glasgow, where the country set new targets to install 500 GW of renewable energy capacity by 2050 and source 50% of its energy demand from renewables by 2030 and announced a net zero target for the year 2070. The actions taken towards meeting these targets can accelerate city-level climate action, resulting in steeper emissions reduction.

In the Ambitious scenario, emissions are forecasted to reduce by 27% by the year 2030 and by 72% by the year 2050 as compared with the emission levels in 2019. This implies that the city will have a residual emission amounting to a 30% gap in meeting the 2050 target of net-zero emissions. A majority (two-thirds) of the residual emissions in 2050 is originating in buildings coming from use of LPG as cooking fuel, implying a perceived lack of policy appetite to shift from using LPG as cooking fuel. The rest of the residual emissions is mostly from wastewater treatment that remains predominantly facultative treatment without biogas capture systems. Further research would be required to gauge the reduction of all long-term residual emissions. Meanwhile, BMC is committed towards mitigation efforts before they begin exploring options to offset any eventual residual emissions.

UNIT	SCENARIO	2019	2030	2040	2050
% reduction below base year level	E&P		-43.3% 	-78.5% 	-119.4% 
	Ambitious		 27.1%	 43.8%	 71.5%

Table 6: % emission reduction under E&P and Ambitious scenarios.

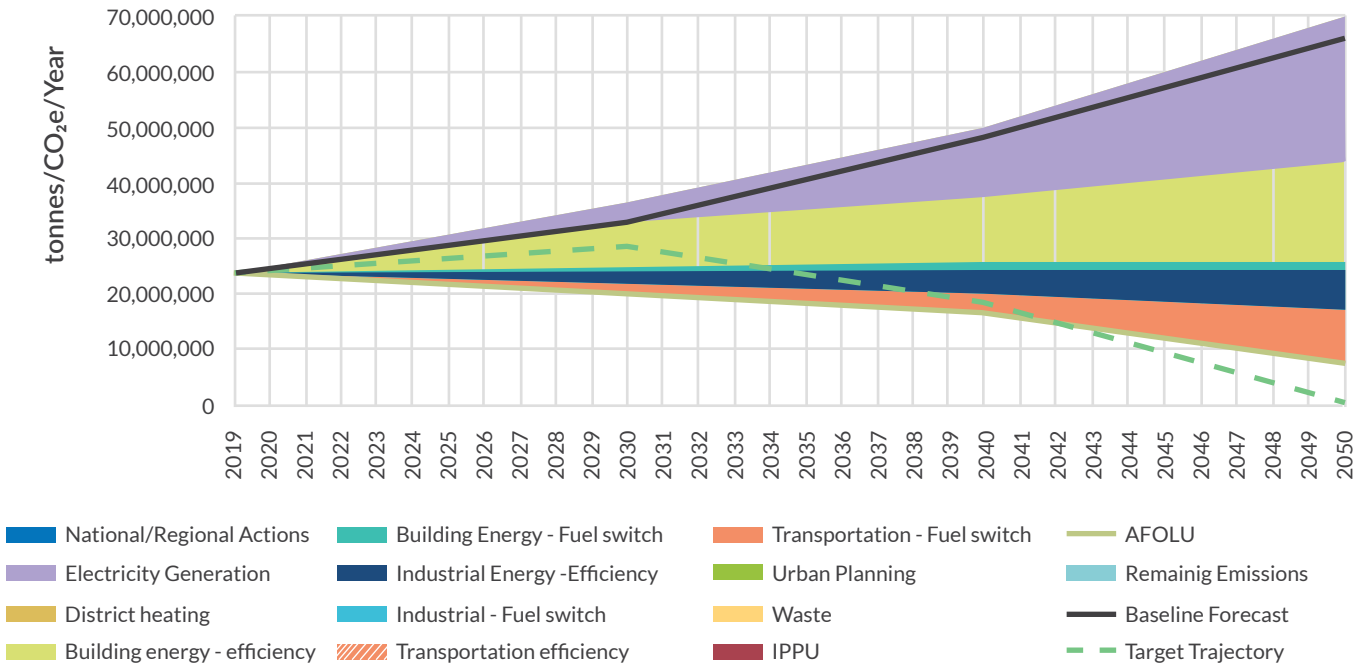


Figure 28: Emission reduction potential of actions in the ambitious scenario (Source: Analysis by C40 & WRI India)

3.3 Sectoral Strategies

The assumptions and targets developed for the Ambitious scenario were based on secondary research and consultations with various stakeholders, such as city administrators such as Environment Department, Solid Waste Department, transport operators, MMRDA and Development Planning Department, community organizations and political leaders. The complete list of stakeholders is presented in Annex 3.

Energy

Mumbai's GHG emissions inventory reveals that energy is the most emissions-intensive sector in the city, followed by transport and waste. This scenario assumes a 50% share of total grid electricity from renewables by 2030 and 90% by 2050. This is because utility companies such as Adani Electricity, TATA Power, MSEDCL and BEST have committed to 50% renewable energy-driven electricity generation by 2030. Moreover, India has committed to sourcing 50% of its energy demand from renewables by 2030. The targets of 100% LED lighting in residential and commercial subsectors, 60% low flow fixtures in residential buildings and 80% commercial buildings with high efficiency chillers is based on the heroic effort scenario modeled in the Maharashtra State Energy Calculator tool (MHSEC) 2050, a scenario building tool developed by NITI-Aayog and the UK government with the support of the Energy Department, Government of Maharashtra.

Transport

The key assumptions include 96% electrification of cars by 2050, in line with the aggressive effort scenario in MHSEC 2050. According to the India Emissions Model developed by the International Council on Clean Transportation (ICCT), in order to achieve India's air quality goals and its Nationally Determined Contribution (NDC), 28.1% of light duty trucks need to be electrified by 2030 and 100% by 2044 (Gode et al., 2021). It also estimates that 100% of all three-wheelers and taxis need to be electrified by 2047. Thus, the ambitious scenario for Mumbai assumes 100% electrification of light duty trucks, three-wheelers and taxis by 2050. By 2030, all buses will be electric, based on the government's target of 100% bus electrification by 2028 (Marpakwar, 2021).

This scenario assumes that while vehicle ownership of two- and four-wheelers is likely to increase till 2030, given the current policy landscape, the city will witness a shift from use of private vehicles to that of public transport, particularly mass transit, given the proposed Metro expansion. This scenario aims at retaining the current share of non-motorized transport (46%) and increasing the share of public transport, from 32% to 42% by 2050. This can be achieved by harnessing Mumbai's dense public transport network and implementing strategies to increase access, affordability, data-driven multimodal integration and inclusive last mile access. This can also be coupled with demand management strategies that focus on principles such as parking management and congestion pricing.

Waste

Currently, the city's waste composition includes plastic waste (4%), paper and metals (3%), organic wet waste (73%), organic dry waste (3%) and sand and stones (17%). However, only a negligible amount of paper and plastic waste is recycled while only 9% of organic waste is composted and the rest is landfilled. BMC has floated tenders for five dry waste sorting centers, each having a capacity of 100 MT/day and expandable up to 250 MT/day. With plans to expand recycling capacities, the Ambitious scenario assumes 80% of paper and plastic waste will be recycled by 2050, supported by strategies to improve mass awareness, decentralized infrastructural capacities and better waste data management at the city level. This scenario also assumes composting of 60% of organic waste by 2050, driven by strategies focused on decentralized composting pilots, landfill gas capture, and market creation for compost with local capacity building, particularly for informal communities.

Recycling paper | By Sebastian73

The Key Strategy Goals are Listed in Table 7.

Energy and Buildings

Table 7: Strategy goals for the ambitious scenario for mumbai

Target	2030	2040	2050
% share of total grid electricity from renewables	50%	70%	90%
% of total residential buildings with solar PV installed	10%	20%	40%
Residential water flow technology in buildings (% low flow fixtures)	20%	40%	60%
LED lighting in commercial and residential buildings (%)	100%	100%	100%
Commercial cooling system technology (% of high efficiency chillers)	38%	59%	80%

Waste

Target	2030	2040	2050
% of paper recycled	20%	40%	80%
% of plastic recycled	20%	40%	80%
% of organic waste composted	20%	40%	60%
% Waste water treated by tertiary treatment	10%	15%	17%
% landfill gas captured	20%	30%	50%

Transport

Target	2030	2040	2050
% Mode share for public transport and NMT	73%	78%	85%
% Electrification of passenger automobiles	35%	70%	96%
% Electrification of light duty freight	29%	70%	100%

The strategies in the Ambitious scenario inform sector-wise targets and actions for the waste, energy and transport sectors. An example of pathways strategies and associated actions under each strategy for the three sectors is illustrated in Figure 29.

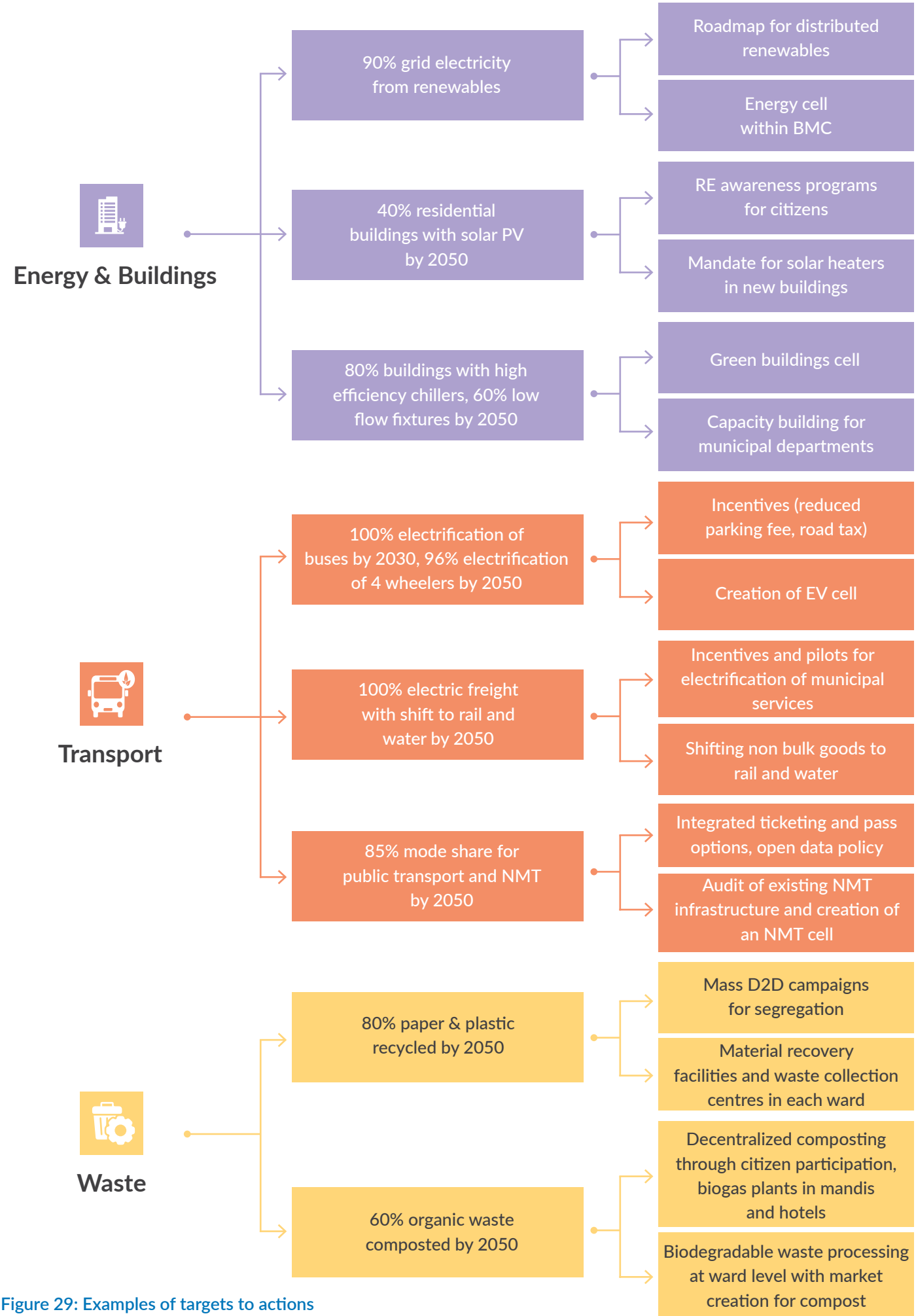


Figure 29: Examples of targets to actions

Versova-Andheri-Ghatkopar Metro | By Hari Mahidhar

Chapter 4:
Sectoral Priorities

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

4.1 Six Priorities

While these priorities are aligned with existing sectoral departments within BMC to ensure the efficient implementation of the MCAP, there is immense scope to converge across sectors, catalyze collaborations across Departments and reap the co-benefits of holistic solutions. The six priorities identified are as follow:

Energy & Buildings

Decarbonizing Mumbai's energy grid and building energy-efficient and climate-resilient infrastructure

The city will work to decarbonize the energy grid, increase proportion of renewable energy and improve climate-resilient buildings in Mumbai. This priority directly aligns with the Paris Agreement. To tackle Mumbai's energy sector emissions, the approach addresses both the supply side – increasing RE– and the demand side – improving energy efficiency (EE). The impact of this action will reduce the overall carbon emissions and heat effects, enabling good health for all residents of the city. Achieving this priority implies increasing the availability of RE mix-energy generation, improving energy efficiency in new and existing infrastructure, promoting green buildings, integrating passive design strategies for thermal comfort in all affordable housing projects and ensuring equity in energy access.

Sustainable Mobility

Promoting low-carbon mobility solutions, with a strong focus on non-motorized transport infrastructure and zero-emission fuels

The city will work towards integrated modes of transport, increase ridership in public transport and promote EV vehicles in new registration and increased EV infrastructures city-wide. BMC has launched EV Cell on 23 rd February 2022 action directly results in improved air quality and human health, reduced travel time and less congestion in the city. To manage Mumbai's transport system with effective transport demand management measures, trip integration and seamless trip chains, and real-time transit and traffic information dissemination systems, it is essential to have a robust parking policy.

Achieving this goal implies retaining the mode share of non-motorized trips and improving NMT infrastructure while ensuring increased pedestrian safety and last mile connectivity, as well as a transition to zero-emission vehicles and vehicles with more efficient engines by 2050 (electrification of all buses by 2027, all two-wheelers, taxis and autorickshaws by 2050, 96% of all private four-wheelers by 2050). It is equally important to develop a sustainable freight policy for Mumbai, with the aim to electrify 100% of light duty trucks and 2W freight and 46% of medium- and heavy-duty trucks by 2050, improving public transport ridership and multimodal connectivity and shifting demand away from private vehicles for improving human health.

Sustainable Waste Management

Adopting an inclusive and zero-landfill waste management strategy

The city will work for creating value from waste by decentralizing municipal waste management through inclusive climate solutions. This priority recognizes that the city needs to focus on the 4R approach (Reduce-Reuse-Recover-Recycle) to manage its waste in a sustainable and inclusive manner. To do this, the city must implement actions such as segregation at source, organic waste composting, processing of dry waste to recover and recycling and reusing C&D waste as building material. In addition, wastewater must be treated at the tertiary level and treated water reused in industry as well as for purposes other than human consumption. If treated with low-carbon technology, energy can also be produced.

Urban Greening & Biodiversity

Increasing the urban green cover to reduce heat risk and increase the city's resilience to flood events

The city will work towards green space access for all citizens, undertake conservation and extend biodiversity to protect the city from the impacts of climate change. Urban green cover helps minimize the mean rising temperature, reduce the effect of heat waves and arrest urban flooding. This goal can be achieved by increasing the vegetation cover and permeable surface of the city surface area by 30-40% by the year 2030 and reducing the heat island effect by increasing the permeable surface along the city streetscape. Ensuring an equitable distribution of open spaces, increasing the per capita open space to 6 sq m by 2040 and restoring, maintaining and enhancing the city's biodiversity and eco-system will also be important.

Urban Flooding & Water Resource Management

Increasing resilience by reducing water-sanitation inequity and adopting nature-based solutions for water conservation and flood risk management

The city will work to reduce flood risk and losses to its economy, infrastructure and ecosystem and increase water security for all citizens. Mumbai faces extreme precipitation, resulting in water logging at various low-lying areas. In addition, increasing coastal risks due to storm surge, sea level rise and an increasing trend of tropical cyclones in the Arabian Sea are increasing incidents of coastal inundations in the city.

The city will work to build flood-resilient infrastructure to protect physical and economic assets by introducing nature-based solutions to strengthen the drainage network and increase the percolation and holding capacity of the existing flood management infrastructure. Efforts will be made towards disaster risk reduction through an improved early warning system and the sensitization of vulnerable and coastal communities. Mumbai is water-rich, but non-revenue water losses during transmission and infrastructure gaps in slum communities and older neighbourhoods with aging infrastructure have resulted in severe water-sanitation inequity in the city. By adopting robust water resource management policies to reuse water and increase percolation and harvest rainwater, additional and local sources will be explored.

Air Quality

Reducing air pollution through improved monitoring, effective regulations and a shift to cleaner technologies

In terms of air pollution, Mumbai is one of the most polluted cities in India. Air quality improvement depends upon co-benefits from other sectors, such as green cover and biodiversity, transport, waste, energy and building construction. Poor air quality impacts human health, biodiversity and ecosystems adversely. To improve air quality, efforts should be taken to curb pollution levels by 20-30% by the year 2030, increase publicly available information and data through improved monitoring, implement forecasting and awareness programs and build community health resilience through decentralized planning, capacity building and training initiatives.

The MCAP is framed as a policy document with an evidence-based approach to planning and mobilizing for action plans as well as strategic projects. Each of the six sectoral action plans (presented in detail in Chapter 5) are inclusive and closely aligned with the principles of Majhi Vasundhara Abhiyan or My Earth Vision (MVA), an initiative of the Department of Environment and Climate Change, Government of Maharashtra, as well as the Sustainable Development Goals (SDGs). Each sectoral strategy presents a set of goals aligned with the city-wide targets.

4.2 Ensuring Inclusivity and Equity

India is committed to the goals of the Paris Agreement, whereby it strives to reduce climate risk, alleviate poverty, build shared prosperity and promote sustainable development. This can be achieved well through Inclusive Climate Action Planning (ICAP) that facilitates local governments to assess climate-related risk and identify actions that are consistent with the country's climate goals. In other words, inclusivity can be achieved by engaging relevant stakeholders in the policy-making process, ensuring universal accessibility of the policy process, while also ensuring an equitable impact of climate programs, actions and policies. ICAP must target 1) a consultative process engaging the stakeholders, 2) policies that encourage people-centred planning and decision making and 3) programs that ensure equity in the distribution of resources and information and in institutional access. The MCAP team has adopted the globally applicable ICAP guidelines to integrate inclusivity and equity throughout the climate action planning process.

The MCAP integrates co-benefits for its residents, such as improving urban health and well-being, increasing economic prosperity and promoting education and skill development. All actions that are a part of the MCAP (that are presented in detail in Chapter 5) were assessed using the action analysis database in order to understand the inclusivity and equity implications of climate actions planned. The vulnerable groups, such as women, the elderly, persons with disabilities, children, low-income communities, and informal communities (residents and workers) were mapped in the vulnerability assessment (detailed in Chapter 2.1), and specific mitigation and adaptation actions have been suggested. Lastly, the planning process (as described in the Executive Summary) has been highly consultative, and integrated feedback from various stakeholders within the government, civil society groups and citizens.

The MCAP aligns with the goals and targets set at higher levels of planning and governance to leverage favourable policy environments, align with funding and financing mechanisms and ensure coherent reporting mechanisms across common climate and environment protection goals. At the national level, India announced new climate action targets at the COP26 summit (Mitra et al., 2021):

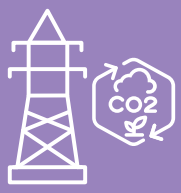
4.3 Aligning with Global, National and Sub-national Planning Goals

The MCAP aligns with India's commitment and the SDGs at the global level. The six sectoral action plans align with relevant national programs and policies, such as the National Clean Air Programme (NCAP), the Swachh Bharat Mission and the Climate Smart Cities, thus ensuring continuity and coherence across outcome indicators and targets. This has also led to an alignment of budget priorities since intended outcomes at the city level are well aligned.

At the state level, Mumbai was third in a ranking done under the Majhi Vasundhara Abhiyan (MVA). The initiative MVA focuses on identifying potential action points on behalf of the local bodies in the state in order to improve the environment by improving five elements in nature, or the *panchamahabuta*. These five elements are the *Earth*, *Air*, *Water*, *Energy and Enhancement*. The goals and actions of the MCAP are aligned with the principles and initiatives recommended in MVA to enable Mumbai to achieve its targets and leverage critical resources and support from the State Government.

Shot at The Taj Mahal Palace, Mumbai | By Sonika Agarwal

ENERGY AND BUILDINGS



Decarbonize electricity grid

Transition to clean fuels and resource efficiency

Promote low carbon buildings

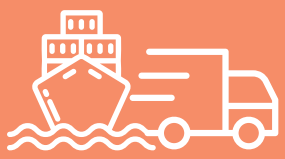
Encourage passive design strategies

SUSTAINABLE MOBILITY

Enhance public transport ridership

Improve access to NMT transport and infrastructure

Transition to zero emission vehicles



Shift to zero emission freight

SUSTAINABLE WASTE MANAGEMENT

Reduce landfilled waste

Decentralized waste management

Expedite remediation and scientific management of landfills

URBAN GREENING AND BIODIVERSITY

Increase vegetation cover and permeable surfaces

Reduce urban heat island effect

Promote equitable access to green open spaces

Restore and enhance biodiversity

AIR QUALITY

Curb pollution concentration levels

Improve monitoring and availability of information

Decentralized planning and increase awareness to enable community health resilience

URBAN FLOODING AND WATER RESOURCE MANAGEMENT

Build flood resilient systems and infrastructure

Localize water conservation and efficiency

Reduce pollution and restore aquatic ecosystems

Provide safe and affordable drinking water

Ensure clean, safe and accessible toilets

Manage disaster risk and reduce impacts

Chapter 5: Sectoral Plans – Goals, Actions & Implementation Strategies

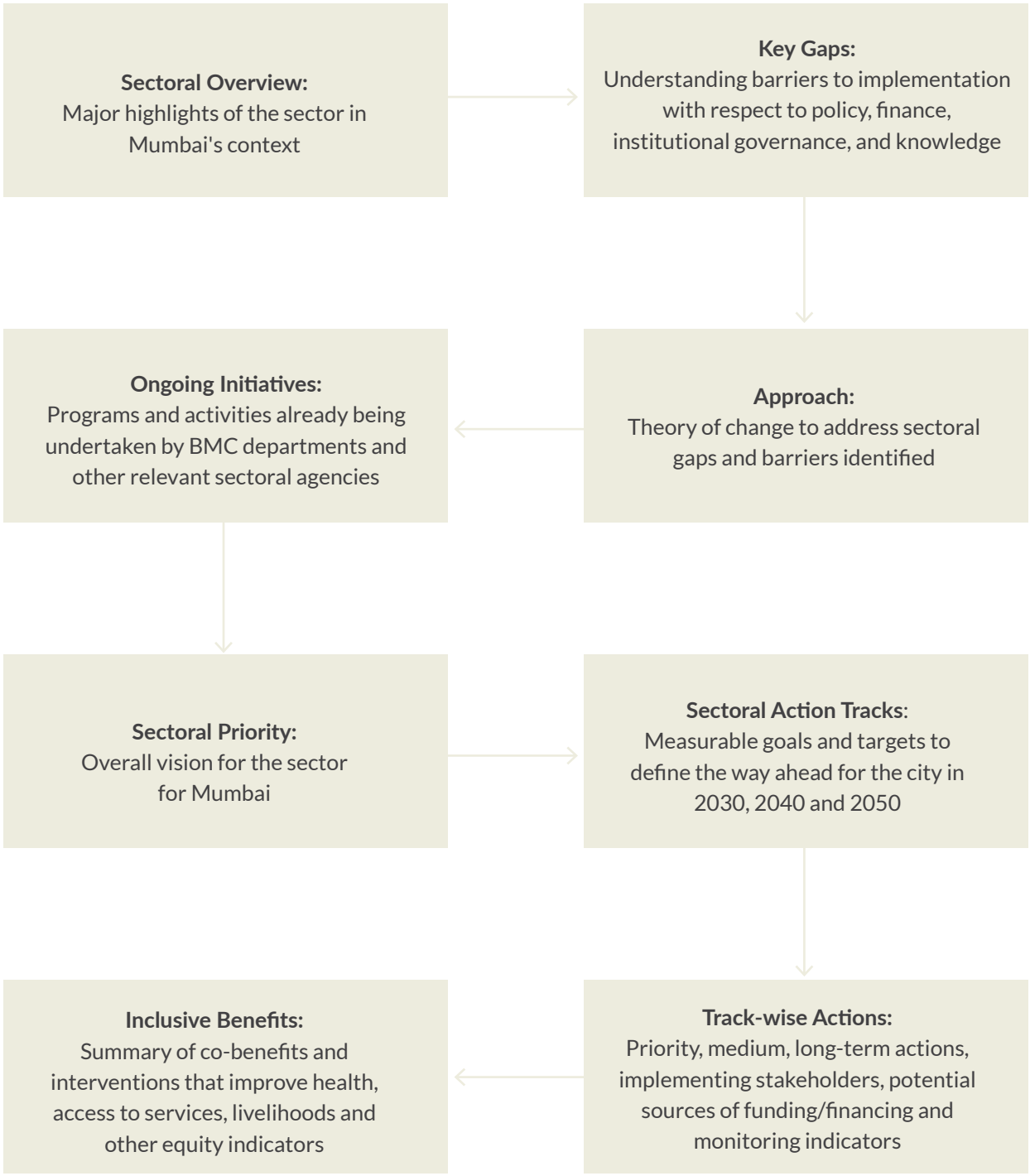


Figure 30: Chapter flow

5.1 Energy and Buildings

Mumbai's electricity generation mix is currently dominated by coal, natural gas and fossil fuel based-thermal power (95%), followed by hydro, wind and solar power (5%). This makes it highly carbon-intensive, with electricity generating over 72% of the total emissions. Four distribution companies supply electricity to different parts of Mumbai.

BEST, an undertaking of BMC supplies to the island city area from Colaba to Sion and Mahim and accounts for 25% of the total electricity supply.

Adani Electricity Mumbai Limited (AEML) supplies to suburban Mumbai — from Bandra to Bhayandar on the western side and from Sion to Mankhurd on the eastern side — and accounts for 46% of the total electricity supply in the city.

Maharashtra State Electricity Distribution Company Limited (MSEDCL) supplies to the suburbs of Mulund and Bhandup and accounts for 5% of the total electricity supply.

Tata Power Company Limited supplies to the remaining areas, a few industrial units and the railways and accounts for 24% of the total electricity supply.

According to a 2017 study, the city has a potential of generating 1,724 MW of solar energy from the rooftops of buildings, which could help meet almost half of the city's total energy demand. Up to 1,300 MW can be generated from rooftop solar installation in residential buildings alone, followed by 223 MW from industrial buildings and 71 MW from educational buildings. The areas with the highest potential are Andheri West (K-West Ward) and Borivali (R-Central Ward) (Sahoo, 2017).

The dominant source of emissions from buildings in Mumbai is electricity consumption, generating 77%, followed by LPG with 10%. Cooking, cooling, and heating water are the key activities in the buildings sector that consume the most amount of energy, leaving a large footprint. Based on the future scenario pathways analysis, the emissions from residential, commercial and institutional buildings' are estimated to increase 3.3 times by 2050 in a BAU scenario. Thus, buildings and households are important sites for developing city-level mitigation strategies and the scope for energy efficiency improvements in the existing buildings is immense. Energy audit studies have revealed a savings potential to the extent of 40% (BEE, n.d.). Of the 373 certified green buildings in Maharashtra, Mumbai has 144.

The Maharashtra Energy Development Agency (MEDA) is the agency that has been designated to coordinate, regulate and ensure ECBC compliance, promote and develop energy efficiency in the state and facilitate RE development.

In Mumbai, the energy decarbonization story is as much about grid decarbonization and green buildings regulations and ratings as it is about thermal comfort and affordable cooling solutions. Mumbai is home to the world's largest slums — Mankhurd and Dharavi. Here, over half of the city's population lives in informal settlements made of temporary building materials that absorb and reflect heat and are uninhabitable on extremely hot days. These areas are almost 5-6 degrees warmer than residential neighborhoods having trees and open spaces. Buildings with large glass and concrete facades, with no trees or adequate setbacks, reflect excess heat onto streets, producing heat island effects; certain areas are much warmer than others with better green cover and lesser reflective surfaces. Poor choice of building materials increases indoor temperatures and building energy demand and increases heat risk on public streets. Figure 31 maps the increase in land surface temperature over a decade, before and after the Metro Line 1 was built, resulting in increased temperatures along the corridor due to densification.

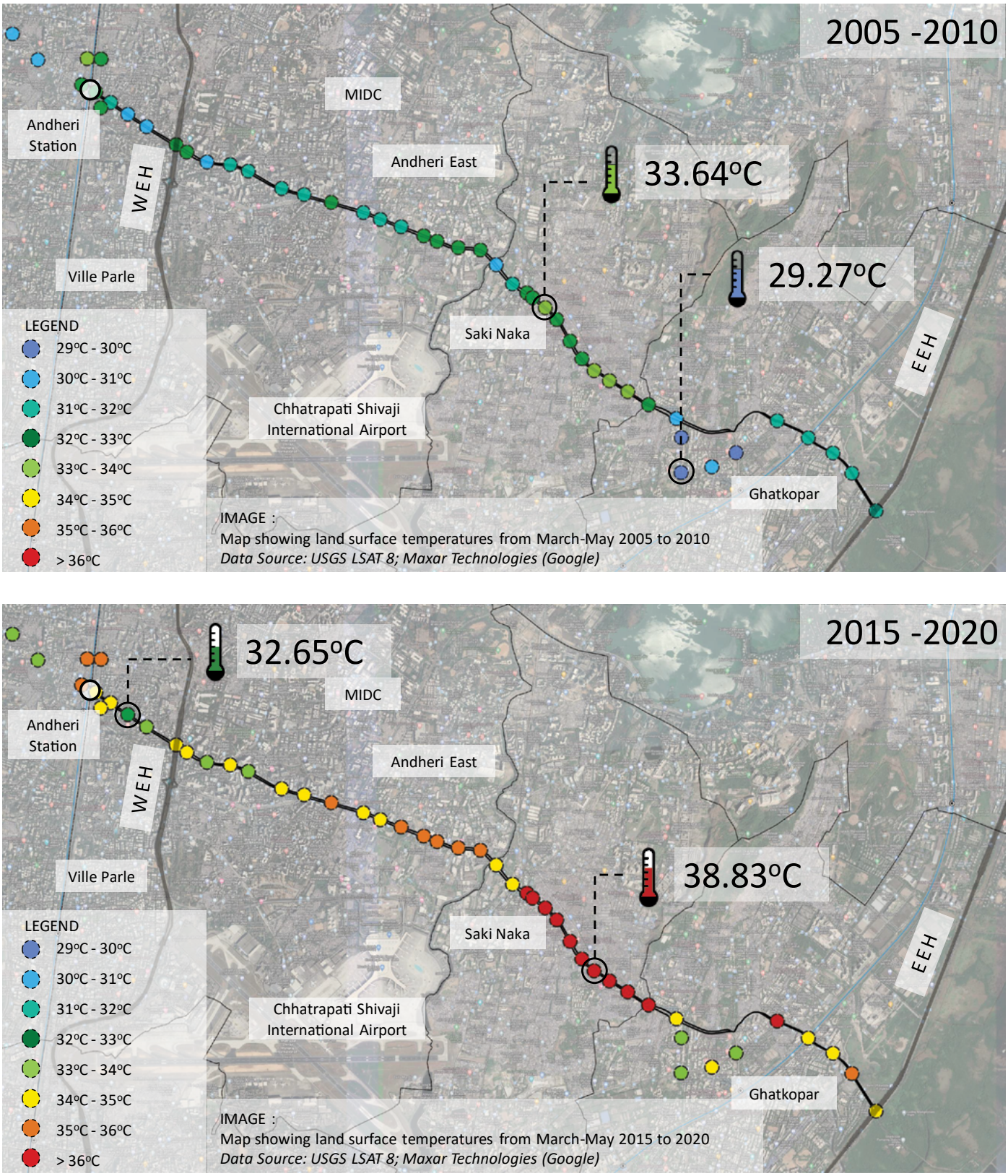


Figure 31: Land surface temperature increase over 10 years (range from 2005-2010 [top] and 2015-2020 [bottom]) along Andheri-Ghatkopar link road due to heat island effect

Key Gaps in the Energy & Buildings Sector

Neither have any targets been set for decarbonizing Mumbai's grid, nor are there any mandatory polices in place for achieving energy efficiency in the existing and new infrastructure. In order to ensure thermal comfort, there are a few green buildings and passive design strategies that have been integrated.

No state- or city-level mandate for ECBC compliance in new buildings

Energy Conservation Building Code (ECBC), which is set for commercial buildings, has neither been mandated at the state level nor at the city level, which weakens the overall compliance. Similarly, there is no policy mandate for the implementation of Eco-Niwas Samhita 2018 (ECBC-R) for residential buildings.

Large stock of existing buildings

Being a historical city, Mumbai has a large stock of existing buildings. However, no retrofitting roadmap or plan has been developed for these buildings and infrastructure. Also, neither is it mandatory to conduct regular energy audits and benchmarking that could be analysed centrally, nor is it compulsory for businesses to report year-on-year. While there have been instances of old buildings collapsing and frequent redevelopment initiatives, the old and existing building stock is a much bigger source of emissions than new buildings. There is also no plan or roadmap for improving energy efficiency and retrofitting in the slums of Mumbai, which are home to more than 50% (Liyanga de Silva, 2018) of the city's population.

Absence of guidelines and frameworks focusing on climate resilience and water efficiency

There is an absence of city-level policies or rules that focus on resource efficiency and climate resilience in buildings, including water efficiency, designs for reducing heat stress, water retention and recycling, and flood management design (in relevant areas). There are no official guidelines for adopting passive building and infrastructure design that improve thermal comfort and address the heat risk for public streets.

This is a challenge especially for low-income and informal housing as there are no strategies or guidelines in place to improve thermal comfort in the building typology.

Fossil fuel-dependent grid

Mumbai's electricity consumption is predominantly dependent on coal, natural gas and other fossil fuel-based thermal power. The energy sector falls in the purview of the state government, leaving BMC with limited control and authority. Thus, there is no authority at the city level to monitor and increase the proportion of renewables in the city's energy mix. At the COP26 summit in, India committed to achieve new climate action targets, which includes a target to source 50% of the energy requirement from renewable sources by 2030 and another to install non-fossil fuel electricity capacity of 500GW by 2030 (Mitra et al., 2021). At the state level, Maharashtra has approved the Renewable Energy Generation Policy 2020, which proposes to deploy 17,385 MW of renewable power in the state by 2025. As part of this policy, solar projects having a total capacity of 12,930 MW have been proposed, as well as 2,500 MW of wind power projects, 1,350 MW co-generation, 380 MW small hydro, 200 MW solid waste-based and 25 MW from new technology-based renewables (Prasad, 2020).

No dedicated capacity or city-level authority to monitor the buildings sector

In India, building approvals are usually managed either by the local authority or the municipal corporation. However, Mumbai neither has a city-level green buildings cell nor an energy efficiency cell to improve ECBC compliance, increase the uptake of green building certification and monitor the development of buildings in the city. Also, there is no dedicated capacity within BMC to focus on energy efficiency activities and strengthen ECBC compliance. Although MEDA is the state dedicated agency (SDA) for increasing the uptake of energy-efficient equipment and improving energy efficiency in the state, the implementation will have to be undertaken at the city level.

Lack of awareness about the benefits of passive design strategies

Information on the impact of poor strategies for ventilation and thermal comfort in low-income housing is not readily available with BMC. The lack of assessments and studies on the socioeconomic and health impacts of heat, flooding and climate change across different housing typologies across most urban centers is a huge gap. Cross-disciplinary information and involvement of experts from different areas (urban planners and architects) can help improve the uptake and understanding of passive design and energy efficiency strategies in buildings.

Low uptake of distributed renewables and green buildings

Although a city-wide study suggests that Mumbai's rooftop potential is 1,700 MW, the uptake of rooftop solar (RTS) in residential, commercial, and industrial buildings has been limited due to high capital and procedural costs and time (Sahoo, 2017). In addition, although most building certification programs are headquartered in Mumbai, it is an expensive and time-consuming process to secure certification and has been highlighted as a hindrance to the uptake of certification programs in consultations.

Transition to clean fuels, energy efficiency and passive design measures in low-income and informal housing

Informal households in the city continue to use firewood and kerosene as cooking fuel and for heating water and are vulnerable to indoor air pollution. The lack of monetary resources and the informal nature of housing pose as huge barriers to improved accessibility to basic services. With rising temperatures, the demand for cooling, and thereby electricity, will also rise; however, people living in low-income housing will have only limited access to cooling equipment and in many cases poor access to electricity too. The increase in indoor temperatures and a lack of space, light and ventilation make these communities most vulnerable to vector-borne diseases, causing perpetual health concerns.

Approach for Energy & Buildings

To overcome the barriers in the current energy and buildings landscape of the city, the MCAP has developed a four-pronged approach:

Figure 32: Approach to decarbonize Mumbai's grid and make buildings resilient

Ongoing Initiatives

Table 8 Ongoing renewable energy and green building initiatives by BMC

Renewable Energy	Energy Efficiency	Green Buildings
• 100 MW floating solar-hydropower hybrid power project at the Middle Vaitarna dam in Maharashtra • Green power tariff of INR 0.66/ kWh over and above the normal tariff for 100% clean energy • Solar panels on the rooftop of the four-storied Engineers' Hub building in Worli. (Eeshanpriya, 2019) • 40% subsidy to residential consumers, 20% to housing groups and RWAs for rooftop solar • BEST to procure 400 MW of wind-solar hybrid power from Solar Energy Corporation of India (SECI) Limited for 25 years	• State Energy Conservation Policy 2017 envisioned a savings of INR 6,000 crore and 1,000 MW of electricity • Mandate for bulk power users, such as multiplexes, malls and commercial buildings, to undergo energy audits every two years • The UJALA scheme to encourage consumers to transition to energy-efficient lighting • Establishment/strengthening of Energy Clubs in schools to make children aware and educate and involve parents	• Highest numbers of certified green buildings across the country – 119 out of 437 in the state of Maharashtra. • All certification agencies are headquartered in Mumbai; however, the city has struggled to implement green building certification in the commercial and residential subsectors. • BEE's voluntary Star Rating Programme for commercial buildings is based on the actual performance of a building in terms of energy usage in the building over its area, expressed in kWh/sq. M/ year.

The sectoral priority, action tracks and the associated actions were developed on the basis of the city-level barrier analysis, ongoing city initiatives, inputs from external and internal stakeholder consultations and zonal consultations along with citizens' inputs received on the website. The stakeholders who were consulted in the process are listed in Annexure 3.

Sectoral Priority

Decarbonizing Mumbai's energy grid and building energy-efficient and climate-resilient infrastructure.

The key priorities are to incorporate 50% renewables in Mumbai's electricity generation mix, assess the potential for rooftop solar on buildings and promote this technology and encourage 100% energy-efficient street and public lightings and energy-efficient or low-carbon technology for utility energy consumption such as WTPs, STPs etc. Additionally, the city must prioritize the use of energy-efficient materials for building construction, a transition to energy-efficient building lightings and cooling equipment and the use of clean fuel and electric stove in cooking and promote thermal comfort design and climate-resilient affordable housing.

Sectoral Action Tracks

Table 9 Energy & Buildings: Sectoral action tracks

Track 1	Increasing the proportion of clean energy in Mumbai's energy mix
Track 2	Switching to clean fuels and ensuring energy and water efficiency in all buildings
Track 3	Promoting low-carbon buildings through ECBC compliance and green building certification
Track 4	Integrating passive design strategies to make buildings climate-resilient

Track-wise Actions

Table 10 Energy & Buildings: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 1: Increasing the proportion of RE to 50% by 2030 and to 90% by 2050 in Mumbai's energy mix			
Priority Actions			
Develop a roadmap for distributed renewables in the city by documenting city-level rooftop solar potential, making the information on installation and information regarding savings accessible to users, incentivizing RE-based power through open access and integrating RE systems within building by-laws to cover 25% requirement. **Timeframe:** 2022-2030	**Lead:** RE Cell, BMC Supporting: DISCOMs, Ministry of Power (MoP), Maharashtra Electricity Regulatory Commission (MERC), Ministry of New & Renewable Energy (MNRE), MEDA, technology provider	Corporate social responsibility (CSR), DISCOM's budget, BMC budget, RE generator's budget, technology providers/ entrepreneurs	**Output:** % of total area of RTS or RE potential; % share of the city's total energy consumption **Outcome:** % of total energy generated from renewable sources as a share of city's total energy consumption, % of total population consuming electricity supported by RE, emission reduce due to use of RE
Ensure 100% of electricity used by BMC and other municipal agencies is from renewable sources by 2030, especially by assessing the potential of land/ roof stock of municipal property. **Timeframe:** 2021-2022	**Lead:** RE Cell, BMC Supporting: DISCOMs, Planning/ Building Dept of BMC	CSR, DISCOM's budget, BMC budget,	**Output:** % of total area of RTS or RE potential implemented on BMC buildings **Outcome:** % of total energy generated from renewable sources as a share of the city's total energy consumption, % of total emission reduced due to use of RE

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 1: Increasing the proportion of RE to 50% by 2030 and to 90% by 2050 in Mumbai's energy mix			
Priority Actions			
Develop a local energy supply plan to define the optimal diversified energy supply portfolio to achieve 50% RE mix by 2030. To do so, introduce RE procurement policy for public buildings and RE transition program for alternative options in informal and low-to-middle income communities. **Timeframe:** 2022-2025	**Lead:** RE Cell, MoP, MERC Supporting: DISCOMs, BMC, MEDA, energy expert, technology providers	MoP, MEDA or MERC fund, CSR, DISCOM's budget, BMC budget, RE generator's budge	**Output:** % of total area of RTS or RE potential; % of emission reduction by use of RE **Outcome:** % of energy generated from RE, as a share of the city's total energy consumption, % low-income/ informal population with electricity generated from RE
Medium- and Long-term Actions			
Set up an Energy Cell in BMC to facilitate city-level RE and EE implementation, coordinate with relevant stakeholders, develop strategies for low-income groups, ensure that correct benchmarking data is requested and analyzed centrally and businesses report year-on-year. **Timeframe:** 2030-2045	**Lead:** RE Cell, BMC Supporting: DISCOMs, MEDA, Planning/Building Dept of BMC, technology partner	MoP, MEDA or MERC fund, CSR, DISCOM's budget, BMC budget, RE generator's budget BEE fund, MNRE fund	**Output:** % of total area of RTS or RE potential; % of emission reduction by use of RE **Outcome:** Setting up Energy Cell; % of total emissions reduces due to use of RE and EE. % of monthly income spent on electricity
Collaborate with research institutions and community organizations to undertake research on other alternative clean sources of energy such as tidal, green hydrogen and solar-wind hybrid. **Timeframe:** 2030-2045			**Output:** Research text on alternative clean sources of energy **Outcome:** % of energy generated from RE as a share of the city's total energy consumption, level of public investment in research & development

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Upgrading existing infrastructure and 100% adoption of energy-efficient and water-efficient equipment and technology in new buildings and switching to clean fuel			
Priority Actions			
Develop a roadmap for retrofitting low-income and informal housing with energy-efficient equipment by 2050 **Timeframe:** 2022-2030	**Lead:** RE/EE Cell, BMC, MEDA Supporting: DISCOMs, technology providers, Planning/Building Dept of BMC, energy expert, BEE, MNRE	Technology provider's budget, MEDA or MERC fund, BMC budget, CSR and DISCOM's budget, Green Building fund	**Outcome:** % of population with an electricity connection, % of monthly income spent on electricity, water consumption per capita/household **Output:** % of homes/buildings retrofitted; % of emission reduction **Outcome:** % of Energy Efficient equipment in low income/informal communities (20% by 2030)
Mandate new buildings to have SWH through building bylaws, particularly hotels and hospitals, with consideration of other technologies such as commercial heat pumps. **Timeframe:** 2022-2030			
Introduce energy- and water-efficient equipment as a mandate in building bylaws for existing and new buildings by 2050. For instance75% of commercial equipment (by 2030), 80% of commercial cooling, 85% of residential appliances and 60% of new water fixtures are to be low-flow fixtures by 2050. **Timeframe:** 2022-2030			
Make 100% transition to energy efficient or RE-powered streetlight and public spaces by 2024 and all residential and commercial buildings by 2030 through mandates and incentives. **Timeframe:** 2022-2030	**Lead:** RE cell, BMC Supporting: DISCOMs, technology providers, Planning/ Buildings Dept of BMC, MEDA, builder associations	MoP, MEDA or MERC fund, BMC budget, DISCOMs funds, Green building fund, NABARD climate fund	**Output:** % of all building floor area complying with climate-related policies; % of homes/buildings retrofitted **Outcome:** % of street and public lighting replaced by energy efficient or RE-powered, % of monthly income spent on electricity

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Upgrading existing infrastructure and 100% adoption of energy-efficient and water-efficient equipment and technology in new buildings and switching to clean fuel			
Priority Actions			
Collaborate with NGOs, CBOs, local/ward-level agencies to distribute energy-efficient LEDs and appliances in low-income and informal settlements and slums.[12]	**Lead:** RE cell, BMC Supporting CBOs, NGOs, ward officers, technology providers	CSR and philanthropic funding	**Output:** Quantity of EE equipment distributed **Outcome:** Percentage of monthly income spent on energy costs, % of population having access to a legal electricity connection
Sensitize citizens about RE and efficiency through awareness programs and leverage existing platforms and windows for engagement with them. **Timeframe:** 2022-2025	**Lead:** EE Cell, BMC, Builder Assoc. **Supporting:** DISCOMs, technology providers, Planning/Building Dept of BMC, MEDA	Multilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund; CSR, MOP, MEDA or MERC fund	**Output:** % of population sensitized through awareness programs **Outcome:**% of buildings implemented ECBC codes voluntarily, energy consumption per capita/ HH, water consumption per capita/HH

[12]The energy footprint in informal and low-income housing and slums is generally low. With space and light constraints and uncertain services, it may not be practical to apply generic RE & EE solutions.

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Upgrading existing infrastructure and 100% adoption of energy-efficient and water-efficient equipment and technology in new buildings and switching to clean fuel			
Medium- and Long-term Actions			
Transition from LPG, PNG and other fossil fuels to clean energy for cooking by changing mindsets and behaviors through IEC programs, introducing efficient cook stoves for poor and informal settlements, mandating new apartments with inbuilt electrified cooktops and making these available to a variety of demographics. **Timeframe:** 2025-2035	**Lead:** EE Cell, BMC, Builder Assoc. Supporting: DISCOMs, technology providers, Planning/ Building Dept of BMC, MEDA	MoP, MEDA or MERC fund, CSR, DISCOM's Budget, BMC budget, RE generator's budget BEE fund, MNRE fund	**Output:** % of citizens purchased electric cooktops; **Outcome:** Mortality rate attributed to indoor air pollution, energy consumption per capita/HH **Outcome:** % of air quality improvement in area; % of buildings transitioned from fossil fuel to clean energy
Initiate city-wide energy saving mass awareness campaign and build a platform to disseminate information on availability of energy-efficient materials and products to engage directly with consumers and buyers on a continuous basis. **Timeframe:** 2025-2035			
Collaborate with MEDA and the private sector to roll out a program on energy efficiency services for commercial and public sectors, including targeted advice, training, assistance and subsidized energy audits. **Timeframe:** 2025-2035			

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 3: Promoting green buildings through retrofitting in existing buildings and ECBC compliance and certification in new buildings			
Priority Actions			
Mandate ECBC compliance and set up an ECBC/green building cell for monitoring new building approvals and overall building stock growth at city-level and setting up a task force at ward level. Categorize building stock by type, age, number of floors and size. MEDA can support through capacity building. **Timeframe:** 2022-2030	**Lead:** EE Cell, BMC, builders associations Supporting: DISCOMs, technology providers, Planning/Building Deptof BMC, MEDA, Green building certification Society	Multilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund; CSR, MoP, MEDA or MERC fund, public private partnership (PPP) mode	**Output:** Records on database for equipment transitions; % of buildings implement ECBC compliance. **Outcome:** % of energy demand reduced after implementation of ECBC codes, % of monthly income spent on electricity, % of population in slums and informal settlements
Develop an action plan for implementing ECBC-R, which involves the establishment of ward-level committees by 2030. **Timeframe:** 2022-2030			
Conduct energy audit as per ECBC compliance for all municipal buildings and infrastructure and retrofit for energy efficiency and RE by 2030. **Timeframe:** 2022-2027	**Lead:** EE Cell, BMC, Energy Audit experts Supporting: DISCOMs, technology providers, Planning/Building Dept of BMC, MEDA	MoP, MEDA or MERC fund, CSR, BMC budget, RE generator's budget, BEE fund, MNRE fund	**Output:** % of building retrofit solutions for energy conservation and efficiency; **Outcome:** impact on government officers' behavior through various trainings
Build capacity in all municipal departments to improve efficiency and RE in all municipal infrastructure. **Timeframe:** 2022-2027			
Undertake a demonstrative low/zero carbon buildings project (such as a station, an office or a museum) to set an example in sustainable building and infrastructure design and operation. **Timeframe:** 2022-2027			

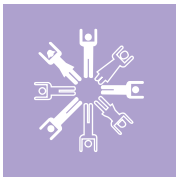
Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 3: Promoting green buildings through retrofitting in existing buildings and ECBC compliance and certification in new buildings			
Priority Actions			
Create a retrofit accelerator program on the lines of New York City and London programs to identify retrofit needs of the existing buildings and priorities based on ownership and management structure. **Timeframe:** 2022-2026	**Lead:** EE Cell, BMC, energy-based IT experts Supporting: DISCOMs, technology providers, Planning/Building Dept of BMC, MEDA, town planners/ architects/designers' associations	MEDA or MERC fund, CSR, DISCOM's budget, BMC budget, RE generator's budget BEE fund, MNRE fund	**Output:** % of existing households undergoing retrofitting of low-carbon green building measures; **Outcome:** % of all building floor area complying with climate-related policies; % of HHs lacking formal land tenure % of monthly income spent on electricity % of population with access to electricity
Establish a system to allow informal housing to retrospectively gain official licence/status through the introduction of simple energy efficiency measures that bring them up to code. Benefits to the homeowners could include business licences to trade, access to further subsidies and official tenure, among others. **Timeframe:** 2022-2026			
Establish a mandate to improve the envelope technology of existing buildings to have advanced wall and roof insulation and double-glazed low-E windows to help reduce the cooling load. **Timeframe:** 2022-2026			
Establish a system to conduct regular energy performance benchmarking of buildings by 2025, and mandate a building energy management system in all new buildings. **Timeframe:** 2022-2025	**Lead:** EE Cell, BMC, energy-based IT experts Supporting: DISCOMs, technology providers, Planning/Building Dept of BMC, MEDA, town planners/ architects	MoP, MEDA or MERC fund, CSR, DISCOM's budget, BMC budget, BEE fund, MNRE fund	**Output:** % of building retrofit solutions for energy conservation and efficiency; % of building following the energy audit benchmark **Outcome:** % of energy demand reduced in new buildings, energy consumption per capita

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 3: Promoting green buildings through retrofitting in existing buildings and ECBC compliance and certification in new buildings			
Medium- and long-term actions			
Adopt circular economy principles to reduce environment impact through managing construction and demolition (C&D) waste, and recycle a certain a percentage; design typologies that use less materials; achieve a reduction in embodied emissions through procurement and regulations to limit construction within carbon-optimal range. **Timeframe:** 2022-2045	**Lead:** EE Cell, BMC, builder associations, SWM Supporting: Technology providers, Planning/ Building Dept of BMC, MEDA	Multilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund; CSR, MOP, MEDA or MERC fund, PPP mode	**Output:** % of C& D waste reuse for new building construction; types of building stock identified; **Outcome:** % of new buildings following the use of climate-resilient materials; % of emission reduction through building material
Promote voluntary certifications, such as EDGE Zero Carbon and Indian Green Business Council (IGBC)/Net Zero Energy Buildings (NZEB) standards, that buildings of certain types can adopt as a first step. **Timeframe:** 2025-2045	**Lead:** EE Cell, BMC, builder associations Supporting: Technology providers, Planning/ Building Dept of BMC, MEDA	MoP, MEDA or MERC fund, CSR, DISCOM's budget, BMC budget, RE generator's budget BEE fund, MNRE fund	**Output:** % of buildings exceeding minimum specification/policy requirements; % of homes/ buildings retrofitted **Outcome:** % of improvement in the energy usage per person, energy consumption per capita/HH, % of total energy coming from RE sources as a share of the city's total energy consumption, % of population using electricity generated from RE, availability of climate-resilient, low-carbon affordable housing
Prepare a roadmap/coordinated program to address how bylaws can be stepped up to integrate Zero Carbon Buildings (ZCB) by 2040 for all new buildings. Adopt EDGE/IGBC standards, starting with all government-owned buildings and identify challenges to amend relevant byelaws. **Timeframe:** 2025-2045			
Conduct a feasibility study for Mumbai to set protocols for calculating the carbon footprint of select building typologies. Integrate the provision of electric charging infrastructure in building bylaws, and allot unique IDs-linked building passports. **Timeframe:** 2025-2045			

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 4: Integrate passive design strategies to ensure well-being and thermal comfort for all			
Priority Actions			
Mandate heat-resistant roof and wall materials in all new building structures, including in housing schemes for economically weaker sections, government offices and commercial buildings **Timeframe:** 2022-2030	**Lead:** EE Cell, BMC, builders' associations, green building agencies Supporting: DISCOMs, technology providers, Planning/Building Dept of BMC, MEDA	MOP, MEDA or MERC fund, multilateral/ bilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund, CSR, PPP mode	**Output:** Length (km) of cooling routes established; **Outcome:** % of population cover for cooling district centre % of population with electricity; energy consumption per capita or HH; % of population vulnerable to excessive heat
Conduct a comprehensive socio-economic vulnerability assessment at the ward level to understand the needs of the city's communities to ensure the implementation of appropriate programs in response to reduction of heat-related risk. Implement a cooling pilot in vulnerable areas, including cooling centres and cool roofs, and strategic greening in vulnerable areas. **Timeframe:** 2022-2030			
Ensure stricter implementation of guidelines on building materials, built form and density to reduce heat on streets and public spaces through the imposition of penalties. **Timeframe:** 2022-2030			
Ensure access to energy to build adaptive capacity, considering that with increase in heat, more electricity will be required for cooling purposes. **Timeframe:** 2022-2030			

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 4: Integrate passive design strategies to ensure well-being and thermal comfort for all			
Priority Actions			
Prepare a thermal comfort guidance for different typologies of buildings in the city in collaboration with architects, planners and academia, particularly for low-income housing and multi-storey buildings, and incorporate the same into the city's development, urban design and urban land use schemes **Timeframe:** 2022-2030	**Lead:** EE Cell, BMC, builders associations Supporting: DISCOMs, technology providers, Planning/Building Dept- of BMC, MEDA	MOP, MEDA or MERC fund, multilateral/ bilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund, CSR, PPP mode	**Output:** % of land use and building design with building typology; % of all new building which are benchmarking **Outcome:** % of all building floor area complying with climate-related policies; availability of climate-resilient affordable housing
Develop a climate-resilient low-income housing project with mitigation and adaptation solutions ,such as passive cooling, rainwater harvesting, and solar energy, to improve livelihoods and overall well-being **Timeframe:** 2025-2030	**Lead:** EE Cell, BMC, MEDA Supporting: DISCOMs, energy policy experts, technology providers, BEE, Planning/ Building Dept of BMC, builders associations	MOP, MEDA or MERC fund, multilateral/ bilateral finance opportunity, banking finance, MNRE funds, NABARD climate fund, CSR, PPP mode	**Output:** No. of households (disaggregated by income levels) undergoing retrofitting of low-carbon green building measures; no. of building codes integrating benchmarking policy **Outcome:** Availability of affordable housing

Sector-specific Inclusivity Benefits



- Facilitating the adoption of distributed renewable energy through community or cooperative projects can increase access to clean energy, especially in low-income communities where the high upfront cost of installation is a huge challenge and physical infrastructure is lacking.
- Mainstreaming low-carbon buildings, including retrofitting, and upgrading new building projects could open up job opportunities for the semi-skilled as well as create green jobs and opportunities for reskilling or upskilling.
- Conducting advocacy and engagement on women's involvement in renewables can lead to awareness raising, knowledge sharing and information dissemination among individuals and CSOs.
- Monitoring energy usage per person rather than per unit of living area would lead to a fairer energy performance indicator system. Further, bundling energy efforts with renewable energy will reduce energy poverty and lower the cost barrier for low-income groups.
- Introducing flexibility in building codes with appropriation as per different market segments, thereby setting up targets to incorporate efficiency measures, would make the process more affordable for the community as well as increase willingness for the developer to invest in thermal comfort for all.

5.2 Sustainable Mobility

Public transport, walking and cycling can be considered as the triple bottom line of sustainable mobility in cities (European Environment Agency, 2020). Mumbai's extensive public transport system comprises five modes (Figure 33). Not only is 46% of all trips made on foot, walking is also the mode for meeting 60% of last-mile connectivity for public transport trips (BMC, 2016). This indicates a huge potential to further strengthen active mobility in the city. The modal split for 2015 was as follows: taxi 3.56%, autorickshaw 3.13%, two-wheeler 7.99%, car 6.26%, bus 11.83%, suburban rail 20.09%, light rail 1.13% and non-motorized transport 46%. Intermediate public transport, such as autorickshaws and taxis, supplement public transport and provide door-to-door as well as last-mile connectivity. The city has around 75,000 commercial cabs, 18,000 black-and-yellow taxis or *kaali-peelis* (Sen, 2019) and 2,00,000 autorickshaws (Korde, 2019). However, these are predominantly fossil fuel-driven. Only around 36 taxis in the city are electric (Mishra, 2019; Tech2, 2019).

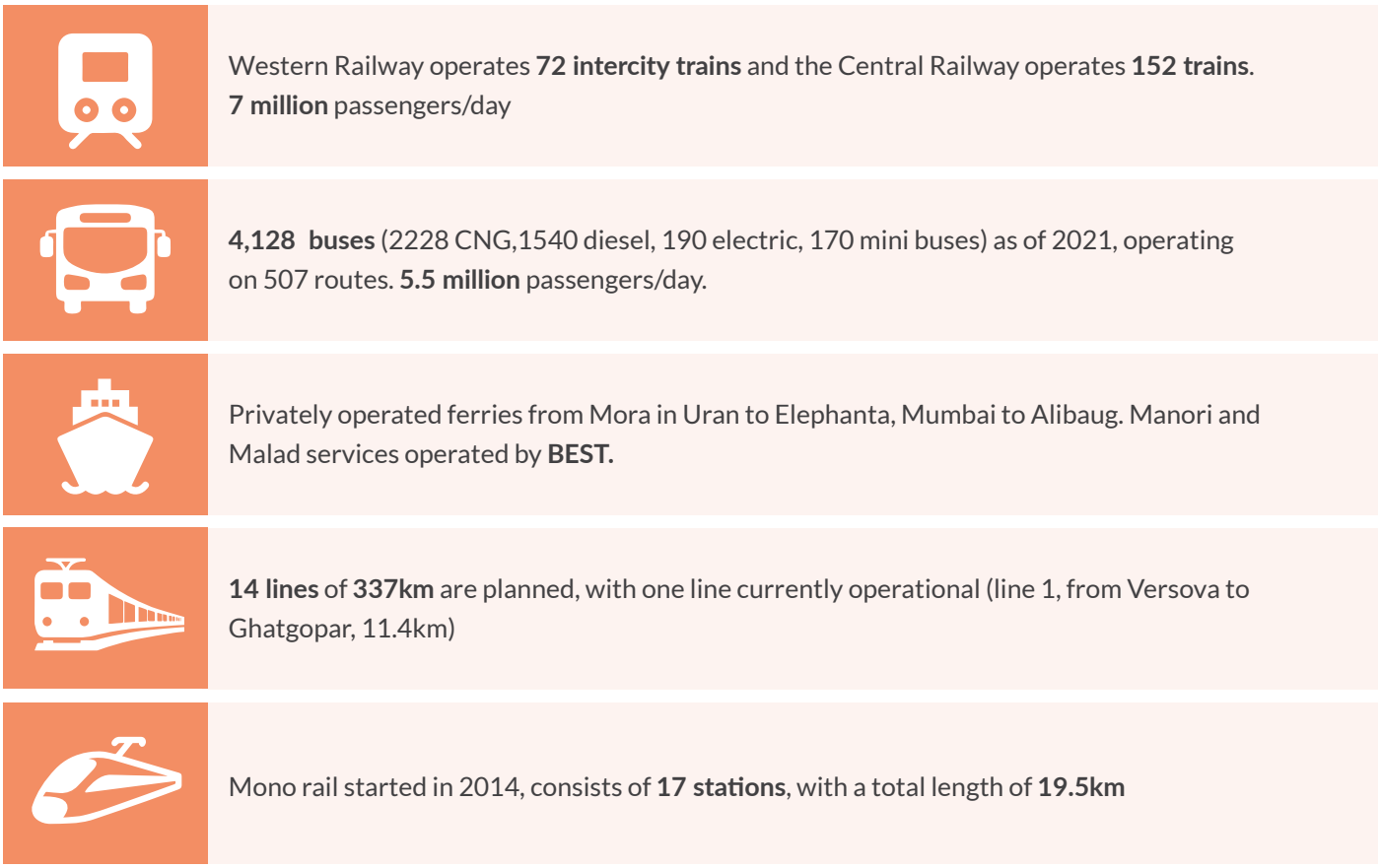


Figure 33: Public transport in Mumbai

Key Gaps in the Transport Sector

The transport sector accounts for 19.4% of the total emissions generated in the city, amounting to 4.5 million tonnes CO_2e. Road transport contributes 83% of the emissions in the transport sector, followed by railways (17%).There is an urgent need to shift towards cleaner fuels, particularly for the on-road subsector.

Limited integration of low-carbon transport and land-use planning

Despite high non-motorized transport usage in the city, only 22% of Mumbai's streets are walkable (FJP Bureau, 2019). There is a need to strengthen coordination between land-use planning and transport infrastructure planning and prioritize active mobility through inclusive, climate-resilient, accessible and safe pedestrian infrastructure. This would reduce transport sector emissions, shift demand away from fossil fuel-heavy private vehicles and improve commuter safety, especially for pedestrians.

Fragmented multimodal and institutional coordination

Mumbai's public transport modal share declined from 88% to 70% between 2008 and 2015 (Saxena, 2019). Strategies such as effective multimodal integration through integrated ticketing, non-motorized transport (NMT) last-mile infrastructure and passenger information services can play a major role in increasing public transport ridership, reliability and commuter satisfaction. A strategic, integrated approach is required across modes.

High fossil fuel dependency

The city currently has less than 1% electric vehicles in its total fleet. Decarbonizing the road transport subsector would require an urgent shift towards zero emission fuels as well as improved fuel efficiency. This must be supported with policies, finance and sufficient infrastructure. For example, 90% of taxis and autorickshaws run on CNG, but they face high re-fuelling waiting times due to insufficient CNG filling stations in the city (Ganapatye, 2018).

Congestion and parking demand

Ranked as the second-most congested city in the world, traffic congestion remains a major contributor to air pollution, high travel time and fatalities in Mumbai. (The TomTom Traffic Index 2020). If stringent measures are not taken, transport is likely to equal industrial PM 2.5 emissions by 2030 (TNN, 2019). Thus, the city should focus on transport demand management to disincentivize private transport and shift the demand from low-occupancy private vehicles to high-occupancy shared vehicles and from fossil fuel-based vehicles to zero carbon-based modes.

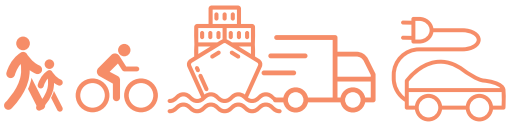
Limited focus on sustainable freight management

Freight contributes 7% of the total transport emissions in India but does not fall in the purview of city policies. There is a need to begin by analyzing the emissions from Mumbai's freight sector and develop a strategic policy approach towards decarbonizing the sector.

Approach for Moving Towards Low-carbon Transport in Mumbai

Based on an assessment of the gaps and barriers in the transport sector, the MCAP has identified a four-pronged approach with aligned actions for reducing emissions from the transport sector. The approach also includes improved accessibility of public transport, improved multimodal integration and zero-carbon freight and passenger modes, with a focus on inclusivity.

Table 11 Approach for sustainable transport



Clean	Manage	Integrate	Optimize
Promoting zero emission fuels as well as fuel efficiency improvements	Adopting transport demand management to discourage private vehicle usage and shifting towards low-carbon modes	Integrating across multiple transport modes and improved last-mile access	Optimizing the existing transport capacities through intelligent transport systems

Ongoing Initiatives in the City

Mumbai is currently implementing certain initiatives within this sector, which can be broadly categorized using the sectoral approach (Table 12). The actions proposed within the CAP will help integrate the climate lens in these initiatives and further accelerate the efforts.

Table 12 Ongoing transport initiatives undertaken by BMC

Clean	Optimize
• BEST has plans to ply 340 electric buses in Mumbai by 2022 (Ahmed, 2020), and electrify 100% of fleet by 2028. • Initiatives have been taken to promote EV transition in line with the Maharashtra EV policy.	• Mobile application for passenger information on bus arrival and routes with GPS tracking (Tiwari, 2019)
Manage	**Integrate**
• Expanding metro network (Saxena, 2019). • 257-km-long exclusive bus lane corridors and 4 intercity bus terminals by 2034. • Ropeways proposed from Malad to Marve and from Gorai to Borivali (The TomTom Traffic Index, 2020) • ROPAX services on four routes and water taxis on 12 routes by December 2021 (Ministry of Ports, Shipping and Waterways, 2021). • Parking cell within BMC, 77 locations for pay-and-park scheme (MPCB, 2019).	• MMRDA is designing and implementing multi modal integration (MMI) for improved last mile access to metros (The TomTom Traffic Index, 2020). • BMC, in collaboration with WRI India, is creating super footpaths (Joshi, 2019), connecting railway and metro lines. • The city is reviving Bellasis Road, with pedestrian-friendly features (Tak & Hirandas, 2021). • The CMP[1] proposes 240 km of cycle tracks by 2024 (LEA Associates South Asia Pvt. Ltd, 2016).

Sectoral Priority

Promoting low carbon mobility solutions, with a strong focus on non-motorized transport infrastructure and zero emission fuels

The sectoral priority, action tracks and associated actions were developed on the basis of the city-level barrier analysis, the ongoing city initiatives, inputs from external and internal stakeholder consultations and zonal consultations along with citizens' inputs received on the website. The stakeholders who were consulted in the process are listed in Annexure 3.

Building upon Mumbai's extensive public transport network, multimodal integration and equitable access and affordability for women, children and low income groups were identified as key priorities. As Mumbai is highly congested, parking management and safer intersections need to be prioritized along with inclusive pedestrian and cycling infrastructure for reduced congestion, commuter safety and better air quality. With less than 1% electric vehicles in the mix, incentives and policies to shift towards 100% zero-emission vehicles by 2050 for passenger and freight modes is a key priority for reducing GHG emissions as well as improving air quality. The priority climate action tracks and actions based on these considerations are presented in Table 13.

Sectoral Action Tracks

Table 13 Sustainable Transport: Sectoral action tracks

Track 1	Improving public transport ridership through multimodal integration and demand management away from private vehicles
Track 2	Improving NMT access and infrastructure for a healthier and safer city
Track 3	Transitioning towards 100% zero emission vehicles by 2050, with increased access to finance, policy enablers and incentives
Track 4	Transitioning towards zero emission freight through policies, route management and incentives

Track-wise Actions

Table 14 Sustainable Transport: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/financing	Indicators[2]
Sectoral Action Track 1: Shifting demand away from private vehicles and ensuring inclusive public transport access and multimodal connectivity			
Priority Actions			
Develop integrated ticketing and pass options with clear pricing systems and finance distribution. **Timeframe:** 2026 Integrated fare structures (2040)	**Lead:** MMRDA Supporting: BEST, Western and Central Railways, Dept of Transport-Government of Maharashtra	INR 150 crores were allocated in the MMRDA budget (Chacko, 2018) (2018-19)	**Output:** No. of integrated passes, no. of passes for low income groups, women and elderly **Outcome:** % mode share of public transport, ridership (disaggregated by gender, income level), waiting time, % of monthly income spent on transport
Develop a comprehensive open data strategy for real-time communication of data (fares, routes, timing, etc.). **Time frame:** 2026	**Lead:** BMC-Roads & Transport, Traffic) Supporting: MMRDA, BEST, Railways, MMRC, Mumbai Maritime Board, ferry operators	BMC budget, Smart Cities Mission (Data on Smart Cities)	**Output:** Strategy, public data platform, no. of bus stops with passenger information systems **Outcome:** % mode share of public transport, ridership (disaggregated by gender and income), waiting time, Level of perceived comfort and quality of public transport service (safety, reliability, frequency, crowding, availability of seats)

Action Description	Stakeholders	Funding/financing	Indicators[2]
Sectoral Action Track 1: Shifting demand away from private vehicles and ensuring inclusive public transport access and multimodal connectivity			
Priority Actions			
Formulate a parking policy focusing on off street parking, technology-driven parking management, paid parking, etc. for reduced congestion and air quality improvement. **Time frame:** 2024	**Lead:** Mumbai Parking Authority-BMC **Supporting:** BEST, MMRDA, research organizations, housing societies	BMC budget	**Output:** Parking policy, % paid parking spots, **Outcome:** Reduced congestion (Tomtom index), increase in average travel speeds, PM10 and PM2.5 concentrations
Facilitate bus lane markings and signal prioritization for smooth bus movement. **Time frame:** 2026	**Lead:** MMRDA, BMC **Supporting:** BEST, Maharashtra State Road Development Corporation (MSRDC), Traffic police, Navi Mumbai Municipal Transport (NMMT), Thane Municipal Transport (TMT), Kalyan Dombivli Municipal Transport (KDMT)	BMC budget	**Output:** Km of bus markings, approved framework, % of buses with ramps, special seats for women and the elderly and other special groups, routes in low income areas, level of perceived comfort and quality of public transport service (safety, reliability, frequency, crowding, availability of seats) on services and routes used **Outcome:** Reduced fuel consumption, average travel speeds (kmph), % of bus mode share, ridership (disaggregated by gender and income level)
Develop a sustainable bus framework across MMRDA, with mandates for optimizing capacities, energy efficiency, commuter comfort and infrastructure with universal access. **Timeframe:** 2026			
Offer incentives such as green credits, tax rebates to companies to encourage public transport. **Timeframe:** 2023	**Lead:** BMC **Supporting:** Private organizations, MMRDA, financial institutions	BMC budget	**Output:** No. of companies with public transport incentives, % employees shifting to public transport **Outcome:** % mode share of public transport, ridership (disaggregated by gender and income level)
Establish commuter helpline to address grievances around public transport safety, access, reliability, etc. **Timeframe:** 2024	**Lead:** BMC **Supporting:** BEST, MMRDA, Railways	BMC budget	**Output:** Common helpline desk **Outcome:** Increased commuter safety, % mode share of public transport, ridership (disaggregated by gender and income level)

Action Description	Stakeholders	Funding/financing	Indicators[2]
Sectoral Action Track 1: Shifting demand away from private vehicles and ensuring inclusive public transport access and multimodal connectivity			
Medium- and Long-Term Actions			
Develop walking corridors with climate-resilient components, based on an assessment of transit routes. **Time frame:** 2035	**Lead:** MMRDA **Supporting:** BMC (Roads & Traffic Dept), Research organizations, BEST, Western and Central Railways, cab aggregators, Mumbai autorickshaw drivers' union	Tender costs of around INR 85-90 crores per station (MMRDA 2020)[3]	**Output:** No. of transit stations with last mile connectivity within 500m station radius, % commuters walking/cycling to and from stations (disaggregated by gender and income), **Outcome:** % mode share of public transport, job density around new metro lines, no. of low income areas within 1km from transit stations
Plan for last-mile access for metros (public bike rentals, cabs and autos near stations, feeder buses, etc.). **Time frame:** 2035			
Create dedicated bus lanes, where feasible **Time frame:** 2040	**Lead:** MMRDA, BMC **Supporting:** BEST, MSRDC	INR 5,397 crores allocated between 2016-2034 for 257km of exclusive bus lanes (BMC, 2016)	**Output:** Km of exclusive bus lanes, **Outcome:** Average travel speeds for public transport,% bus mode share
Study the areas with high congestion, and develop curated pricing mechanisms. **Timeframe:** 2045	**Lead:** BMC (Roads & Traffic) **Supporting:** MMRDA, public transport operators, resident welfare associations, NGOs	BMC budget	**Output:** No. Congestion pricing, **Outcome:** TomTom index ranking, average speed of vehicle, PM10 and PM2.5 concentrations
Conduct a study on policy levers to encourage the practice of owning one vehicle per household. **Timeframe:** 2050			**Output:** No. of vehicles per household **Outcome:** Reduced congestion, PM10 and PM 2.5 concentrations, no. of road fatalities
Adopt a science-based approach to tackle station crowding. **Timeframe:** 2050	**Lead:** MMRDA **Supporting:** BMC, Railways, BEST, third party research organizations		**Output:** Reduced transfer time at stations, reduced rate of fatalities **Outcome:** Level of commuter satisfaction, ridership, no. of fatalities in stations

Action Description	Stakeholders	Funding/financing	Indicators
Sectoral Action Track 2: Retain the mode share of non-motorized trips and improve NMT infrastructure while ensuring increased pedestrian safety, inclusive access and last mile connectivity			
Priority Actions			
Conduct an audit of the existing pedestrian infrastructure (coverage, encroachments, lighting, etc.) **Time frame:** 2023	**Lead:** MMRDA **Supporting:** BMC-Roads & Traffic Dept, MSRDC	INR 2 crores budgeted per intersection, INR 0.15 crore for installing 1 traffic signal, INR 0.33 crore per km of cycle track (BMC, 2016)	**Output:** % of roads with usable, accessible walkways, % of roads with street furniture, play areas, good lighting and ramps **Outcome:** NMT mode share, % of safe intersections, PM2.5 and PM10 concentrations, reduction in fatality rates for pedestrians, km of pedestrian walkways in low-income areas
Implement pilot pedestrianization projects in high footfall areas,such as Central Kala Ghoda, with age-friendly, gender-neutral and universally accessible components, such as ramps on curbs, street furniture and lighting, play areas. **Time frame:** 2025			
Redesign traffic signals and infrastructure such as underpasses near tourist spots. **Timeframe:** 2030			
Fix signs near pedestrian crossings, and increase signal timings for pedestrians. **Timeframe:** 2030			
Create a multistakeholder NMT cell within the Transport Department. **Timeframe:** 2024	**Lead:** BMC **Supporting:** MMRDA, MSRDC, NGOs, RTO	AMRUT	**Output:** Functioning NMT cell, no. of trainings, **Outcome:** Reduced fatalities, % of roads with NMT infrastructure
Mandate defensive driving training for new licenses. **Timeframe:** 2024			
Medium and long term actions			
Develop NMT street design guidelines, a cycle master plan and an NMT policy for Mumbai. **Timeframe:** 2035	**Lead:** BMC (NMT cell) **Supporting:** MMRDA, MSRD, MYBYK and other organizations	AMRUT, BMC budget	**Output:** Cycle master plan, street design guidelines and NMT policy **Outcome:** Fatality rates for pedestrians, % of road length with NMT (in low income and high income areas), mode share for cycling

Action Description	Stakeholders	Funding/financing	Indicators
Sectoral Action Track 3: Transition to zero emission vehicles and vehicles with more efficient engines by 2050 (electrification of all buses by 2027, electrification of all two-wheelers, taxis and autorickshaws by 2050, electrification of 96% of all private four-wheelers by 2050) for reduced GHG emissions and improved air quality			
Priority Actions			
Offer incentives for BSVI vehicles, such as road tax and registration fee reductions and scrapping. **Time frame:** 2025	**Lead:** Department of Transport-Govt of Maharasthra **Supporting:** BMC, MMRDA, RTOs, EV manufacturers, charging infrastructure companies such as Magenta Power, Mumbai autorickshaw drivers' union, Mumbai Parking Authority, banks	Phase-II of FAME scheme, Maharashtra EV Policy 2021, low interest loans	**Output:** No. of incentives, reduction in average TCO for EVs, EV cell, no. of incentives for low income drivers **Outcome:** Increase in EV vehicle sales and registrations by vehicle type for Mumbai, no. of BS VI vehicles out of total registrations, PM10 and PM2.5 concentrations
Offer incentives for EVs such as reduced parking fee and toll charges, waiver on fitness certificates and metering for 3-wheelers up until 2028. **Time frame:** 2025			
Make access to finance easier through strategies such as better communication of MUDRA loans. **Timeframe:** 2025			
EV cell **Timeframe:** 2025			
Pilot EV chargers integrated with urban infrastructure, such as streetlights. **Timeframe:** Pilot: 2026 Scale up based on learnings: 2040	**Lead:** BMC **Supporting:** Magenta Power, HPCL, MMRDA, BEST, Mumbai Parking Authority, OEMs, energy utilities, private companies	Average CAPEX for installing public charging stations: INR 10-40 lakhs, based on charging type, average OPEX- INR 9-10 lakhs (Shah, 2019)	**Output:** of charging stations in a 3x3km grid, or per million population, % street lights with charging infrastructure **Outcome:** No. of EVs registered
Develop common charging infrastructure standards across vehicle types and OEMs. **Timeframe:** 2026			Common standards
Conduct a study on the existing battery recycling infrastructure (formal and informal), rates and locations. **Timeframe:** 2024 Development of battery recycling guidelines (2030)	**Lead:** BMC **Supporting:** Research organizations, NGOs working on waste management, OEMs	BMC budget	**Output:** Comprehensive study **Outcome:** Reduced EV waste (kg), no. of low income livelihoods supported

Action Description	Stakeholders	Funding/financing	Indicators
Sectoral Action Track 3: Transition to zero emission vehicles and vehicles with more efficient engines by 2050 (electrification of all buses by 2027, electrification of all two-wheelers, taxis and autorickshaws by 2050, electrification of 96% of all private four-wheelers by 2050) for reduced GHG emissions and improved air quality			
Priority Actions			
Implement a pilot on the conversion of CNG buses to buses that run on bio-CNG from mandi waste **Time frame:** 2025	**Lead:** BMC (SWM) **Supporting:** MPPCB, BEST, MMRDA, local mandi vendors, financial institutions, private organizations	INR 15 crores capital cost for 25 TPD capacity, generating 115 ton per day biogas, in the case of Indore (Warsi, 2019), carbon credits	**Output:** Kg of waste treated in the plant, kl of bio-CNG produced per day, no. of bio-CNG buses in the city, **Outcome:** Reduction in AQI
Promote fuel efficiency and conduct training on driving techniques for bus drivers and workshops on EV benefits and infrastructure for households. **Timeframe:** 2024	**Lead:** BMC **Supporting:** RTOs, resident welfare associations, NGOs, charging companies such as Magenta Power	BMC budget	**Output:** No. of trainings conducted, no. of workshops in households (disaggregated by income level) % increase in fuel savings at post training sessions **Outcome:** % of EV-ready parking lots in residential buildings
Medium and long term Actions			
Increase the CNG stations network in a phased manner, with the long-term objective of a shift to EV. **Timeframe:** Commencement (2023), continuation in the medium term (2030)	**Lead:** BMC **Supporting:** Fuel companies such as HPCL, BPCL, IOCL and Mahanagar Gas, Mumbai autorickshaw drivers' union, financial institutions	BMC budget, PPP	**Output:** No. of CNG stations in the city, waiting time for refuelling autos **Outcome:** PM2.5 and PM10 concentrations

Action Description	Stakeholders	Funding/financing	Indicators
Sectoral Action Track 4: Developing a sustainable freight policy for Mumbai with the aim to electrify 100% of light duty trucks and 2W freight and 46% of medium and heavy duty trucks by 2050, along with shifting to low-carbon modes (rail and water)			
Priority Actions			
Offer incentives for electric freight (parking fees reduction, road tax exemptions, flexible timings), relaxations in approvals or rebates for EV-ready warehouses. **Time frame:** 2025	**Lead:** BMC **Supporting:** Freight operators, mandi vendors, charging companies such as Magenta Power, organizations such as Bombay Goods Transport Association	Phase-II of FAME scheme, Maharashtra EV Policy 2021	**Output:** No. of incentives, % electric 2W, 3W and 4W freight, no. of warehouses with EV charging infrastructure **Outcome:** PM10 and PM2.5 levels reduced
Pilot the electrification of SWM management vehicles or mandi vehicles. **Time frame:** 2025			
Study freight movement and fuel composition. **Timeframe:** 2025			
Collaborate with ferry operators, railways, e-commerce companies and government agencies to understand the gaps in infrastructure, finance and data gaps for improved multimodal integration. Develop incentives for companies to shift to low -carbon freight modes. **Timeframe:** 2025 (continuous process)	**Lead:** BMC **Supporting:** Fleet operators, Western and Central Railways, Mumbai Railway Vikas Corporation (MRVC), Traffic Department, Mumbai Port Trust, MMB	Railways budget, MCGM budget, National Investment and Infrastructure Fund (NIIF)	**Output:** % of freight transported by waterways or railways for each fleet operator, modal share of rail, road and water freight, common standards **Outcome:** Improved PM levels, reduced GHG emissions from freight
Pilot the shift of non-bulk freight to railways and water. (There is an ongoing pilot between Central Railways and Amazon.) **Timeframe:** 2026			
Develop roadside remote sensing to identify freight emission hotspots and contribute towards GHG inventory. **Timeframe:** 2030	**Lead:** BMC **Supporting:** Private companies for technology and data assistance, Traffic Police, freight operators	One remote sensing device could cost around INR 2.5 crores, depending on models (Roychowdhury, 2018)	**Output:** Emissions inventory for freight, no. of remote sensors installed **Outcome:** Reduced GHG emissions from freight, improved PM levels

Action Description	Stakeholders	Funding/financing	Indicators
Sectoral Action Track 4: Transition to zero emission vehicles and vehicles with more efficient engines by 2050 (electrification of all buses by 2027, electrification of all two-wheelers, taxis and autorickshaws by 2050, electrification of 96% of all private four-wheelers by 2050) for reduced GHG emissions and improved air quality			
Medium and Long Term Actions			
Give preference to agencies with low-carbon fleets when contracting for municipal services or mandatorily include the requirement in new tenders. **Time frame:** Contract preference and inclusion in tenders: 2030 onward (or when current lease expires)	**Lead:** BMC **Supporting:** Private agencies, freight operators		**Output:** Increase in low carbon freight, reduction in number of HDVs plying within city boundaries **Outcome:** PM2.5 and PM10 concentrations
Limit HDV freight vehicles based on age/efficiency/size in terminals outside the city and allow only EV-powered LDVs in the city **Timeframe:** Start: 2030 Implementation by 2040, with regular monitoring	**Lead:** BMC **Supporting:** Transport Dept- Government of Maharashtra, freight operators		

Sector-specific Inclusivity Considerations

- Incorporating age-friendly, disability-friendly and women-friendly policies for public transport accessibility and non-motorized transport (NMT) planning would enable an inclusive and equitable mobility approach. This is important since 46% of population prefers walking, with a large share being women, children and the elderly
- Increasing the uptake of public transport through fare integration, improved infrastructure and feeder services, particularly in low income areas
- Providing low-income drivers and small businesses with easy loans to reduce the upfront costs of EVs
- Training women drivers and incorporating components such as panic buttons and women only compartments, to improve women's safety
- Designing junctions with signal management to ensure safety for commuters, especially pedestrians and children.

5.3 Sustainable Waste Management

The BMC, on average, manages 5,500 MT of municipal solid waste per day, excluding approximately 800 TPD of C&D waste[13]. The composition is depicted in Figure 34. The waste sector accounts for 8.2% of the total GHG emissions in the city.

Although waste is responsible for a relatively smaller proportion of emissions as compared with the stationary energy and transportation sectors, it is intricately linked to public health, hygiene and livelihoods of workers handling waste (BMC, 2021).

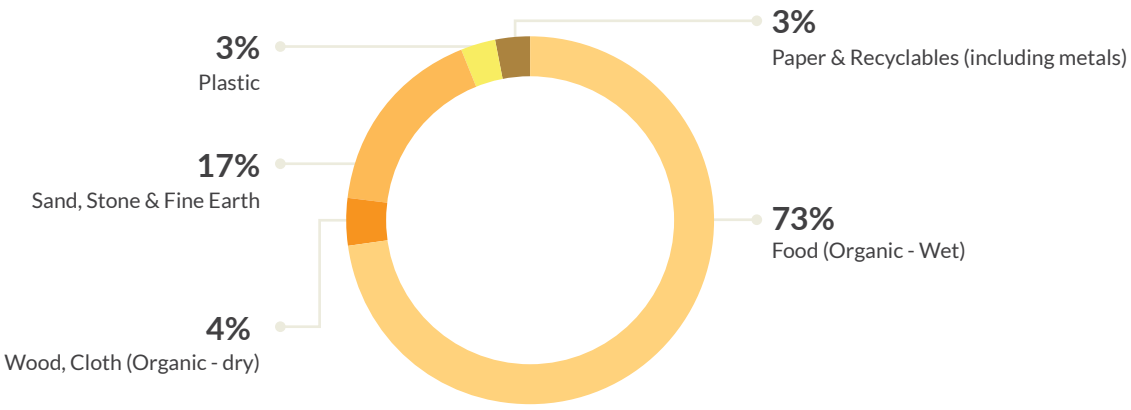


Figure 34: Municipal Solid Waste Composition

Mumbai currently has three waste disposal sites, one each in Deonar, Mulund and Kanjurmarg, with only the latter two being operational. A dumpsite at Gorai was scientifically closed in 2009. In 2020-21, about 85% of Mumbai's waste was transported to Kanjurmarg, a five-year-old disposal site, and treated using the bioreactor technology and windrow composting, while the remaining 15% was disposed of by dumping and levelling at Deonar.

The Deonar site is the oldest dumping ground in the city and has exhausted its capacity to receive more garbage, with BMC planning its closure. Meanwhile, the 24-year -old Mulund dumpsite stopped receiving waste in 2019 and is currently under remediation through biomining (BMC, 2021). Figure 35 presents a map of the disposal sites in the city and their current status.

[13]The Environment Status Report provides data on the waste that is formally collected by BMC and not the total waste generated in the city.

Figure 35: Waste disposal sites in Mumbai
(Source: BMC, WRI India 2021)

Key Gaps in the Waste Sector

The implementation of the Solid Waste Management (SWM) Rules 2016 encouraged source-level segregation and treatment, resulting in a 40% decrease in waste reported by BMC in the last five years. The use and manufacturing of plastic carry bags less than 50 microns in thickness was banned in 2016. Around 325 MT of plastic waste has been collected since the ban came into effect, and Maharashtra Pollution Control Board (MPCB) is the monitoring authority for ensuring compliance. The following are some key gaps and opportunities in this sector:

Waste minimization and segregation

In Mumbai, 'segregation at source' received the lowest score among the mandatory parameters in the Garbage-free City Report under Swachh Survekshan 2019[14]. The Environment Status Report 2020-21 for Mumbai city reports that 82% of waste is being segregated; however, this segregation is not taking place at source. Mumbai currently does not have a city-level SWM plan that can enable decentralization at the ward level. Centralized response strategies often tend to be resource-heavy and do not lead to reduction and segregation of waste. With the city's population and economy growing, there would be inadequate landfill space in the coming years. Thus, waste minimization along with segregation is essential.

Collection and transportation

While the BMC is actively working towards a 100% D2D collection service, this is a challenge in some areas in the city, especially in slum settlements. For example, 34% of the complaints in 2020 were related to garbage collection and were from predominantly low-income wards, such as F-North, P-North, P-South, R-North, R-South, M-West, N, L and S. However, community-based organizations such as Stree Mukti Sanghatana and initiatives such as the Swach Mumbai Prabodhan Abhiyan have been able to close this gap in some areas and achieve zero-waste slum certification. These learnings can be integrated with the soon to be launched SWM plan.

Dry waste recovery through recycling and reprocessing

Waste recovery in the city is low despite the presence of Advanced Local Management Committees, guidelines for bulk generators and the Swach Mumbai Prabodhan Abhiyan (SMPA) scheme. According to SWM rules 2016, at least 80% of the waste generated by local bodies needs to be recovered. However, Mumbai has only been able to recover 35%, over the last five years (Praja, 2021). There is a need for community engagement to promote recycling and waste recovery and integrate informal waste pickers with the system. The Praja report also states that 11 wards are not processing wet waste on-site and 12 wards (A, B, C, E, F/S, F/N, G/S, H/E, K/E, L, M/W and T) do not have waste composting units. The wards with the highest number of SMPAs and highest quantities of segregated waste are depicted in Figure 36.

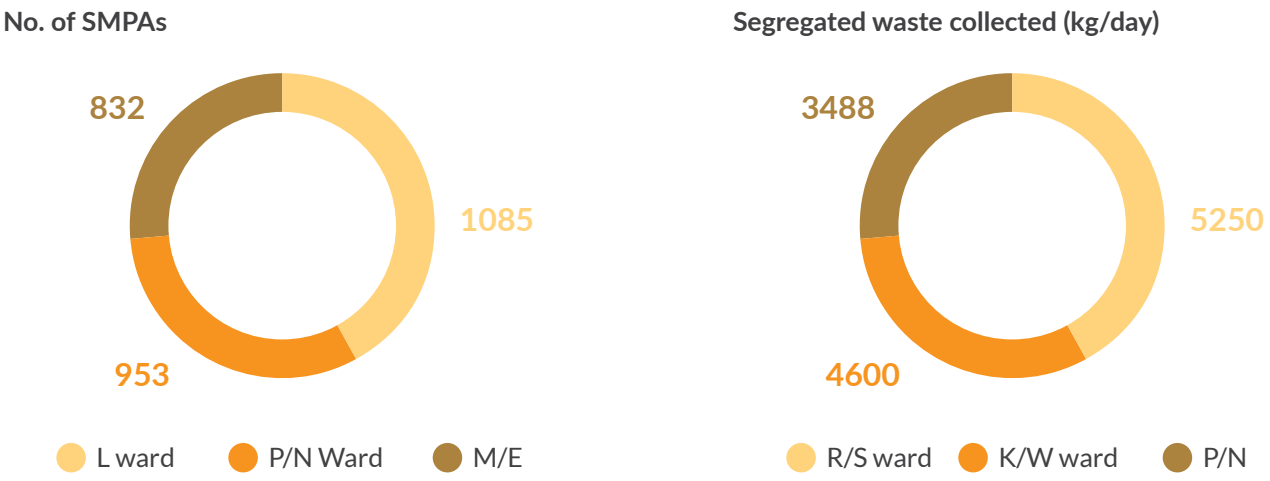


Figure 36: Wards with the highest number of SMPAs (left) and highest quantities of segregated waste (right)

[14]In the sweeping of public, commercial and residential areas, Mumbai was marked as FAIL.

Wet waste recovery through composting and biogas plants

Although 73% of the city's waste is biodegradable, the city has not been able to successfully recover it through composting. On-site wet waste processing was given the lowest score of 25 in the Swachh Survekshan survey.

Restore: Remediation of dumpsites

Severe environmental and social hazards that are affecting the quality of marine life and surrounding localities and creeks nearby have been observed at dumping grounds/landfill sites. The market value of the properties in the area has also reduced, leading to lower property taxes. Fishermen's incomes and livelihoods have been negatively impacted as leachate flowing into the waterbodies leads to water pollution and loss of marine life, biodiversity and livelihood. There are additional problems of foul odour, fires, health hazards and breeding of flies and rodents around dumping and landfill sites (BMC, 2010). Hence, serious efforts are needed to remediate dumpsites and reduce landfilled waste.

Approach: Sustainable Waste Management Hierarchy

To overcome the above barriers in waste management, the approach for the waste sector is modelled along the sustainable waste management hierarchy, which places an emphasis on reducing, reusing and recycling as the key to sustainable materials management.

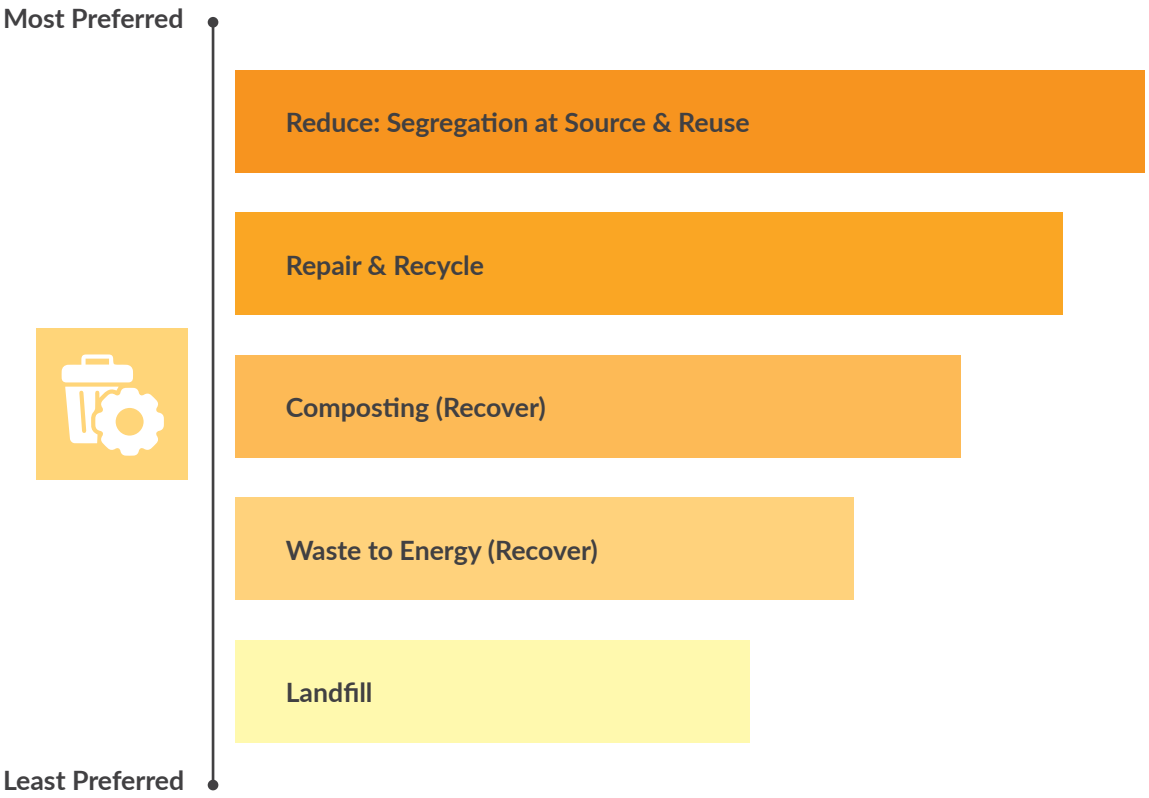


Figure 37: Approach for the waste sector

Ongoing Initiatives

Mumbai is currently implementing certain initiatives in this sector, which can be broadly categorized using the sectoral approach, as presented in Table 15. The actions proposed in the MCAP will help integrate the climate lens within these initiatives and enhance the city's efforts in sustainable waste management.

Table 15 Ongoing initiatives in the waste sector

Reduce	Restore
• The BMC is currently developing a city-level SWM plan and has launched an online citizen survey under its Vision 2030 initiative. • Property tax relief of 5-10% is provided to residential societies that segregate and compost waste. • A total of 19 organic waste convertors has been proposed for vegetable and fruit markets. • In 2018, BMC issued an order, mandating bulk waste generators to set up biodegradable waste composting units. A total of 3,367 additional bulk waste generators have been notified, and 50% of the bulk generators identified by BMC are currently composting waste at source.	• Dumpsite reclamation is taking place at Mulund, with 3,35,150 MT of legacy waste having been disposed till 2021. • Waste-to-energy projects having a total capacity of 600 TPD and 4MW energy generation have been proposed for Deonar. A total of 1,200 TPD of W2E projects are in the pipeline. • A total of INR 5,600 per unit per month has been allocated for waste management in slums under SMPA. An eligible organization is awarded an area between 5 and 18 units. The contract for this work is renewed annually.
Recover	**Recycle**
• A total of 85 hectares of land has been allotted for scientific waste. • The BMC has tied up with recyclers, and a rebate of up to 10% on property tax is being offered to housing societies that segregate waste. • Decentralized community-level composting and biomethanation is being promoted. • M/s. Godrej Industries has begun 10 TPD green waste processing pelletisation in Ghatkopar (N ward) through its CSR division and processes 3-4 MT of green waste per day. • A total of 32 parks in the city have compost pits across all wards; In the last quarter of 2017, 3,285 kg of compost was generated here.	• Currently, the city has 46 dry waste segregation centers handled by waste and ragpickers associations. In 2019, 188.5 TPD of dry waste was managed. Plastic shredding machines are installed at a few of these centers. • BMC is planning to undertake collection, transportation, processing and disposal of 1,200 TPD of C&D waste (BMC, 2021). • Under Extended Producer Responsibility (EPR), companies such as Bisleri and Coca Cola are setting up plastic processing units in the city. • BMC has proposed that MPCB be appointed the authorized e-waste recycling agency to set up e-waste collection centers in wards.

Sectoral Priority

Adopting an inclusive and zero landfill waste management strategy

The sectoral priority, action tracks and associated actions were developed on the basis of the city-level barrier analysis, ongoing city initiatives, inputs from external and internal stakeholder consultations and zonal consultations along with citizens' inputs received on the website. The stakeholders who were consulted in the process are listed in Annexure 3.

The city must work towards improving efficiency for recycling and recovery. Actions in the SWM sector include initiating extensive awareness and infrastructure and capacity building to ensure waste processing at the local/unit-level, discouraging waste-to-energy as a long-term solution and expediting the remediation of the Deonar dumpsite. Since over 70% of the city's waste is organic, the goal to increase segregation and treatment of organic waste and reduce its disposal to landfills is key to achieving all three waste-relevant climate targets for the city. Additionally, the climate goals and action tracks for Mumbai for the period 2020-2050 are aligned with Majhi Vasundhara Abhiyan's (MVA) action groups, enhancement of Akash (environmental awareness), Dharti (the Earth) and Vayu (clean air), as well as the SDGs. With the aim to move towards zero landfill waste by 2050, the sectoral action tracks promote waste minimization, decentralized waste management for enhanced segregation and recycling as well as dumpsite remediation.

Sectoral Action Tracks

Table 16 Sustainable Waste Management: Sectoral action tracks

Track 1	Reduce waste disposed to landfill sites by 40% by 2030
Track 2	Decentralized waste management for recovery and recycle
Track 3	Scientific dumpsite remediation for healthier ecosystems and communities

Aerial shot of Parel | By Hardik Joshi

Track-wise Actions

Table 17: Sustainable Waste Management: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Reduce waste disposed to landfills by 40% by 2030			
Priority Actions			
Develop litter-free/single use plastic-free zones/campuses in the city, thereby creating demonstrative examples in the city and increasing awareness among citizens. **Timeframe:** 2024	**Lead:** SWM Dept, BMC Supporting: MPCB, ward-level authorities, CSOs/ NGOs	Swachh Bharat Mission - Urban City-level SWM plan CSR MVA Green bonds	**Output:** No. of litter-free zones **Outcome:** Volume of waste collected from littering, % of waste recycled, single-use waste generation per capita (kg/person/year)
Conduct an analysis of the barriers in the compliance of single-use plastic ban. **Timeframe:** 2023			
Organize mass door-to-door awareness campaigns for segregation and phasing out of single-use waste, thereby reducing plastic pollution in the city. **Timeframe:** 2024/2025			
Conduct an assessment of waste characteristics and consumption patterns across different income groups and public utilities to create strategies for formal and informal housing and establishments. **Timeframe:** 2023/2024	**Lead:** SWM Dept Supporting: CSOs/ NGOs, research/ academic institutions	Swachh Bharat Mission - Urban City-level SWM plan	**Output:** Assessment study **Outcome:** % of city solid waste regularly collected with adequate final discharge

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Reduce waste disposed to landfills by 40% by 2030			
Priority Actions			
Establish designated ward-level waste management units/cells to strengthen coordination between Advanced Locality Management (ALM) groups, SMPA, bulk waste generators, etc. and different city departments (market, gardens, etc.) and create mechanisms to manage waste at the household level. **Timeframe:** 2023	**Lead:** Ward-level authorities **Supporting:** SWM Dept, SMPAs	Swachh Bharat Mission - Urban BMC Budget – SWM Dept	**Output:** Guidelines and approval for waste management cells, % of wards with cells, no. of functional cells **Outcome:** % of monthly income spent on solid waste collection/processing, % of population with regular solid waste collection at home, waste generated per capita (kg/person/year), % of waste recycled ward-wise, revenue recovered from recyclables (INR/year)
Route the rationalization and collection system optimization to reduce fuel consumption for waste collection. **Timeframe:** 2024/2025	**Lead:** SWM Dept of BMC **Supporting:** IT Dept of BMC, waste CSOs/ NGOs		**Output:** Fuel consumption to operate the collection fleet, coverage of HHs (tons) **Outcome:** Reduced fuel use from waste sector, % of population with regular solid waste collection at home
Develop waste management guidelines for public and religious functions to improve hygiene, reduce littering and influence behaviors. **Timeframe:** 2025			**Output:** Guidelines at the city level **Outcome:** Waste generated per capita (kg/person/year)
Discourage the dependence on landfills and waste-to -energy plants by setting up new centralized waste processing units (in Taloja and Mulund East) to reduce water and soil pollution. **Timeframe:** 2030/2032	**Lead:** SWM Dept, BMC	BMC budget – SWM Dept MVA	**Output:** % of waste diverted from landfills **Outcome:** Mortality rate and livelihoods lost due to air, water and soil pollution and contamination

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Reduce waste disposed to landfills by 40% by 2030			
Priority Actions			
Develop a waste dashboard on consolidated ward-level data (daily generation, segregation, waste recycled, % of segregation, location of community collection/ recycling centers/vendors), thereby making information publicly available and increasing accountability. **Timeframe:** 2024	**Lead:** Ward-level authority, SWM Dept of BMC **Supporting:** SMPAs, ALMs, waste startups	BMC budget – SWM Dept Swachh Bharat Mission - Urban MVA	**Output:** Public dashboard **Outcome:** Ward-level waste generation per capita (kg/ person/year), % of solid waste that is recycled ward-wise, revenue recovered from recyclables (INR/year), % of population with regular solid waste collection at home, number of green enterprises/ jobs created
Establish a central control and command center for Integrated Solid Waste Management (ISWM) monitoring, GPS tracking of vehicles, geotagging of bins, geo location of waste collection points, digital storage, Cloud linking of data and automation of transfer stations to ensure waste collection services for all. **Timeframe:** 2024	**Lead:** SWM Dept of BMC **Supporting:** IT Dept of BMC, Contractor		**Output:** Integrated command and control center **Outcome:** % of solid waste that is recycled ward-wise, , % of city solid waste regularly collected with adequate final discharge, % of population with regular solid waste collection at home
Implement a pilot program on zero waste wards. **Timeframe:** 2025/2027	**Lead:** SWM Dept of BMC **Supporting:** Ward authorities, research institutes, NGOs		**Output:** No. of wards **Outcome:** Ward-level waste generation per capita (kg/ person/year), % of solid waste that is recycled ward-wise, jobs created for informal workers, % of monthly income spent on solid waste collection
Develop a strategy, rules and framework to strengthen implementation and reporting of extended producer responsibility (EPR). **Timeframe:** 2025	**Lead:** MPCB **Supporting:** Private companies, SWM dept, BMC	BMC budget – SWM Dept Swachh Bharat Mission – Urban	**Output:** City-level mandate/ strategy **Outcome:** % of e-waste or plastic waste recycled, number of green enterprises/ jobs created

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 2: Decentralized waste management to ensure 80% recovery through segregation, recycling and composting by 2050			
Priority Actions			
Initial perception survey and subsequently decentralizing Mumbai's SWM plan with ward -level strategies for residential, commercial and public sectors **Timeframe:** 2023	**Lead:** SWM Dept of BMC **Supporting:** CSOs/ NGOs, Consultant agency	BMC budget – SWM Dept Swachh Bharat Mission – Urban MVA CSR	**Output:** Perception survey, % of wards covered in survey, no. of ward-level waste management recycling/ composting units **Outcome:** Waste generated per capita (kg/person/year), % of population with regular solid waste collection at home
Levy on non-compliance of waste segregation at households **Timeframe:** 2023	**Lead:** Ward-level authorities **Supporting:** SWM Dept, Contractor - agency		**Output:** Levy by waste type (INR/kg), revenue collected annually **Outcome:** % of monthly income spent on solid waste collection, % of segregation ward wise
Household infrastructure, training for workers and retrofitting collection vehicles for waste segregation **Timeframe:** 2025	**Lead:** SWM Dept of BMC **Supporting:** Contractor, MPCB, NGOs.		**Output:** No. of trainings conducted, % of vehicles retrofitted, no. of households with waste segregation infrastructure **Outcome:** % of population with regular solid waste collection at home or in-situ waste management infrastructure
Promote decentralized composting through citizen participation, biogas plants in mandis and hotels, and compositing in all parks and gardens **Timeframe:** 2024	**Lead:** SWM Dept of BMC, ward-level authorities **Supporting:** Market Dept of BMC, Gardens Dept of BMC		**Output:** No. of biogas/ composting units set up, % of wards with biogas plants **Outcome:** % of monthly income spent on waste collection, % of wet waste composted,

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 2: Decentralized waste management to ensure 80% recovery through segregation, recycling and composting by 2050			
Priority Actions			
Strengthened enforcement of C&D rules 2016 through amendment of building byelaws to include rules on segregated collection systems, disposal sites, tipping fees, use of waste in roads and landfilling, etc. **Timeframe:** 2024	**Lead:** SWM Dept of BMC, Urban Development Dept GoM **Supporting:** Buildings Dept of BMC	BMC budget – SWM Dept Swachh Bharat Mission – Urban MVA CSR	**Output:** Approved building bylaws, % of C&D waste segregated and recycled, revenue recovered from C&D waste **Outcome:** Reduced emissions and pollution due to C&D waste, % of income spent on C&D waste collection/ processing
Analysis of current and projected C&D waste in the city and feasibility of using recycled aggregates in construction/roads **Timeframe:** 2024	**Lead:** SWM Dept **Supporting:** Technical/academic institution, Buildings Dept	BMC budget – SWM Dept Swachh Bharat Mission -urban MVA	**Output:** Waste from construction sites (kg), % of C&D waste segregated and recycled **Outcome:** Reduced emissions and pollution due to C&D waste, % of population with on-call C&D waste collection at home
Quantification of waste generation in construction sites and mandating reuse **Timeframe:** 2024	**Lead:** MMRDA, Buildings Dept BMC	BMC budget – SWM Dept	
Monthly e-waste collection drives **Timeframe:** 2024	**Lead:** MPCB, SWM Dept **Supporting:** Zone/ward-level authorities	BMC budget – SWM Dept	**Output:** % of e-waste recycled

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 2: Decentralized waste management to ensure 80% recovery through segregation, recycling and composting by 2050			
Medium- and Long-term Actions			
100% source segregation and collection in slums (waste exchange for services like bus ticket, books, etc.) **Timeframe:** 2027	**Lead:** SMPA, SWM Dept **Supporting:** BMC	BMC budget – SWM Dept Swachh Bharat Mission -urban MVA CSR	**Output:** Segregation rate in slums **Outcome:** % of waste recycled ward-wise, % of monthly income spent on waste collection
Promote self-help groups to manufacture cloth bags, leaf plates, etc. through market creation and finance. **Timeframe:** 2027	**Lead:** SWM Dept, BMC **Supporting:** CSO/ NGOs, SMPA		**Output:** No. of groups supported, no. of incentives provided (e.g., loans) **Outcome:** % of waste recycled, no. of new green jobs created and individuals participated in green skills training
Robust recycling across 16-24 categories through market creation and infrastructure **Timeframe:** 2028			**Output:** % of city's solid waste that is segregated into X number of categories **Outcome:** Emissions from waste, no. of green jobs created and new green startups
Biodegradable waste processing units in each ward based on land and resource availability with market creation and subsidies for compost (e.g.: coupons, manure, subsidies for home compost kits, etc.) **Timeframe:** 2027	**Lead:** SWM Dept, Marketing Dept – BMC **Supporting:** MPCB		**Output:** No. of ward-level waste management units for recycling, composting etc. **Outcome:** % of city's organic wet waste that is composted/ recovered, % of income spent on waste processing, % of population with waste processing units accessible within 500m of home

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 2: Decentralized waste management to ensure 80% recovery through segregation, recycling and composting by 2050			
Medium- and Long-term Actions			
Setting up MRF units and waste collection centers in each ward along with local network of buyers for glass, paper, etc. Financial support for waste sector enterprises can be provided. **Timeframe:** 2027	**Lead:** SWM Dept **Supporting:** Ward-level authorities, Buildings Dept, Development Planning (DP) Dept, start-ups	CSR BMC Budget MVA	**Output:** No. of Material Recovery Facilities (MRF) units/collection centers ward wise, no. of enterprises supported **Outcome:** % of waste recycled
Waste pickers program with existing ragpickers associations **Timeframe:** 2024/2025	**Lead:** BMC, SWM Dept **Supporting:** NGOs	CSR, philanthropic funding, BMC budget	**Outcome:** No. of jobs created for informal workers
Sectoral Action Track 3: Remediation of all existing dumpsites and 100% scientific disposal of waste by 2030			
Priority Actions			
Divert daily waste dumped at the Deonar dumpsite to the Kanjurmarg site and mandate remediation at Deonar after scoping study including NCV, emissions and environmental impacts **Timeframe:** Scoping study (2023), implementation (2025)	**Lead:** SWM Dept, BMC **Supporting:** MPCB, contractor, academic/ technical institution	Green bonds – IFC investment SBM – Urban BMC budget – SWM Dept	**Output:** % of waste that is diverted away from landfills, area of waste disposal site recovered/reclaimed (m^2) **Outcome:** Surface of urban land that is contaminated
Discourage waste to energy due to the high investment require for W2E infrastructure and the NCV potential (high organic waste content) of MSW in the Indian context **Timeframe:** 2024	**Lead:** SWM Dept **Supporting:** Technical institution/experts, Energy Dept, MEDA	City-level SWM plan – BMC budget	**Output:** Study conducted **Outcome:** Volume of waste generated per person/HH, % of HH waste that is recycled, % of waste being managed at central processing sites

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Medium- and Long-term Actions			
Monitoring of remediation and converting the landfill into a green space/park **Timeframe:** 2030-2035	**Lead:** SWM Dept **Supporting:** Gardens Dept, Development Planning (DP) Dept	Green bonds – IFC investment SBM – Urban BMC budget – SWM Dept	**Output:** Progress reports, no. of saplings planted, survival rate, green cover or park area (m^2) **Outcome:** , % of landfill area converted to green space
Capture landfill gas and collect leachate at existing and new waste disposal sites and convert to electricity/piped gas **Timeframe:** 2027	**Lead:** SWM Dept **Supporting:** Technical expertise, MEDA, Energy Dept		**Output:** Volume of gas captured, capture rate, amount of gas generated **Outcome:** GHG emissions from waste, incidence of diseases, injuries and sickness due to pollution caused by landfills

Sector-specific inclusive benefits

- Introducing legality and licensing mechanism for ragpickers and waste workers would facilitate the transition of informal labor to a formalized and secure system, thereby ensuring equity in the job market within the waste sector. This would also improve wages and ensure stability for workers, a majority of whom belong to vulnerable low-income backgrounds or are migrants.
- Decentralized waste management would create accountability within the community to reduce waste at source and create opportunities for new green businesses.

5.4 Urban Greening and Biodiversity

Although Mumbai is rich in ecological assets (refer to Chapter 2 of this plan), a mere 3.7% is accessible open space for the citizens. Mumbai is the least green metro (Devulapalli & Padmanabhan, 2019), with the lowest per capita green cover of 1.8 square meters (Jha, 2021), as compared with 10-12 square meters prescribed in the Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines.

The vegetation cover has reduced, from 46.42% in 1988 to 26.67% in 2018, mostly in the low-income areas. During the same period, the area having a mean land surface temperature (LST) of around 30.5°C has increased, from 5232 ha in 1988 to 14,339 ha in 2018 (Rahaman et al., 2021). The shrinking green cover, the increasing concretization of the urban landscape in the form of buildings and infrastructure, the expansion of high-density informal settlements having no trees and the excessive use of temporary metal roofs have resulted in urban heat islands with temperatures up to 5 to 6 degrees higher than in well-shaded and green residential areas of the neighborhood. Mumbai is experiencing a warming trend, with increasing frequency of heatwaves. According to an IPCC report, the city is expected to experience high mean temperatures of up to 35°C for almost 117 days in a year by the end of the century, an increase in total rainfall by almost 32% by 2060 (Basu, 2021) and sea level rise with increasing frequencies of cyclones (refer to Chapter 3.1 of this plan).

Key Gaps

The landscape of the city would be a major factor in addressing the increasing heat- and flood-related risks.

Gap in demand and availability of green public spaces

A spatial survey by P.K. Das & Associates (2011) highlighted that of 2152 open spaces in city, 600 were encroached upon and the remaining were unaccounted for. In order to safeguard and conserve open spaces, it is necessary to create an inventory. Moreover, there are areas, such as Mankhurd, that have a higher vegetation cover; however, most of these are inaccessible as these are mangroves and wetlands. Meanwhile, Bandra has a relatively low vegetation cover, but its per capita green public spaces is high.

Lack of holistic landscape framework

The green and blue natural ecosystems in Mumbai are in the jurisdiction of BMC, MMRDA and Government of Maharashtra. This calls for coordination between different authorities to develop policies for maintenance, ecological zone identification, conservation and safeguarding of these natural ecosystems.

Poor enforcement of regulations for protection and conservation of ecological assets

Mangroves act as a natural coastal flood protection system. However, there have been around 350 cases of destruction since 2013. There is a need for a strong enforcement mechanism to protect mangroves from the hazards of rising sea levels and increasing storm surges. Despite CRZ regulations, there is uncontrolled construction, garbage dumping and sewage disposal, leading to pollution and the shrinking of beaches. The development plan lacks a clear demarcation of hills and forests, thus failing to protect these from illegal quarrying and deforestation.

Lack of data-driven and scientific methods

BMC intends to increase the green cover of the city by planting and introducing dense groves of trees through the urban thickets program. However, a scientific approach and data-driven method is necessary to ensure the selection of native species with high carbon sequestration potential, an equitable distribution as per demand-supply gaps and the integration of nature-based solutions against any biodiversity loss. Moreover, there is a need for capacity building on scientific methods of tree planting, pruning and maintenance. This applies to mangroves and wetlands as well.

Financial and spatial constraints

In 2017-18, BMC allocated 1.3% of its total budget for open space maintenance, and reduce it to 0.7% in the 2020-21 budget. In order to improve the urban green cover and biodiversity, the percent share must be increased. Mainstreaming climate actions would require a sufficient allocation of funding and would need to be accounted for in every term budget of the city. Moreover, space is a huge challenge in Mumbai. Mechanisms to encourage the private sector and citizen participation in policies and strategies for urban greening in private plots will help address this and accelerate action.

Integrated approach

There is a lack of infrastructure related to water provision and sanitation, especially in the low-income areas, which leads to increased vulnerabilities during climate-induced disasters (refer to Chapter 3.1 of this plan). This calls for the integration of low-cost nature-based solutions with gray infrastructure to address heat and flood resilience as well as water security for vulnerable communities.

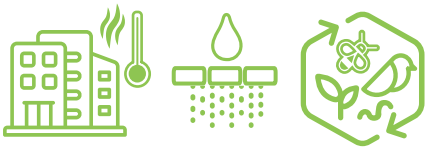
Data, Information and Communication

There is a need to develop a Biodiversity Index and a Biodiversity Register at ward level, thereby making it accessible to citizens and to get them to be involved in and informed about the city's flora and fauna. Moreover, the city census data indicates that the population accessible to cell phones, radio/transistors and the Internet is 60%, 36% and 20%, respectively. This calls for innovative methods of communicating important information to a larger population, which would induce better adaptive capacity and reduce shocks and stress (Refer Chapter 3.1 of this report).

Approach for Urban Greening and Biodiversity

Based on an assessment of the gaps and barriers in the transport sector, the MCAP has identified a four-pronged approach with aligned actions for reducing emissions from the transport sector. The approach also includes improved accessibility of public transport, improved multimodal integration and zero-carbon freight and passenger modes, with a focus on inclusivity.

Table 18 Approach for urban greening and biodiversity



Heat and Flood	Carbon Sequestration	Open space Accessibility	Biodiversity
Increasing the vegetation cover and permeability of the city in a planned manner to tackle heat and flood risks	Scientific method for species selection, planting, pruning and maintenance, thereby increasing the city's carbon sinks	Managing the demand and availability gap of green open spaces through a data-driven and inclusive approach.	Documenting, conserving and enhancing city biodiversity in an inclusive way

Increasing the vegetation cover in the city in a planned and scientific manner not only reduces urban heat islands but also creates carbon sinks. Such enhanced greening also improves the liveability and biodiversity of the city as well as health of the city dwellers. The matrix in of Table 18 presents the co-benefits of the green spaces in the city with respect to accessibility, ownership, and the co-benefits it offers.

	Municipal Parks Gardens Tree lined avenues	Forests Mangroves Wetlands	Maidans Beach Promenade	Mudflats Saltpans	Residential township parks	Gymkhana grounds, Golf course Stadium	Rivers & creeks Tanks, ponds and lakes
	Public green accessible	**Public green accessible**	**Public brown accessible**	**Public brown accessible**	**Public green accessible**	**Public brown accessible**	**Public blue accessible**
Biodiversity	★	★	★	★	★		★
Flood mitigation		★	★	★			★
Carbon sequestration	★	★			★		★
Heat resilience	★	★			★		★
Daily urban recreation space	★		★				

Ongoing initiatives in city

Mumbai city is currently taking up certain initiatives within this sector, which can be broadly categorized as presented in Table 19.

Table 19 Ongoing greening initiatives undertaken by BMC

Urban Greening and Open Spaces	Coastal Resilience	Biodiversity Management
• Signatory to C40 Cities Urban Nature Declaration (C40Cities, 2021) • Developing a new gardens policy, with the aim to convert 1,068 plots into gardens/playgrounds through multi-stakeholder engagement (Mumbai Mirror, 2019) • Amendment to the Maharashtra (Urban Areas) Tree Protection and Conservation Act, 1975, for protecting heritage trees (Singh, 2021) • Planting 3,77,416 trees at a cost of INR 35 crores across 100 locations (Deshpande, 2019)	• Waterbody inventory with external consultant (Terracon, 2020) • Construction of 10 feet of walls for mangrove and wetland protection (Chatterjee, 2018)[15] • Beach nourishment project being implemented in Dadar-Chowpatty (Mumbai Waterfronts Centre & P.K.Das & Associates, 2012) • Chimbai village waterfront project • Mithi river restoration (Maharashtra Pollution Control Board, 2019) with the aim of 100% sewage collection and treatment and 100% MSW collection by 2023.	• Established a biodiversity committee as per directives of State Government under the chairmanship of Joint Municipal Commissioner (Disaster Management) / Deputy Municipal Commissioner (Garden). • Developing parks near biodiversity hotspots and reclaiming un-used quarry sites and landfills into urban green areas, such as Parsik Hill, Ambernath and Kalyan (MMRDA, 2016)

Sectoral Priority for Urban Greening and Biodiversity

Increasing the urban green cover to reduce heat risk and increase the city's resilience to flood events

The priority action tracks were developed on the basis of the gaps and barriers observed in the landscape analysis, the ongoing city initiatives, inputs from external and internal stakeholder consultations, zonal consultations as well as citizens' inputs received on the MCAP website [Refer to Annexure 3]

The gap in demand and availability of green public spaces, the poor enforcement of protection and conservation of ecology, the lack of a scientific and data-driven approach and financial and spatial constraints are factors that need to be considered in formulating actions and setting goals.

Mumbai city has partnered in the Cities4Forest initiative and has signed the Call to Action for Forest and Climate and the C40 cities Urban Nature Declaration to protect, conserve and manage its natural ecosystems. Sector specific goals and actions have been developed on the basis of the baseline assessment, SDGs and the principles of MVA.

Sectoral Action Tracks

Table 20 Urban Greening and Biodiversity: Sectoral action tracks

Track 1	Increase the vegetation cover and permeable surface of the city to tackle heat and flood risks
Track 2	Ensure equitable access to green open spaces for higher per capita green cover
Track 3	Restore and enhance the biodiversity of the city

Shot in Dadar | By Aaran Patel

Track-wise Actions

Table 21 Urban Greening and Biodiversity: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Increase vegetation cover and permeable surface to 30-40% of the city surface area by 2030 to tackle flood- and heat-related disaster risk			
Priority Actions			
Undertake scientific identification of land parcels and brownfields, especially in areas exposed to high heat, for increasing vegetation cover. **Time frame:** 2022	**Lead:** Development Plan (DP) Department, Garden Department, Estate Dept of BMC Assistant Commissioners Support – Storm Water Drains (SWD)- BMC, Mumbai Sewage Disposal Project (MSDP)-BMC, Advance Locality Management (ALMs), co-operative housing societies, developers, private sector, field experts, BEST, MbPT, MMRDA, Western Railways	Based on Garden Department's estimate of urban forests of INR 20 million per hectare; Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Area of canopy cover created (m^2), area of (shaded) cover created (m^2), volume of water retention capacity created(m^3), area of permeable surfaces (m^2) **Outcome:** difference in temperatures in shaded and non-shaded areas, % of heavy rainfall leading to flooding, difference in temperatures in permeable and non-permeable areas (in °C or °F)
Prepare a heat action plan for the city, with a strong focus on precautionary measures, early warning systems and urban greening measures, to maintain ambient temperatures. **Time frame:** 2022-2023	**Lead:** Disaster Management Cell, Health Department Support – Garden Department, public and private hospitals	Part of BMC budget	**Output:** % city covered under the plan, number of early warning systems in place for each hazard **Outcome:** % emergency situations where emergency services responded safely and on time, % of population reached through early warning systems for each hazard
Organize capacity building of health workers in identifying and treating heat-related illness. **Time frame:** 2022	**Lead:** Public Health Department Support – Disaster Management Cell	Annually between INR 0.5 and 1 million as part of BMC budget	**Output:** Number of workshops conducted **Outcome:** % population trained to respond to the hazard risk

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Increase vegetation cover and permeable surface to 30-40% of the city surface area by 2030 to tackle flood- and heat-related disaster risk			
Priority Actions			
Establish cooling centres and health care provisions within heat stressed areas of the city with high vulnerable population. **Time frame:** 2022	**Lead:** Disaster Management Cell Support – Public Health Department, Garden Department	Part of BMC budget	**Output:** Number of cooling centres/shelters created per capita within vulnerable and low-income neighbourhoods, distance of cooling routes established from these neighbourhoods (km) **Outcome:** % of population residing at a distance of 15 minutes from a Cooling centre (disaggregated by income and vulnerability) % of population using cooling centres (disaggregated by income and vulnerability)
Develop low-cost nature-based solutions to reduce heat stress in low-income neighbourhoods **Time frame:** 2022	**Lead:** BMC Support - MMRDA, TISS	Part of BMC budget	**Output:** % of areas under Nature Based Solutions (NBS) **Outcome:** % of vulnerable area covered by NBS, temperature difference (in °C or °F)
Increase budget allocation for urban green development and maintenance to tackle heat and flood risks. **Time frame:** 2022	**Lead:** Garden Department Support – Disaster Management Cell, SWD, MSDP	Additional sources through MVA, CSR funds, green bonds, AMRUT	**Output:** Finance committed **Outcome:** % target achieved for urban greening sector
Offer incentives in the form of property tax rebates and fast-track procedures for individuals and housing corporations showing initiative in urban greening. **Time frame:** 2022	**Lead:** Assessment and Collection Department, Garden Department Support – Building proposals dept, DP Department	N/A	**Output:** Area of canopy cover created (m^2), area of shaded cover created (m^2), Volume of water retention capacity created (m^3), area of permeable surfaces (m^2) **Outcome:** Difference in temperatures in shaded and non-shaded areas (in °C or °F), % of heavy rainfall leading to flooding, difference in temperatures in permeable and non-permeable areas (in °C or °F)

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Increase vegetation cover and permeable surface to 30-40% of the city surface area by 2030 to tackle flood- and heat-related disaster risk			
Priority Actions			
Ensure strict enforcement of reservations, especially for hills and forests, to protect these from illegal quarrying and deforestation. **Timeframe:** 2022	**Lead:** DP department Support – Forest Department-State govt, Planning Department (MMRDA)	N/A	**Output:** Area demarcation in development for forest and hill, area of slopes stabilized (m2 / km2) **Outcome:** % change from the demarcated area for forest and hills, % of heavy rainfall leading to landslides/erosion
Undertake capacity building on applying scientific approach towards tree species selection, planting, maintenance and pruning with respect to time of year, method and sensitivity to social and ecological aspects. **Time frame:** 2022	**Lead:** Garden Department Support – Training and research institute, technical consultants	Annually between INR 0.5 and 1 million as part of BMC budget	**Output:** Number of workshops conducted **Outcome:** % population trained to respond to the hazard risk
Establish Tree Helpline to file grievances and illegal activities. **Time frame:** 2022	**Lead:** Garden Department Support – IT Department	Between INR 0.5 and 1 million as part of BMC budget based on previous budgets	**Output:** No. of grievances filed **Outcome:** % of grievances addressed, % reduction in grievances
Develop a city dashboard to access information regarding urban greening and heat island to monitor at city and ward levels. **Time frame:** 2023	**Lead:** Garden and IT Departments, Disaster Management Cell Support – Public Health Department	Around INR 1.5 million as part of BMC budget, based on previous budgets	**Output:** City-level dashboard **Outcome:** % target achieved for green cover, % reduction in heat prone areas, difference in temperatures in shaded and non-shaded areas
Promote CSR funding or public private partnerships for initiatives towards increasing vegetation cover and permeable surface. **Time frame:** 2022	**Lead:** Garden Department, Assessment and Collection Department Support – Accounts, Auditors Dept	N/A	**Output:** Finance committed **Outcome:** % target achieved for urban greening sector

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Increase vegetation cover and permeable surface to 30-40% of the city surface area by 2030 to tackle flood- and heat-related disaster risk			
Priority Actions			
Introduce green bonds for financing municipal greening initiatives. **Timeframe:** 2023	**Lead:** Garden Department, Assessment and Collection Department Support – Accounts, Auditors Dept	N/A	**Output:** Number of jobs created and number of bonds issued **Outcome:** % target achieved for urban greening sector
Integrate public open spaces with storm water drainage to create retention areas as part of nature-based solutions. **Time frame:** 2023	**Lead:** Garden and SWD Departments Support – DP Department, Road and Traffic Department, MSDP	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Volume of water retention capacity created (m^3), Volume of increased storage capacity (m^3) / flow capacity **Outcome:** % of heavy rainfall leading to flooding
Integrate green roofs, green walls and community gardens with the Development Control Regulations (DCRs) and incentivize these. **Time frame:** 2023	**Lead:** Garden Department, building proposal Dept, DP Department, building maintenance dept Support – SWD, MSDP, Estate and Land Management, Assessment and Collection Department	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Area of vegetated area created (m^2) **Outcome:** % of heavy rainfall leading to flooding, difference in temperatures in vegetated and non-vegetated areas (°C or °F)

Action description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 2: Reduce heating effect and increase permeable surface to 100% by 2050 along the city streetscape			
Priority Actions			
Establish guidelines for street-side landscape to tackle heat and flood risks. **Timeframe:** 2022	**Lead:** Garden Department Support – SWD, Road & Traffic Department, MSDP	Part of BMC budget	**Output:** City-level guidelines **Outcome:** %Reduced vulnerability to heat and floods, % of heavy rainfall leading to flooding

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 2: Reduce heating effect and increase permeable surface to 100% by 2050 along the city streetscape			
Priority Actions			
	Lead: Garden Department Support – SWD, Road & Traffic Department, License Dept, Legal Dept	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Area of vegetated area created (m^2), area of canopy cover created (m^2), area of shaded cover created (m^2) **Outcome:** % of heavy rainfall leading to flooding, difference in temperatures in vegetated and non-vegetated areas (°C or °F), difference in temperatures in shaded and non-shaded areas (°C or °F)
	Lead: AMC, Garden Department Support – All departments with infrastructure related projects	Should be part of the project budget	**Output:** Vegetated area in the city (m2), increase in tree count **Outcome:** % target achieved for urban greening sector
Medium- and Long-term Actions			
Introduce tree banking systems to encourage citizens to adopt a tree and receive financial aid in return. **Time frame:** 2030	**Lead:** Garden Department Support – Assessment and Collection Department, legal dept, auditors dept, Road & Traffic Department	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** % of trees adopted **Outcome:** Difference in temperatures in shaded and non-shaded areas (°C or °F), % of heavy rainfall leading to flooding, % of healthy trees
Undertake 100% conversion of footpaths and on-street parking to permeable surface material. **Time frame:** 2030	**Lead:** Garden Department, Roads & Traffic Department, SWD Department Support – MnE, MSDP	Based on previous BMC budget INR 200 crore	**Output:** Volume of water retention capacity created (m^3), area of permeable surfaces (m^2) **Outcome:** % of heavy rainfall leading to flooding, °C °F Difference in temperatures in permeable and non-permeable areas (°C or °F)
Undertake the standardization of asphalt and concrete color to cool/light gray to reduce land surface temperature. **Time frame:** 2023	**Lead:** Road & Traffic Department	Part of BMC budget	**Output:** Area of cool/white surfaces (m^2) **Outcome:** Difference in temperatures in cool/ white spaces and non-cool/ white spaces (°C or °F)

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 2: Reduce heating effect and increase permeable surface to 100% by 2050 along the city streetscape			
Medium- and Long-Term Actions			
Integrate street-side landscape with storm water drainage network as a nature-based solution. **Time frame:** 2023	**Lead:** Garden Department, Sewage Operations Dept, Road & Traffic Department Support – MSDP, Mechanical and Electrical	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Vegetated area created (m2), Volume of water retention capacity created (m3), Volume of increased storage capacity (m3)/ flow capacity **Outcome:** % of heavy rainfall leading to flooding
Integrate street-side landscape with storm water drainage network as a nature-based solution. **Time frame:** 2022		N/A	

Action Description			
Sectoral Action Track 3: Equitable distribution of open spaces and increase per capita open space to 6 square meters by 2040			
Priority Actions			
Integrate street-side landscape with storm water drainage network as a nature-based solution. **Time frame:** 2023	**Lead:** Garden Department	Part of BMC budget	**Output:** Guidelines for inclusive open space design and ecosystem services **Outcome:** % increase per capita green open space in low income areas, % of population residing at a distance of 15 minutes from open spaces (disaggregated by income level)
		Part of BMC budget	**Output:** Number of workshop sessions conducted **Outcome:** % increase in per capita green open space in low income areas, % of population residing at a distance of 15 minutes from open spaces (disaggregated by income level)

Action Description

Sectoral Action Track 3: Equitable distribution of open spaces and increase per capita open space to 6 square meters by 2040

Medium- and Long-term Actions

Plan and provide new open spaces based on the demand and availability gap analysis for equitable distribution of open spaces. **Time frame:** 2022	**Lead:** Garden Department Support – DP Department, SWD, MSDP, Road & Traffic Department, Estate and Land Management, Disaster Management Cell, citizen groups, Planning Department (MMRDA), field expertst	Part of BMC budget, MVA, CSR funds, green bonds scheme, AMRUT	**Output:** Number of new open spaces developed as per guidelines **Outcome:** % increase in per capita green open space in low income areas, % of population residing at a distance of 15 minutes from open spaces (disaggregated by income level)

Action Description

Sectoral Action Track 4: Restore, maintain and enhance city biodiversity and eco-system

Priority Actions

Mandate the use of native plant species as per BMC guidelines. **Time frame:** 2022	**Lead:** Garden Department	N/A	**Output:** % of new plantation as per the native species, captured through tree census **Outcome:** % increase in biodiversity and conservation, % reduction in non-native species
Update tree census parameters to capture carbon sequestration and biodiversity aspect. **Time frame:** 2022	**Lead:** Garden Department	Part of BMC budget	**Output:** Number of parameters increased in tree census data collection **Outcome:** % change in carbon sink and native species
Prepare a biodiversity index and place it in the public domain. **Time frame:** 2022	**Lead:** Garden Department, Biodiversity Committee	Part of BMC budget, generally, between INR 15 and 25 lakh	**Output:** Documentation and data collection for biodiversity **Outcome:** Active involvement of citizens
Coordinate a participatory biodiversity register at the census ward level. **Time frame:** 2022	**Lead:** Garden Department, Biodiversity Committee	Part of BMC budget	**Output:**Documentation and data collection for biodiversity **Outcome:** Active involvement of citizens

Action Description

Sectoral Action Track 4: Restore, maintain and enhance city biodiversity and eco-system

Priority Actions

Develop a local biodiversity strategy and action plan (LBSAP) **Time frame:** 2024	**Lead:** Biodiversity Committee, Garden Department Support – Forest Department-State govt, Mangrove Cell-State govt, Planning Department (MMRDA)	Part of Environment and Climate Change Department of State Government of Maharashtra and BMC	**Output:** Policy document/ framework for biodiversity conservation **Outcome:** Biodiversity index
Conduct GIS mapping of habitat degradation and demarcation of biodiversity hotspots. Develop a mobile application and QR code-based toolkit for interactive biodiversity conservation and management. **Time frame:** 2022	**Lead:** Garden Department, Biodiversity Committee Support – IT Department	Part of BMC budget Generally, around INR 25 lakh	**Output:** Documentation and data collection for biodiversity **Outcome:** Active involvement of citizens
	Lead: DP Department, Garden Department Support – SWD, MSDP, Road & Traffic Department, Public Health Department, Planning Department (MMRDA), Mangrove Cell-State govt, Forest Department-State	N/A	**Output:** % of areas under NBS **Outcome:** A% floods that lead to river bank collapse/ erosion, % of heavy rainfall leading to flooding, % of heavy rainfall leading to landslides/ erosion, Volume of collected rainwater available (m^3), % of vulnerable area covered by NBS, temperature difference (°C or °F)

Action Description

Sectoral Action Track 4: Restore, maintain and enhance city biodiversity and eco-system

Priority Actions

	Lead: Municipal Commissioner, Additional Municipal Commissioner (all five) Support – Garden Department, Environment Department, Public health Department, SWD, MSDP, DP Department, Road & Traffic Department, Department of Environment and Climate Change-State govt, Forest Department-State govt, Mangrove Cell-State govt), Planning Department (MMRDA)	Part of BMC budget, around INR 1 crore	**Output:**Comprehensive landscape management and development **Outcome:** % change in area under natural open spaces, number of types of natural assets conserved and restored, % change in public green spaces, city biodiversity index

Medium- and Long-term Actions

Develop Landscape Framework to demarcate and conserve biodiversity hotspot areas and corridors. **Time frame:** 2024	**Lead:** Garden department, Environment department, Landscape cell, Biodiversity committee Support – Planning (MMRDA), Forest (state), Mangrove cell (state)	Part of BMC budget	**Output:** Comprehensive landscape framework **Outcome:** City biodiversity index
Integrate recreation networks, such as hiking trails and NMT connections, using the landscape framework. **Time frame:** 2025	**Lead:** BMC Support - MMRDA, Department of Environment and Climate Change-State govt	Part of BMC budget, MVA, green bonds scheme, AMRUT	**Output:** Km of trails, vegetated area in the city, area of canopy cover created (m^2), area of shaded cover created (m^2) **Outcome:** % of population residing at a distance of 15 minutes from green cover (disaggregated)
Integrate nature-based solutions with disaster risk management and prevention protocol. **Time frame:** 2025	**Lead:** BMC Support - Disaster Management department, MMRDA, Department of Environment and Climate Change	Part of BMC budget, MVA, green bonds scheme, AMRUT	**Outcome:** Reduced frequency of flooding, % of rainfall leading to floods, reduced heat vulnerability and heatwaves

Sector Apecific Inclusive Benefits

- Increasing green cover in areas exposed to high heat would decrease the sensitivity especially amongst the vulnerable population within low-income areas with poor ventilation, dense housing and compromised access to affordable cooling options. Programs such as urban or rooftop farming can create employment opportunities as well.
- Developing low-cost affordable greening or nature-based solutions would reduce vulnerability amongst the low-income population living in flood or landslide prone areas.
- Increasing per capita green cover would increase accessibility to open spaces, especially for women, children and the elderly, thereby improving health and liveability.

Shot in Aarey Colony | By Aaran Patel

5.5 Air Quality

The air pollution in Mumbai has worsened over the years, taking a toll on the health of the citizens due to prolonged exposure to vehicular and industrial emissions, burning of landfill waste and indoor air pollution from burning of firewood. The city was ranked the fourth-most polluted megacity in the world for the year 2016 by the global air pollution database of World Health Organization (WHO), which was published in 2018 (Chatterjee, 2018). In 2018, Greenpeace India too ranked Mumbai as the 37th most polluted city in India in a report called Airpocalypse-IV. However, in recent times the concentration of the pollutants has mildly stabilized due to the COVID-19 related lockdown and curbs and some stringent control measures.

Temporal and Spatial Variability of Concentration of Air Pollutants

The vulnerability assessment (Refer Chapter 2) undertaken as part of the MCAP identifies particulate matter (PM) PM2.5 and PM10 and nitrogen dioxide (NO_2) as the critical pollutants in the city, which were generated primarily from vehicular emissions, dust from construction sites, industrial units and power plants[1]. Have shown There has been a very nominal decrease in the trend of concentration of PM2.5 and PM10 during the period 2015-2021, though these are much higher than the CPCB permissible limit of 40 µg/m3 (for PM 2.5) and 60 µg/m3 (for PM10). On the other hand, NO_2 has shown a steady upward trend during the period 2010-2018, much higher than the CPCB permissible limit of 40 µg/m^3, with a steep decline in 2019 and 2020, possibly owing to the COVID-19 lockdown.

Pollution concentration also varies in different months of the year and time of the day, with winter months (late November to February) and morning and evening peak hours of the days having the maximum concentration of the pollutants. (Refer Annex A 3.1) A recent study by SAFAR under Indian Institute of Tropical Meteorology, Pune, has revealed the share of PM2.5 emissions from vehicles was 30.5% in 2019-20 as compared with 16% in 2016-17 (Tembhekar, 2021).

Spatially also, (during the pre-pandemic year of 2019) the critical pollutants NO_2, PM2.5, CO and SO_2 are concentrated predominantly in the central and south -eastern parts of the city, which are devoid of the influence of sea breeze and corresponding dispersion of pollutants. A ward-wise analysis characterizes wards M/E (Deonar, Govandi, Mankhurd, Trombay) M/W (Mahul, Chembur) F/N (Antop Hill, Sion) and N (Ghatkopar, Vikhroli) as very critical. Amongst these, M/E ward consistently records the highest level of pollution in the city. The other hotspots include the airport area, Andheri, Kurla, and traces in South Mumbai in Worli and Colaba. (Refer Annex A 3.2) Similarly areas such as Mahul, Ambapada and Chembur have been identified as "gas chambers", owing to the petroleum industries, through emissions from logistic services, gas and chemical items and volatile organic compounds (Saigal, 2020)[2]. Accordingly, Maharashtra Pollution Control Board (MPCB) was directed to prepare a comprehensive action plan to control air pollution. (Refer Chapter 2)

Indoor Air Pollution

Indoor air pollution is a significant threat for low income settlements, resulting in high PM2.5 concentration. Based on a WRI analysis conducted as part of the MCAP study, 2% of the households that use firewood as cooking fuel are exposed to maximum indoor concentration of PM2.5 from kitchen areas, which is almost two times higher than the households exposed to indoor PM2.5 concentration from kitchen areas due to the usage of kerosene and LPG. (Refer Chapter 2)

Sources of Pollutants

Studies on source apportionment (MPCB, 2010; MPCB, 2020) reveal that paved and unpaved road dust, construction activities, heavy duty diesel vehicles and open and landfill burning are the primary sources of PM. NO_2 is emitted most by large-scale industries, heavy duty diesel vehicles, domestic sectors, railway locomotives and TATA Thermal Power Plant Ltd.

The high concentration of carbon monoxide (CO) in and around M/E ward, Mulund and traces in South Mumbai are due to large-scale landfill burning from the Deonar dumping ground and indiscriminate burning of waste at isolated places. The presence of the airport and corresponding traffic movement and prevalence of small- and medium-scale industries, service centres and commercial activities have resulted in a high concentration of SO_2 in M/E ward and Bandra and Bandra Kurla Complex in H/E and H/W wards.

Bakeries are also a significant source of pollutants in the city. As per estimates, in 2018, over 2,800 bakeries were operational, of which only 400 were registered while the remaining functioned without licenses and mainly used wood for cooking (MPCB, 2010). Bakeries contribute varied types of pollutants, such as 6.7% of PM 2.5, 0.089% of SOx, 0.58% of NOx, 44.05% of hydrocarbon (HC) and 48.62% of CO (MPCB, 2020). Crematoria too are a major source of pollutants and contribute 48.54% of CO, 43.71% of HC, 6.59% of PM, 0.99% of NOx and 0.17% of SOx.

Exposure and Sensitivity of People

Socio-economic conditions, such as housing condition, poor ventilation and usage of non-LPG cooking fuel, aggravates the risks and vulnerability to air pollution. Usually, people living in low-income informal settlements are more vulnerable to indoor air pollution caused by high concentration of PM. In addition, those working in close proximity to pollution sources and exposed to emissions through occupational risks, such as traffic operators, traffic police and construction workers, are more vulnerable to air pollution-related health hazards.

Key Gaps

The current air quality landscape of the city highlights several multi-pronged sectoral challenges related to data monitoring, inventorization, collection and archiving, institutional co-ordination, awareness and capacity building, congestion and large-scale fuel emissions, increased suspension dust and waste management.

Congestion and large-scale fuel emission

In 2020, Mumbai was ranked the second-most congested city in the world by The TomTom Index, with a high congestion level of 53% mainly owing to large-scale on-street parking and construction activities creating roadblocks. The total number of motor vehicles on the roads has increased 2.47 times, from 2001 to 2015, with private vehicles increasing 2.89 times (BMC, 2016). This has resulted in a high annual concentration of PM and NO_x.

Increased Suspension Dust

Construction activities in Mumbai contribute 8% to the total PM emitted. The Mumbai Metro project alone is responsible for 3.2% of the suspension dust in the city. There is also a lack of enforcement and regulation in the implementation of C&D Rules, 2016.

Waste Management

Frequent fires at landfill sites and indiscriminate burning of waste in isolated places causes the emission of PM, polycyclic aromatic hydrocarbons (PAHs) and traces of CO, thereby adding to air pollution. The extensive burning of firewood in low-income settlements also aggravates PM2.5 concentration and indoor air pollution.

Data inventorization

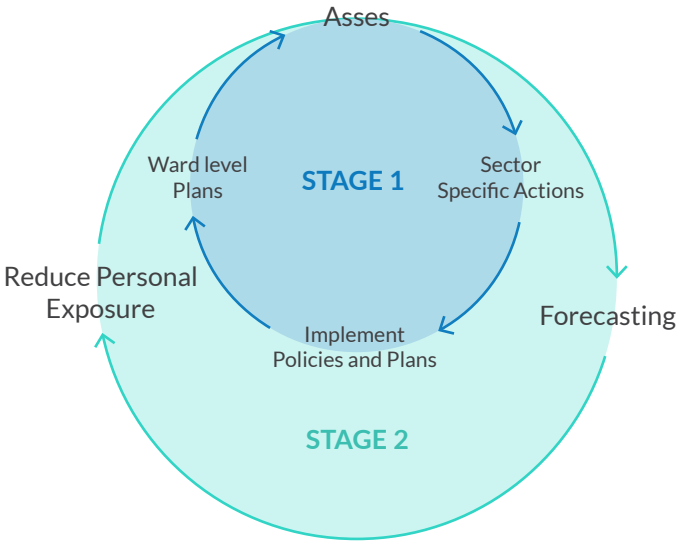
There is a lack of data granularity as well as publicly available published data on monitoring stations. The lack of detailed data on personal exposure levels from indoor air pollution and occupational hazards exacerbates the risk. There is also a lack of robust database management system for systematic data dissemination. The air pollution emission inventory that was last published in 2010 is yet to be revised and updated.

Monitoring, Institutional Co-ordination and Capacity Building

An insufficient number of air pollution monitoring stations in the city is a hindrance in capturing variations in the air pollutant concentration at the local level. An inefficient co-ordination mechanism amongst the institutions involved in data monitoring and data dissemination along with a lack of awareness and absence of capacity building programs for improving the health resilience of communities worsens the situation.

Approach

The assessment of the air quality landscape, including the barriers and sectoral gaps, has helped develop a two-stage approach for moving towards low-emission, cleaner air for Mumbai. The key components of this approach are a robust monitoring, forecasting and information dissemination system, decentralized planning for improved health resilience at the grassroots and defined targets for the reduction of air pollutant concentration in alignment with national and state goals. Sector-specific strategies and Ward Action Plans, which lower the emissions of air pollutants and address health issues, would in turn reduce the exposure of the vulnerable population and improve their resilience.



Ongoing Initiatives in the City

In order to improve air quality and reduce the threat from air pollution, a few initiatives are being undertaken. These are related to data monitoring, policy and program formulation and development of projects for waste management and reduction of emission from transport and industrial sectors.

Table 22 Air Quality: Ongoing initiatives by BMC

Data Monitoring	Policy and Programs
• 11 MPCB CAAQMS and 9 SAFAR CAAQMS stations have been installed, and 5 SAFAR CAAQMS stations have been proposed. In addition, 1 MPCB Manual station and 4 BMC Manual stations have been installed. • **Wind Augmentation and Purifying Units (WAPU)** has been installed at five traffic junctions in Mumbai to purify the ambient air quality.	• **Revised Action Plan for Control of Air Pollution** in Mumbai was prepared in September 2019 by MPCB under the NCAP program. • The Draft Interim Report on **Air Quality and Emission Source Apportionment Studies for Mumbai City** was prepared in January 2020 by MPCB and would be finalized soon.

Projects Related to other Sectors (Transport, Waste and Energy

- BEST is checking and installing PUC for buses every six months.
- Transition to BS VI fuel standard is underway from April 2020.
- Entry of heavy vehicles into the city during peak hours is banned.
- As per the policy of BEST Undertaking, buses attaining 15 years are scrapped.
- A total of 70 traffic signal junctions are in the process of being converted into Fully Adaptive Traffic Control System under Synchronize Traffic Movement, which would reduce congestion.
- Enforcement Marshals have been appointed in several wards to control widespread open burning of waste.
- Dumpsite reclamation at the Mulund dumping ground is being conducted to process and dispose legacy waste.
- BMC is implementing C&D (M&H) Rules, 2016 in the city.
- LPG access is being increased amongst the low-income groups through Pradhan Mantri Ujjwala Yojana.
- Sulphur content in fuel is being reduced in M/S. TATA Power Ltd. through the flue-gas desulphurization technique.
- MPCB has directed the industries in the Mahul area to provide continuous VOC monitoring stations and advance VOC control measures.

Sectoral Priority for Air Quality Management

Reducing air pollution by improved monitoring, effective regulations and a shift to cleaner technologies

The sectoral priority, action tracks and associated actions were developed on the basis of the city-level barrier analysis, ongoing city initiatives, inputs from external and internal stakeholder consultations, and zonal consultations along with citizen inputs received on the website. The stakeholders who were consulted in the process are listed in Annexure 3.

As the key sectoral priority for the next 10-20 years for efficient air quality management in Mumbai, emphasis has been placed on shifting to cleaner fuels, fuel efficiency and adoption of electric vehicles to reduce vehicular and industrial emissions, indoor air pollution and emissions from bakeries and crematoria. Strict regulation and an appropriate enforcement mechanism of policies and rules have also been prioritized, to minimize the indiscriminate burning of waste, burning at landfill sites and release of suspension dust due to construction and demolition activities. There is also an emphasis on and prioritization of increased availability of data and information by strengthening and decentralizing the pollution monitoring and forecasting mechanism and enhancing the health resilience of the vulnerable communities. This sectoral priority is based on the SDGs and the corresponding thematic action tracks of the MVA, Government of Maharashtra.

Sectoral Action Tracks

Table 23 Air Quality: Sectoral action tracks

Track 1	Improving air quality by curbing the pollution concentration level by 20%-30% by 2030
Track 2	Increasing information availability through improved monitoring and forecasting and awareness programs
Track 3	Ensuring community health resilience through decentralized planning and awareness programs

Track-wise Actions for Improved Air Quality

Table 24 Air Quality: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
Priority Actions			
Increase citywide network of PUC centers for efficient monitoring of emissions through vehicles and monitor the functioning of PUC centers. **Time Frame:** a) 2022-2027; b) Continuous activity from 2022	**Lead:** Regional Transport Office (RTO), Traffic Police	Aligned with NCAP activities, Municipal Budget	**Output:** No. of PUC centres established and fully operational in the city **Outcome:** % change in the pollutants' concentration from vehicular emission
Reduce congestion and traffic emissions by (a) management and planning, particularly at junctions through Intelligent Traffic Management system and (b) banning the entry of heavy vehicles into the city during peak hours. **Time Frame:** a) 2023-2029; b) Continuous activity starting from 2022	**Lead:** Road & Traffic Department, RTO, MMRDA, MSRDC, Traffic Police	NCAP Budget and Maharashtra State Transport Department	**Output:** Number/ volume of heavy commercial vehicles plying in the roads during peak working hours **Outcome:** % change in the pollutants' concentration from vehicular emission from heavy commercial vehicles. average exposure of people to pollutants from traffic emission
Retrofit particulate filters in diesel vehicles, and transition 30-40% vehicles to cleaner fuels and EV-powered by RE and provide allied infrastructure. **Time Frame:** 2022-2030	RTO, vehicle manufacturing industries, BEST, MMRDA, State Transport Ministry, RTO, OLA, Uber, Mumbai Bus Malak, Sanghatana, Cityflo	Vehicle manufacturing companies, MVA, Phase-II of FAME, 15th Finance Commission, green bonds	**Output:** No. of diesel vehicles installing particulate filters annually, no. of electric municipal vehicles and vehicles using cleaner fuels, no. of passenger capacity procured per year and cumulative **Outcome:** % change in the pollutants' concentration from vehicular emission, routes (bus/ other) operated by zero emission transport (km), average exposure of people to pollutants from traffic emission

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
Priority Actions			
Build awareness of and strengthen enforcement of the policy on scrapping of older vehicles. **Time Frame:** 2022-2026	RTO, State Transport Ministry, civil society organization	MVA	**Output:** No. of vehicles scrapped **Outcome:** % reduction in number of old vehicles
Ensure stringent regulation and enforcement of Greater Mumbai Cleanliness & Sanitation Byelaws, 2006, that ban open burning	BMC (SWM Dept, Ward Assistant Commissioners)	Swachh Bharat Mission, BMC Budget, MVA	**Output:** % reduction in open burning, Outcome: Emissions (CO, NO2, PM2.5) in key areas of the city (near hospitals, schools, care homes, low -income neighborhoods), average exposure of people to pollutants from waste burning
Create an online grievance redressal portal for citizens to log complaints. **Time Frame:** 2022-2023	BMC (IT Dept)	NCAP budget	**Output:** No. of daily online complaints lodged against MSW burning **Outcome:** % reduction in burning of waste
Install Material Recovery Facility (MRF) at ward level for efficient waste recovery and circularity in waste management. **Time Frame:** 2023-2030	SWM, Ward Assistant Commissioners	Swachh Bharat Mission, BMC Budget, 15th Finance Commission	**Output:** No. of wards which have installed MRF, no. of MRF installed in each ward **Outcome:** % of waste recycled
Ensure in-situ management of waste, where every housing society has a waste composting and management facility. **Time Frame:** 2022-2030	SWM, Ward Assistant Commissioners, Resident Welfare Associations (RWAs), civil society	Swachh Bharat Mission, BMC Budget	**Output:** No. of housing societies having composting facilities. **Outcome:** % of domestic hazardous waste collected and disposed daily

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
PriorityActions			
(a) Develop ward-level action plans for preventing and reducing open waste burning along and (b) organize awareness drives and campaigns against indiscriminate burning of garbage, biomass, crop residues, etc. **Time Frame:** a) 2022-2024; b) Continuous activity starting from 2022	Ward Assistant Commissioners, NGOs and SHGs working on solid waste management, rag pickers' association, SWM Department, RWAs, slum dwellers' association, private corporates, performance artistes	BMC Budget, Swachh Bharat Abhiyan, 15th Finance Commission, CSR, MVA	**Output:** No. of Ward Action Plans prepared to reduce open waste burning, no. of site- or city level awareness drives/ campaign undertaken per year **Outcome:** % waste collected and disposed, emissions in key areas of the city (near hospitals, schools, care homes, low-income settlements), % reduction in cases of open burning of waste, average exposure and incidence of airborne diseases, injuries and sickness due to burning of waste
Ensure stringent enforcement of the implementation of C&D Rules, 2016, for efficient undertaking of duties by waste generators, service providers and the local authority. **Time Frame:** 2022- 2025	SWM Department	NCAP, Swachh Bharat Mission	**Output:** % area affected by the suspension of dust from C&D **Outcome:** Emissions (CO, SO2, PM2.5, NO2) in key areas of the city (near hospitals, schools, care homes, low-income neighborhoods). average exposure and incidence of airborne diseases and sickness from suspension of dusts
Prepare site-specific air quality data repository for disseminating information on poor air quality and corresponding occupational health hazards at the site. **Time Frame:** Continuous site-specific activity, starting from 2022	**Lead:** Construction companies Supporting: MPCB	Construction companies	**Output:** No. of construction sites in each ward preparing Air Quality Data Repository annually **Outcome:** Construction workers taking precautionary measures due to poor air quality, average exposure and incidence of airborne diseases, sickness and injuries amongst construction workers

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
Priority Actions			
Ensure 40% transition in the short term and 100% in the long term to LPG and PNG as cooking fuel through Pradhan Mantri Ujjwala Yojana. **Time Frame:** 40% transition- by Year 2025; 100% transition- by Year 2030	Maharashtra Energy Development Agency (MEDA), Maharashtra Natural Gas Limited (MNGL), Mahanagar Gas Limited (MGL)	MVA	**Output:** % of HH transitioned towards LPG and PNG as cooking fuel by the end of 2030 **Outcome:** Litres per household kerosene fuel consumption per annum, % change in indoor PM2.5 concentration, no. of cases of airborne diseases and injuries from indoor air pollution
Conduct awareness programs to encourage people for complete transition towards cleaner cooking fuel to reduce indoor air pollution exposure **Time Frame:** 2022-2030	MEDA, Ward Assistant Commissioners, NGOs, RWAs, slum dwellers' associations, medical practitioners	MVA, CSR	**Output:** No. of awareness programs undertaken towards transition to cleaner cooking fuel **Outcome:** % HH monthly net income spent on energy, % change in indoor PM2.5 concentration, average exposure and incidence of airborne diseases from indoor air pollution
Offer monetary incentives to opt for cleaner cooking fuel and restrict the burning of wood. **Time Frame:** 2022-2030	MEDA	MVA	**Output:** % users using clean fuels for cooking & heating **Outcome:** % change in indoor PM2.5 concentration, average exposure and incidence of airborne diseases from indoor air pollution

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
Priority Actions			
Ensure 30-40% transition of all industrial units and power plants within city limits to the usage of natural gas renewable energy and low-sulphur fuel **Time Frame:** 2022-2030	MPCB, State Industries Department, owners of industrial units	NCAP, loans from Small Industries Development Bank of India (SIDBI), Industrial Development Bank of India (IDBI), Industrial Investment Bank of India and State Financial Corporations	**Output:** % of industrial units within city transitioned towards natural gas, renewable energy and low -sulphur fuels **Outcome:** % change measured in pollutant concentration, emission in key areas of the city (hospitals, schools, low -income neighborhoods), average exposure and incidence of airborne diseases and injuries due to industrial emissions
Develop an action plan and mitigation strategies for the existing industrial units within the city periphery for reducing industrial pollution. **Time Frame:** 2022-2026	State Industries Department, owners of industrial units/ clusters, MPCB	NCAP, loans from Small Industries Development Bank of India (SIDBI), Industrial Development Bank of India (IDBI), Industrial Investment Bank of India and State Financial Corporations,	**Output:** No. of industrial units having developed Action Plan/ Mitigation strategies for reducing industrial pollution **Outcome:** % change measured in pollutant concentration, emission in key areas of the city (hospitals, schools, low -income neighborhoods)
Ensure stringent enforcement of SO_2/ NO_x/ PM2.5 standards in fuel usage. **Time Frame:** 2022-2030	MPCB	NCAP	**Outcome:** % reduction in industrial emissions containing SO_2/NO_x/PM2.5; % reduction in the incidence of airborne diseases and injuries
100% reduction in the operation of Diesel Generators sets through uninterrupted power supply **Time Frame:** 2025	Power generation and supply companies, BEST	NCAP	**Output:** % of reduction in the operation of DG sets **Outcome:** % change in the concentration of pollutants from DG sets

Action Description	Stakeholders	Funding/Financing	Monitoring Indicators
Sectoral Action Track 1: Improved air quality by curbing the pollution level by 20%-30% by 2030, keeping 2019 as the base year			
Priority Actions			
Ensure 100% conversion of all crematoria to electric or PNG, with the installation of chimneys with filters and 25-30% conversion of all bakeries to PNG or RE with the installation of scrubbers in exhaust systems, mechanized ovens and electric furnaces. **Time Frame:** 2030	MEDA, BMC Mechanical and Electrical & Executive Health Officer, BMC, MPCB, BEST, owners of bakeries	NCAP, 15th Finance Commission, loans from SIDBI, State Financial Corporations	**Output:** % of bakeries transitioned towards PNG and RE, no. of bakeries using mechanized ovens and electric furnaces, no. of crematoria having installed chimneys with filters, no./ % of crematoria converted to electricity **Outcome:** % change in the emission/ concentration of pollutants from bakeries and crematoria, emission in key areas of the city (hospitals, schools, low-income neighborhoods)
Mandate all bakeries to obtain licenses to move to cleaner fuels **Time Frame:** 2022-2027	Food Safety and Standards Authority of India (FSSAI), BMC License Dept., BMC, Bakers' Association	Bakery owners	**Output:** No. of new bakeries being issued licenses **Outcome:** Increased usage of clean fuels by the bakeries
Increase the vegetation cover in the city through tree plantations along streetscapes, urban forestry initiatives and rooftop farming. **Timeframe:** 2022	BMC (Development Planning Dept-BMC, Garden Dept-BMC, MMRDA, Mithi River Development Authority, Assistant Commissioner-Removal of Encroachments	MVA, BMC Budget, AMRUT	**Output:** Areas of green corridors developed **Outcome:** % change measured in pollutant concentration, emission in key areas of the city (hospitals, schools, low -income neighborhoods)

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Ensure increased information and data availability through improved monitoring and forecasting and awareness programs			
Priority Actions			
Increase the number of the monitoring stations, such as CAAQMS, equipped with low -cost indigenous sensors and real-time monitoring technology, based on CPCB criterion for site location. **Time Frame:** 2022- 2027	MPCB	Aligned with NCAP, Majhi Vasundhara program	**Output:** No. of monitoring stations installed per year, updated annual emissions inventory % area/population covered by monitoring **Outcome:** Emissions (CO_2, PM2.5, NO_2) in key areas of the city, Funds allocated for air quality monitoring stations
Develop a robust data survey mechanism to address the issue of varied types of personal exposure to different air pollution risks. **Time Frame:** 3-6 months in 2022	Ward Assistant Commissioners, BMC Executive Health Officer-BMC	BMC Budget	
Organize awareness and outreach programs at ward and city levels in collaboration with BMC and the media, for better dissemination of information regarding health advisories, preventive measures and forecasting. **Time Frame:** Continuous activity starting from 2022	Ward Assistant Commissioners, women, children and the elderly from slums and low-income settlements, NGOs, students, individual sectoral experts, SHGs, performing artists, representatives from media houses, research organizations, universities and schools	CSR, aligned with Majhi Vasundhara, BMC Budget	**Output:** Total no. of outreach plans developed after 1 year, no. of ward/ community -specific awareness programs undertaken per year, no. of D2D campaigns organized per year in each ward **Outcome:** % of area/ population covered by awareness and outreach programs

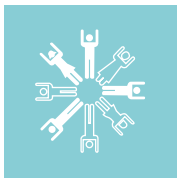
Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Ensure increased information and data availability through improved monitoring and forecasting and awareness programs			
Priority Actions			
Facilitate knowledge exchange on prevention, control and abatement of air pollution through "exposure visits" by officials of BMC and other state government departments **Time Frame:** 2023, 2025 & 2028	BMC, MPCB, State Environment Department, universities (national & international), research organizations	Aligned with NCAP, 15th Finance Commission, Majhi Vasundhara ,BMC Budget,	**Output:** No. of exposure visits conducted in 2023, 2025 and 2028 **Outcomes:** New techniques/ innovations being adopted by BMC towards prevention, control and abatement of air pollution
Undertake air pollution hot spot-based forecasting system, preferably at the ward/ zonal level. **Time Frame:** Continuous and regular activity, starting from 2022	MPCB, Ward Assistant Commissioners	Aligned with NCAP, MPCB Budget	**Output:** Updated annual emissions inventory, publicly available air quality data, no. of air quality sampling points (as compared with the recommended minimum no.) % area/ population covered by monitoring and modelling systems **Outcome:** Emissions (CO^2, PM2.5, NO_2) in key areas of the city (e.g., near hospitals, schools, care homes or low -income neighborhoods)
Strengthen and ensuring timely air quality data monitoring and dissemination of information aligned with NCAP; improved co-ordination amongst the relevant departments within BMC for data dissemination and proper operation, maintenance and functioning of the Air Quality Monitoring Stations **Time Frame:** Continuous and regular activity, starting from 2022	a) BMC Environment Department and other relevant departments-BMC b) MPCB	a) BMC Budget b) Aligned with Majhi Vasundhara, MPCB Budget	**Output:** Updated annual emissions inventory, publicly available air quality data, no. of air quality sampling points (as compared with the recommended minimum no.) % area/ population covered by monitoring and modelling systems **Outcome:** Emissions (CO_2, PM2.5, NO_2) in key areas of the city (e.g., near hospitals, schools, care homes or low -income neighborhoods)

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 2: Ensure increased information and data availability through improved monitoring and forecasting and awareness programs			
Priority Actions			
Undertake source apportionment studies at a frequent interval of 3-5 years, and update the existing emission inventory at a resolution higher than 1kmx1km. **Time Frame:** Continuous and regular activity, starting from 2025 (every five years)	MPCB, SAFAR-Mumbai, BMC Environment Dept-BMC	NCAP	NA
Conduct stringent monitoring of the progress of infrastructural projects and ensure timely completion to avoid congestion on roads. **Time Frame:** Continuous and regular activity, starting from 2022.	BMC	BMC Budget	**Output:** Completion of infrastructural projects in prefixed time **Outcome:** Congestion on road due to construction activities
Medium- and Long-Term Actions			
Scale up the ward/ community -level awareness generation program for the prevention of adverse effects of air pollution. **Time Frame:** 2031- 2040	BMC Environment Dept-BMC, women, children and the elderly from slums and low-income settlements, NGOs, students, individual sectoral experts, SHGs, performing artists, research organizations, universities and schools	CSR, BMC Budget, MVA	**Output:** Types and number of city-level awareness programs on prevention of adverse effects of air pollution **Outcome:** People taking health precautionary measures when exposed to air polluting activities

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 3: Ensure community health resilience through decentralized planning and awareness program			
Priority Actions			
Identify the local causes of air pollution and their spatial concentration within a ward. **Time Frame:** Continuous activity for a period of 6 months, starting from 2022, to be conducted annually	Ward Assistant Commissioners, research organizations, universities, community organizations such as RWAs and slum dwellers' association, local builders, MPCB	MPCB, BMC Budget	**Output:** Areas identified within the wards as air pollution hotspots and possible causes
Conduct a health risk assessment through an extensive survey to identify the community exposed to air pollution-related activities and vulnerable to the corresponding health issues. **Time Frame:** Continuous activity for a period of 6 months, starting from 2022, to be conducted annually	Ward Assistant Commissioners, research organizations, universities, community organizations such as RWAs, slum dwellers association and rag pickers association, local builders, medical practitioners from hospitals and public health centers	BMC, CSR	**Output:** People identified as vulnerable to air pollution risk in each ward, types of health issues arising from air pollution in each ward **Outcome:** Frequent health -related interventions being undertaken at the ward level for targeted groups
Organize regular free health camps among the low-income group to measure their level of exposure to air pollution. **Time Frame:** Regular activity to be conducted every 6 months, starting from 2022; would begin after the identification of the vulnerable population	Ward Assistant Commissioner, medical practitioners from public health centers, government and private hospitals, Executive Health Officer from Public Health Dept-BMC	CSR , NGOs, SHGs and RWAs, BMC Budget, 15th Finance Commission	**Output:** No. of free health camps organized in each ward in a year **Outcome:** Improved health monitoring and diagnosis of vulnerable communities, incidence of airborne diseases, injuries and sickness due to indoor and outdoor air pollution.

Action Description	Stakeholders	Funding/Financing	Indicators
Sectoral Action Track 3: Ensure community health resilience through decentralized planning and awareness program			
Priority Actions			
Establish an online grievance redressal mechanism to lodge complaints against poor air quality. **Time Frame:** 2022 -2023	BMCIT Dept-BMC	BMC Budget	**Output:** No. of daily online complaints lodged and attended against bad air quality **Outcome:** Improved monitoring of bad air quality
Set up "community kitchens (Kundu, 2020)" in low-income informal settlements and slum areas, using LPG cylinders provided by the local government[16]. **Time Frame:** 2022-2025 (includes a period of 1 month for setting up each kitchen)	Ward Assistant Commissioners, BMC	CSR, Central and State Food Ministries, BMC Budget	**Output:** No. of slums/ low -income informal settlement/ population covered under the community kitchen program per year **Outcome:** Improved facility of diet and nutrition amongst low-income people

Sector-specific Inclusive Benefits



- Decreasing air pollution would reduce health exposure to pollutants amongst vulnerable population, such as low-income groups, construction workers and the traffic police.
- Strengthening information, database and the monitoring and forecasting system would improve information dissemination regarding advisory measures to reduce exposure and consequent health hazard, especially amongst vulnerable communities, such as low -income groups and migrants.
- Facilitating improved health resilience at the community level through awareness and training programs and investments as part of decentralized planning for air pollution reduction.

[16]This initiative would be funded through contribution from NGOs, civil society organisation, local corporators, corporate funding and would be supplemented by robust public distribution system to ensure sustainable and long-term food security

5.6 Urban Flooding & Water Resource Management

Mumbai city is an estuary connecting the mainland with the Arabian Sea (Refer Chapter 1). The city has urbanized over the years and undergone reclamation and concretization of its natural terrain, altering several associated ecosystems. The city, which receives an annual precipitation of around 2,000 mm, battles routine flooding and waterlogging during the monsoon season (IMD, 2020). Decadal rainfall data from BMC's Automated Weather Stations (AWS) reiterates the increasing frequency of very heavy and extremely heavy rainfall events in the city.

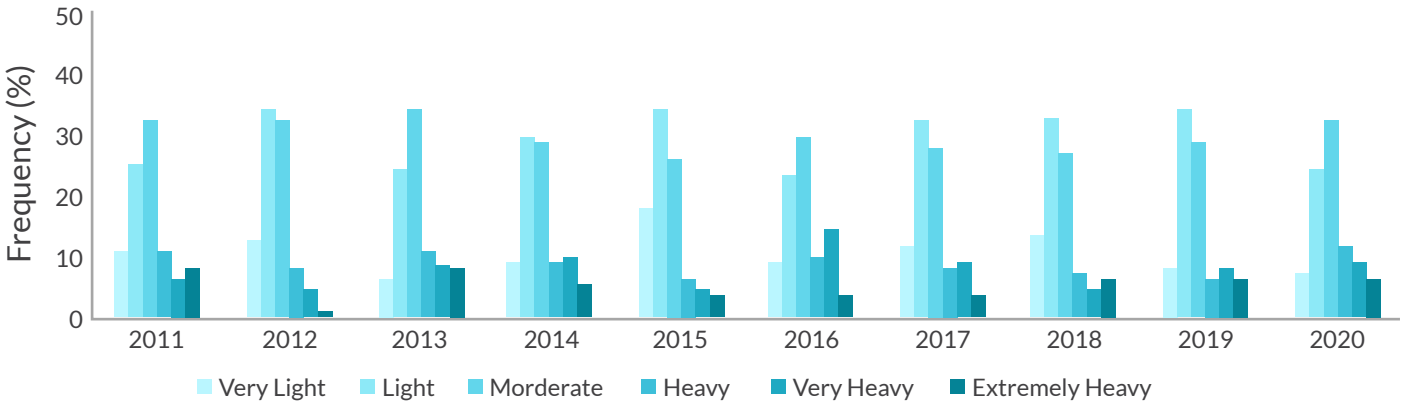


Figure 38: Frequency of heavy rainfall events in Mumbai during 2011-2020

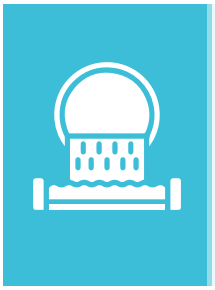
As described in the climate risks assessment, (Refer Chapter 2.1), the recent IPCC AR6 report (2021) points out that the precipitation is expected to increase and become more extreme. The city's storm water drainage network consists of a dense network in the island city and sparsely spread in the suburbs. Considering this, the city is cautioned by the future possibilities of routine inundation or partial submergence if actions towards increasing the city's flood resilience are not taken up. Several habitations within the city are either just above mean sea level or located on hill slopes. This makes these habitations most vulnerable to the compounded impacts of waterlogging, flooding and landslides resulting from the simultaneous occurrence of extreme climatic events. Fishing communities and other informal settlements along the coasts are at the risk of inundation and storm events. However, this is not the only risk these communities face. Accessing water and sanitation services is a routine struggle, which is exacerbated during extreme climate events. Figure 38 presents a snapshot of the water-related infrastructure and service systems in the city.

Storm Water Drainage

- Age-old system with 64% of total length as roadside open drains
- 6 pumping stations with network capacity of 25mm/ hour at low tide
- High surface run-off due to low percolation space and encroachment on natural ecosystems
- Open drains susceptible to clogging and contamination

Water Supply

- Heavy reliance on surface catchments located around 163 km away with 38% non-revenue water (DP 2034)
- Ban on groundwater use for domestic & drinking purposes
- 3850 MLD water supply with an average per capita supply higher national standards but inadequate connections in informal settlements



Sanitation

- 7 sewage zones with STP treatment capacity equal to generation
- 22% increase in sewage generated over the last decade of which around 63% is collected and of that 87% is treated
- High organic content found in wastewater near coastal outfalls
- 58.3% households have toilet amenities within their premises

Figure 39: Water infrastructure and service systems in Mumbai

Thus, it is evident that the city needs to integrate nature-based watershed approach while ensuring water and sanitation access to vulnerable populations.

Key Gaps and Challenges in Managing Water Resources and Urban Flooding

There are inconsistencies in water resource management and service systems at various levels in the city, revealing inconsistencies at various levels, as described below. These inconsistencies make the city vulnerable to increased climatic risk in future.

Data and information systems

Robust data and information systems are needed to ensure the availability of water and sanitation services for all through real-time monitoring of supply and distribution network and the quality of groundwater sources and by preparing an inventory of sanitation data and services. This data can help design appropriate byelaws to ensure that citizens, especially informal habitants, are not denied their basic rights of water and sanitation on account of their housing status. Similarly, to understand the future climate risk and projections more thoroughly, meteorological data such as rainfall, temperature and humidity needs to be recorded consistently.

Policy and planning mechanisms

The city primarily lacks urban planning, which has resulted in high built-up coverage and inappropriate land-use, leading to high surface run-off. The weak enforcement of land-use policies has increased the risk of flooding, loss of biodiversity, reduction in carbon-sinks and sequestration capacity of natural ecosystems. To address these flooding and surface run-off issues, the city needs to adopt a watershed approach, focusing on specific aspects such as rainwater harvesting and decentralized treatment of wastewater.

Infrastructure and service delivery

The citizens of Mumbai, especially those living in informal settlements, have long been struggling for access to water connections and sanitation facilities. Although the city receives abundant water, a lack of connections is forcing the low-income communities to resort to informal water supply mechanisms, impacting their livelihoods. At several locations, the sewage system and storm water drainage network are age-old, making them susceptible to leakages, clogging and contamination. Strong monitoring mechanisms need to be integrated in the systems to plug these gaps. Besides, the capacities and technologies used in wastewater treatment are inadequate, thus polluting the coastal waters and biodiversity.

Regulation and enforcement

Although several policies, guidelines and standards are in place to ensure compliance with the existing environmental norms, the lack of regulation and enforcement is a key gap, resulting in inequities in service provision, loss of permeable surfaces and biodiversity and disasters caused by extreme climate events. Robust regulatory mechanisms with clear monitoring systems will reduce inequities, while safeguarding the natural resources of the city.

A vulnerability assessment presented in chapter 2, identifies current and future risks that the existing systems, both infrastructural and institutional, are unable to address. The gaps outlined in this sub-section add to the challenges. To deal with these challenges, BMC will need to adopt the approach presented in the subsequent sub-sections.

Approach for a Water Resilient Mumbai City

The existing systems and infrastructure arrangements are inadequate in achieving the adaptation goals set for the city, with respect to stormwater drainage, water supply and sanitation and sewage management. This action plan proposes a holistic water resilience approach to better manage water as a resource to reduce flood risk, adopt water conservation approaches and address vulnerability through water and sanitation equity. The barriers identified in the previous sub-section informs this approach and defines the action tracks for the sector.

Figure 40: Water resilient approach for Mumbai

Ongoing City Initiatives

The initiatives taken up by BMC to meet some of the services and infrastructure gaps in the city are summarized in Table 25.

Table 25 Urban Flooding and Water Resource Management: Ongoing initiatives of BMC

Flood Risk Management	WASH Equity
• Underground holding tanks constructed for storing storm water, especially during high tide / water logging incidents near Hindmata junction in September 2021 • Mithi River Clean-up Project commissioned in August 2021	• Extension of sanitation network in slum areas, based on the latest discharge standards recommended by National Green Tribunal • Desalination projects proposed to recycle saline water, provide water, reduce burden on freshwater requirement and prevent deforestation in the catchment areas of the proposed dams
Water Treatment & Conservation	**Data & Information**
• Issuance of occupation certificate after compliance of rainwater harvesting schemes in new property development with plot area more than 500 sq. meters. • Eco-housing program (BMC, n.d.), which encourages environmentally sensitive residential development in the city • Designing of rainwater harvesting schemes free of cost and other related initiatives by RWH and Water Conservation Cell of BMC • Water treatment plants at Bhandup and Panjarapur powered by solar energy of 2.5 MW and 250 Kw capacity, respectively	• Digitization of open and bore wells, with sub-soil details • Impact analysis of groundwater extraction in M/E and P/S wards • Mapping of sewage network based on Geographic Information System (GIS) and sewerage assets based on Global Positioning System (GPS), available through the Web application of BMC • Real-time and online monitoring of treated sewage discharge flow • Online monitoring of pumping stations and their functioning parameters

Sectoral Priority

Increasing resilience by reducing water-sanitation inequity and adopting nature-based solutions for water conservation and flood risk management

Against the backdrop of the barriers and initiatives taken, different stakeholders were consulted to validate the on-ground realities, understand the requirements, and frame the action tracks for the sector. These engagements underpinned these action tracks and helped in prioritizing them based on the sectoral approach. While some sectoral experts highlighted the socio-economic and inequities implications from the lack of service provision in water supply and sanitation, officials of BMC and other agencies explained the necessity to arrest run-off at midstream of catchment areas. Submissions from the MCAP website emphasized on the need to integrate recyclable materials into land surface for increased permeability. Similarly, zonal representatives identified the micro-level risks, hazards due to the changing climate. Future climate risk projections for Mumbai city point towards urgent action on flood resilience, improved management of water resources and inclusive WASH provision. In addition, meeting critical policy and regulatory gaps and intelligent disaster preparedness through smart data and information management systems. The urban flooding and water resource management action plan recommends six goals for the city.

Sectoral Action Tracks

Table 26 Urban Flooding and Water Resource Management: Sectoral action tracks

Track 1	Build flood resilient systems and infrastructure to minimize the risk of flooding and associated impacts
Track 2	Ensure that up to 50% of the city's water demand is met through localized water conservation and efficient use initiatives by 2030
Track 3	Reducing pollution to conserve and restore aquatic & marine ecosystems and associated biodiversity
Track 4	Access to safe and affordable drinking water for all by 2030
Track 5	Provide clean, safe and accessible toilets to all by 2030
Track 6	Ensure disaster risk and impact reduction by strengthening early warning systems, data monitoring and integration, community engagement

By Santosh Verma

Table 27 Urban Flooding and Water Resource Management: Track-wise actions and their implementation

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Build flood resilient systems and infrastructure to minimize the risk of flooding and associated impacts			
Priority Actions			
Restore natural drainage of the city by rehabilitating encroachment, clean-up of waste disposed and conserving the existing open, green and blue spaces. **Timeframe:** 2022 -2030	**Lead:** Housing Department-BMC, Solid Waste Management Department-BMC **Supporting:** Garden & Trees Garden and Tree Authority-BMC, Mithi River Development and Planning Authority, Environment Department-BMC, Disaster Management Department-BMC, Storm Water Drainage Department-BMC, Sewage Operation Department-BMC , Mumbai Sewage Disposal Project-BMC	Cost of Mithi River Clean-up Project is around INR 50 million (MS, 2021), BMC's Departmental budgets for Housing, Garden & Trees, other funds such Swachh Bharat Mission, CSR funds of private companies for conservation of green and open spaces	**Output:** 1. Area of riverbanks stabilized (m^2 / km^2) 2. Number of assets relocated **Outcome:** 1. % of heavy rainfall leading to erosion 2. % of assets protected from floods 3. Percentage of urban area that is greenspace
Reduce the surface run-off coefficient and increase the permeable surface by conserving the existing green and blue spaces, retrofitting land surfaces with recycled material and introducing hybrid (gray and green) and / or nature-based solutions, especially at mid-stream to avoid surface run-off into low-lying areas. **Time frame:** 2022 -2030	**Lead:** Garden & Trees Department-BMC **Supporting:** Roads Department-BMC, Environment Department-BMC, Disaster Management Department-BMC		**Output:** 1. Area of vegetated area created (m^2) 2. Area of riverbanks stabilized (m^2 / km^2) 3. Area of slopes stabilized (m^2 / km^2) 4. Volume of water retention capacity created (m^3) **Outcome:** 1. % of heavy rainfall leading to flooding 2. % of heavy rainfall leading to erosion 3. Percentage of urban area that is green space

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 1: Build flood resilient systems and infrastructure to minimize the risk of flooding and associated impacts			
Medium and Long-term Actions			
Upscale innovative solutions to monitor flood levels in all rivers, tributaries and estuaries of the city. **Timeframe:** 2031 onwards	**Lead:** Disaster Management Department-BMC **Supporting:** Storm Water Drainage Department-BMC	Cost of flood mitigation measures of Mumbai using Japanese technology is INR 5 million (Note: Based on the figure quoted in BMC Budget document Mumbai, Budget Estimate Fund Code 11, 2021-2022), funds from State Disaster Management Programmes	**Output:** 1. Number / frequency of early warnings of flood incidents shared with the citizens 2. Area (m^3) along rivers or in coastal areas saved of inundation/ flooding **Outcome:** 1. % of heavy rainfall leading to flooding 2. Percentage of population vulnerable to natural hazards (e.g., flooding, landslides, cyclones)
Make the installation of Rooftop Rainwater Harvesting (RWH) mandatory in the existing and new government and private buildings. **Time frame:** 2031 -2040	**Lead:** Rainwater Harvesting and Water Conservation Cell-BMC **Supporting:** Water Supply Department-BMC	Cost of RWH system - INR 2,000-30,000, for an existing building of about 300 sq. meter (Rainwater Harvesting Systems for Existing Properties-Challenges & Cost-Effectiveness, 2018), BMC's departmental budget for water supply and rainwater harvesting, funds for specific projects from bilateral, multilateral organizations, civil society and non-profit organizations for carrying out specific projects or activities, Jal Shakti Abhiyan of National Water Mission	**Output:** 1. Volume of water retention capacity created (m^3) 2. Number of assets retrofitted **Outcome:** 1. % of heavy rainfall leading to flooding 2. % of heavy rainfall leading to erosion 3. % of assets protected from floods 4. Percentage of monthly income spent on water 5. Percentage of the city population with safely managed drinking water services 6. Percentage of the city population with safely managed drinking water services

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 2: Ensure that up to 50% of the city's water demand is met through localized water conservation and efficient use initiatives by 2030			
Priority Actions			
Organize large-scale implementation of Rainwater Harvesting (RWH) systems by developing a comprehensive policy for all typologies of buildings based on a detailed water audit report. Conduct monitoring, particularly in slum areas, to ensure long-term utility and sustainability of these systems. **Timeframe:** 2022 -2030	**Lead:** Hydraulic Engineer (HE) Department-BMC **Supporting:** Water Supply Department-BMC, Rainwater Harvesting and Water Conservation Cell-BMC	Cost of RWH system - INR.2,000-30,000, for an existing building of about 300 sq. meter (Rainwater Harvesting Systems for Existing Properties-Challenges & Cost-Effectiveness, 2018), BMC's departmental budget for water supply and rainwater harvesting, funds for specific projects from bilateral, multilateral organizations, civil society and non-profit organizations for carrying out specific projects or activities, Jal Shakti Abhiyan of National Water Mission	**Output:** 1. Volume of water saved through conservation practices, especially in the high 2. Volume of water retention capacity created (m^3) **Outcome:** 1. Reduction in total water demand of the city (m^3) 2. Reduced surface-off in the city 3. % of heavy rainfall leading to flooding 4. Percentage of monthly income spent on water 5.Percentage of the city population with safely managed drinking water services
Decentralize the treatment and reuse of wastewater by introducing byelaws, incentives and nature-based solutions and integrating solar energy in treatment processes. **Timeframe:** 2022 -2030	**Lead:** H Sewage Projects **Supporting:** Sewage Operations Department-BMC, Mumbai Sewage Disposal Project-BMC	Installation of a decentralized wastewater treatment plant of 8-10 KLD capacity would cost around INR 2.5-3 lakhs, average cost of construction annually is INR 10 million annually (Cost estimation for planning and designing of decentralised wastewater treatment system), AMRUT	**Output:** 1. Number of assets retrofitted 2. Volume of wastewater reused **Outcome:** 1. % of wastewater released into the sea 2. Level of dissolved oxygen (DO), phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies 3. Percentage of households connected to sewage system 4. Percentage of monthly income spent on water 5. Number of water supply interruptions per household per day/week/month/year

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 2: Ensure that up to 50% of the city's water demand is met through localized water conservation and efficient use initiatives by 2030			
Priority Actions			
Increase outreach through aggressive campaigning of RWH schemes, organizing sensitization programs for informal communities, stationing a nodal officer at ward level for RWH and introducing water conservation initiatives. **Timeframe:** 2022 -2030	**Lead:** Rainwater Harvesting and Water Conservation Cell-BMC, Sewage Operations Department / Mumbai Sewage Disposal Project-BMC **Supporting:** Ward-level officers, civil society organizations, community representatives, elected representatives	INR 4,50,000 (Note: Calculated based on workshop expenses and remuneration to training faculty of HE Department from BMC Budget 2020-21), MVA	**Output:** 1. % of population aware of campaign 2. Number of workshops conducted 3. List of nodal officers **Outcome:** 4. % population trained 5. % population implementing response actions 6. Number of people implementing response actions 7. Number of residents participating in public planning processes and public awareness events 8. Number and type of NGOs involved in city issues

Action description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 3: Reduce pollution to conserve and restore aquatic and marine ecosystems and the associated biodiversity			
Priority Actions			
Introduce nature-based sewage treatment solutions at outfalls of selected sewage zones to treat 25% of the sewage generated. **Timeframe:** 2022 -2030	**Lead:** Sewage Operations Department-BMC **Supporting:** Sewage Projects Department-BMC, Mumbai Sewage Disposal Project -BMC	Access funds under National Adaptation Fund for Climate Change, international banks including World Bank, Asian Development Bank.	**Output:** 1. Water quality standards of the marine outfalls samples. **Outcome:** 1. Increased marine biodiversity along the coast 2. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 3: Reduce pollution to conserve and restore aquatic and marine ecosystems and the associated biodiversity			
Priority Actions			
Ensure strict regulation and enforcement of no-development zones and buffer zones along rivers. **Timeframe:** 2022 -2030	**Lead:** 1. Development Plan Department-BMC, **Supporting:** Building Proposal, Storm Water Drainage Department-BMC, Disaster Management Department-BMC	BMC's budget under Development Plan	**Output:** 1. Area of riverbanks and slopes stabilized (m^2 / km^2) 2. Area of vegetated area created (m^2) 3. Volume of water retention capacity created (m^3) **Outcome:** 1. % of heavy rainfall leading to landslides/ erosion/ flooding 2. Percentage of urban area that is greenspace 3. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies
Ensure restoration of riparian zone of rivers and other water bodies to reduce pollution. **Timeframe:** 2022 -2030	**Lead:** 1. Garden & Trees Department-BMC **Supporting:** Mithi River Development and Planning Authority, Disaster Management Department-BMC, Storm Water Drainage Department-BMC	BMC's budget of Garden & Trees Department, MVA	**Output:** 1. Area of riverbanks stabilized (m2 / km^2) **Outcome:** 1. % of heavy rainfall leading to erosion 2. % of heavy rainfall leading to flooding 3. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies 4. Percentage of urban area that is greenspace

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 3: Reduce pollution to conserve and restore aquatic and marine ecosystems and the associated biodiversity			
Medium and Long-term Actions			
Implement nature-based sewage treatment solutions phase-wise at outfalls of sewage zones to include 100% of the sewage generated. **Timeframe:** 2031 -2040	**Lead:** 1. Sewage Operations Department-BMC **Supporting: S**ewage Projects Department-BMC, Mumbai Sewage Disposal Project Department-BMC	Access funds under National Adaptation Fund for Climate Change, international banks including World Bank, Asian Development Bank	**Output:** 1. Water quality standards of the marine outfalls samples **Outcome:** 1. Increased marine biodiversity along the coast 2. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies

Action description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 4: Ensure access to safe and affordable drinking water for all by 2030			
Priority Actions			
As per the national standards, ensure per capita water supply of 150 lpcd to 100 % of the population in the city, irrespective of their legal, residential status. **Timeframe:** 2022 -2030	**Lead:** 1. Sewage Water Supply Project Department-BMC, HE Department-BMC **Supporting:** Ward-level officers, community representatives, elected representatives	INR 3,173 million (Note: this is an estimation for 9 years based on the revenue budget estimates of Water Supply Project Department, international banks including World Bank, Asian Development Bank, AMRUT	**Output:** 1. % of population having access to safe drinking water within or close to premises **Outcome:** 1. Improved health, well-being and livelihood 2.Percentage of the city population with safely managed drinking water services 3. Percentage of monthly income spent on water 4. Percentage of monthly income spent on water 5. Number of water supply interruptions per household per day/week/month/year

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 4: Ensure access to safe and affordable drinking water for all by 2030			
Priority Actions			
Regulate or introduce caps on pricing for non-piped water in the wards that are heavily dependent on water tankers for drinking and domestic use. **Timeframe:** 2022 -2030	**Lead:** 1. HE Department-BMC, Public Health Department-BMC **Supporting:** Ward-level officers, community representatives, MPCB		**Output:** 1. Water charges / taxes incurred from water tankers **Outcome:** 1. Reduced expenses for procuring water from tankers 2.Percentage of monthly income spent on water 3. Percentage of the city population with safely managed drinking water services 4. Mortality rate attributed to unsafe water
Formalize groundwater connections for monitoring water quality for distribution in low-income settlements at monthly intervals. **Timeframe:** 2022 -2030	**Lead:** Water Supply Project Department-BMC **Supporting:** HE Department-BMC, MSPCB, Public Health Department-BMC	BMC's budget under Water Supply and Public Health Departments	**Output:** 1. Inventory of groundwater sources with digital maps, wherever feasible 2. Water quality standards from monitoring stations of BMC and other agencies **Outcome:** 1. Reduced cases of water contamination 2. Improved health and well-being of impacted communities 3. Percentage of the city population with safely managed drinking water services 4. Mortality rate attributed to unsafe water

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 4: Ensure access to safe and affordable drinking water for all by 2030			
Priority Actions			
Climate-proof water supply systems to avoid outages during disasters by undertaking energy audit at annual intervals to shift to renewable sources. **Timeframe:** 2022 -2030	**Lead:** Water Supply Department-BMC, HE Department-BMC	INR 1,00,000 for undertaking energy audit[17] (Mumbai, Budget Estimate Fund code 40, 2021-2022). BMC's budget under Water Supply and HE Departments, funds from international banks including World Bank, Asian Development Bank	**Output:** 1. Energy savings of the water supply systems **Outcome:** 1. Reduced expenses on energy supply to the water supply systems 2. Number of water supply interruptions per household per day/week/month/year

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 5: Provide clean, safe and accessible toilets to all by 2030			
Priority Actions			
Expand and monitor toilet facilities phase-wise to serve 100% of the population through suitable toilet models based on a city-wide sanitation data inventory. **Timeframe:** 2022 -2030	**Lead:** Sewage Projects Department-BMC, Sewage Operations Department -BMC **Supporting:** Mumbai Sewage Disposal Project-BMC, Slum Sanitation Programme, organizations such as MHADA or private companies under CSR	Cost for 1 community toilet built under Slum Sanitation Programme is around INR 2,50,000 (UNICEF, 2020), average annual budget of Sewerage Operations Department is INR 1,065 billion (Mumbai, Budget Estimate Fund code 40, 2021-2022), CSR funds of private companies, funds for specific projects from bilateral, multilateral organizations, civil society and non-profit organizations, Swachh Bharat Mission	**Output:** 1. Census service provision parameters 2. Reporting in annual ESR 3. Online dashboard reflecting the numbers, maps to display the spatial distribution of services, location, type, implementing organization, finance related details and status of toilet blocks installed **Outcome:** 1. Improved sanitation services in the city 2. Percentage of population with access to sanitation services 3. Percentage of households connected to sewage system

[17] Based on consultancy charges for energy audit for Hydraulic Engineering Department of BMC's Budget 2020-21

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 5: Provide clean, safe and accessible toilets to all by 2030			
Priority Actions			
Connect slum sewage to the main network for eliminating leakages and manual scavenging . **Timeframe:** 2022 -2030	**Lead:** Sewage Projects Department-BMC **Supporting:** Mumbai Sewage Disposal Project-BMC, Sewage Operations Department-BMC	INR 9,773 million (Note: Based on estimated expenditure figures for sewerage operations department of BMC's Budget 2020-21) MVA, Swachh Bharat Mission, AMRUT	**Output:** 1. Volume of sewage flow monitored through SCADA system of Sewage Department. 2. Water quality of sources located close to the leak points **Outcome:** 1. % of sewage flow from the main network 2. Percentage of households connected to sewage system 3. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies
Generate awareness, especially among underserved communities, about all aspects of sanitation. **Timeframe:** 2022 -2030	**Lead:** Sewage Operations Department-BMC **Supporting:** Mumbai Sewage Disposal Project-BMC	INR 8,00,000 annually[18] (Mumbai, Budget Estimate Fund code 40, 2021-2022), CSR funds of private companies, funds for specific projects from bilateral, multilateral organizations, civil society and non-profit organizations	**Output:** 1. % of population aware of campaign 2. Number of workshops conducted **Outcome:** 1. % population trained 2. % population implementing response actions 3. Number of people implementing response actions 4. Percentage of households connected to sewage system 5. Level of DO, phosphorous, nitrates, nitrites, faecal matter; level of sedimentation in freshwater and marine water bodies 6. Number of residents participating in public planning processes and public awareness events 7. Number and type of NGOs involved in city issues

[18] Based on annual workshop expenses of sewerage based on BMC's budget of 2020-21

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 6: Ensure disaster risk and impact reduction by strengthening early warning systems, data monitoring and integration and community engagement			
Priority Actions			
Strengthen data monitoring and ensure consistency to minimize the gaps in local weather forecasting and tidal changes for sea-level rise, while collaborating with private and non-governmental organizations. **Time Frame:** 2022 -2030	**Lead:** Disaster Management Department-BMC Supporting: India Meteorological Department, private meteorological organizations such as Skymet, ward-level officers	Part of Disaster Management Department budget (Mumbai, Budget Estimate Fund Code 11, 2021-2022), funds from regional organizations for setting up tidal gauge, State and National Disaster Management Programmes	**Output:** 1. Number of early warnings at city and ward levels for each hazard 2. Meteorological monthly data at ward level for 3. Tidal data (e.g., western coast) to monitor sea-level rise **Outcome:** 1. % of population reached through early warning systems for each hazard 2. % of heavy rainfall leading to landslides/ erosion/ flooding 3. Number of deaths from natural disasters per 100,000 population 4. Percentage of population vulnerable to natural hazards (e.g., excessive heat, droughts, flooding, landslides, earthquakes, cyclones)
Integrate past and future climate risks, trends and projections in planning for and implementing climate-proofing infrastructure - public and private, (e.g., SWD outfalls, residential / housing projects) **Timeframe:** 2022 -2030	**Lead:** Disaster Management Department-BMC, Environment Department-BMC **Supporting:** All infrastructure, housing, project development relevant departments, authorities constituted for special projects		**Output:** 1. Climate criteria as part of EIA & internal approval process 2. Dedicated data, norms and guidelines included in the feasibility, DPR, implementation plans **Outcome:** 1. Reduced losses (physical, financial and human) to infrastructure 2.% of assets protected in storm surge flooding 3. % of heavy rainfall leading to landslides/ erosion/ flooding 4. Number of deaths from natural disasters per 100,000 population 5. Percentage of population vulnerable to natural hazards (e.g., excessive heat, droughts, flooding, landslides, earthquakes, cyclones)

Action Description	Stakeholders	Funding/financing	Monitoring Indicators
Sectoral Action Track 6: Ensure disaster risk and impact reduction by strengthening early warning systems, data monitoring and integration and community engagement			
Priority Actions			
Empower vulnerable communities to better understand and integrate early warnings by ensuring diversity of language and technology in early warning systems. **Timeframe:** 2022 -2030	**Lead:** Disaster Management Department-BMC **Supporting:** Environment Department-BMC		**Output:** 1. % of population aware 2. Number of workshops conducted **Outcome:** 1. % population trained 2.% population implementing response actions 3. Number of people implementing response actions 4. Number of deaths from natural disasters per 100,000 population 5. Percentage of population vulnerable to natural hazards (e.g., excessive heat, droughts, flooding, landslides, earthquakes, cyclones) 6. Number of residents participating in public planning processes and public awareness events 7. Number and type of NGOs involved in city issues
Medium and Long-term Actions			
Integrate a nature-, ecosystem- and community-based approach in the overall disaster risk management of the city. **Timeframe:** 2022 -2030	**Lead:** Disaster Management Department-BMC **Supporting:** Environment Department-BMC		**Output:** 1. Reduced disasters and communities affected 2. Percentage of population vulnerable to natural hazards (e.g., excessive heat, droughts, flooding, landslides, earthquakes, cyclones) **Outcome:** 1. Reduced losses (physical, financial and human) to infrastructure 2. Number of deaths from natural disasters per 100,000 population

Sector-specific Inclusive Benefits

- Easy access to safe and affordable drinking water will help reduce the time spent on and the burden of procuring water, especially for the women and children in informal and low-income communities. This would also result in improved well-being and increased job opportunities.
- Improved access to toilet and sanitation facilities would result in an improved living environment and provide health benefits, especially to the women, young girls and children in informal, migrant and low-income communities.
- Low-cost nature-based solutions to address flood and landslide risks would reduce the vulnerability, particularly of the low-income areas, improve livelihood and create green job opportunities.
- Improved forecasting and emergency response mechanisms will help low-income communities and migrant and temporary workers living in informal communities and areas that are risk-prone to flood and landslides in early evacuation to temporary flood shelters. The focus needs to be on a gradual in-situ rehabilitation of these communities to safer locations.

Shot at Mahim Bandra Railway Track | By Pani Haq Samiti

BMC Head Office | By Satyajeet Mazumdar

Chapter 6: Governance and Institutional Structures

This chapter provides an overview of the existing governance structure of the city corporation and describes the organizational structure of the proposed Climate Action Cell with a dedicated climate budget, which will aim for the timely implementation of the MCAP.

6.1 The Existing Organizational Structure of BMC

The organizational structure of the BMC consists of a Deliberative wing comprising the elected representatives of the city and an Administrative wing that represents the bureaucratic profile of the government (see Figure 41). The two wings together are responsible for the overall administration of the city.

Deliberative wing

A total of 227 councillors are elected from each ward who form the Deliberative wing of BMC. These councillors elect, from amongst themselves, the mayor (called the first citizen of Mumbai) and the deputy mayor. The period of the Corporation is five years from the date of its first meeting, and the term of office of the councillors is co-terminus with the duration of the Corporation. There are six committees in the Deliberative wing. These committees perform the function of presenting proposals on behalf of their respective departments. The Standing Committee is the most important committee. It has a statutory role and consists of 36 members. It is entrusted with the responsibility of approving major projects and works costing more than INR 5 million.

Administrative wing

The Administrative wing headed by the Municipal Commissioner (MC) is responsible for developing and maintaining the civic infrastructure of the city, including water supply, roads, storm water drainage and the efficient delivery of various services to the citizens of Mumbai. There are four Additional Municipal Commissioners (AMC) – City, Eastern Suburbs, Western Suburbs and Projects. The AMCs are deputed in various departments. The projects or works with a budget range of INR 2.5-5 million require the administrative approval of the MC. The Deputy Municipal Commissioners (DMC) or Joint Municipal Commissioners (JMC) are appointed to assist the MC and AMCs in discharging their duties. The DMCs/JMCs administer the zones that consist of specific wards (zonal DMC) and manage the departments deputed through MC or AMCs. They are also responsible for approving the projects that have budgets up to INR 2.5 million.

The 24 wards within BMC are administered by Assistant Commissioners (AC) who report to the respective zonal DMCs. For executing any project or activity, the MC leads the coordination with external agencies, such as the MMRDA, MPCB, Western Railway, and the State Government, and is supported by the AMCs, JMCs and DMCs and other counterparts. At the ward level, for improved governance, BMC has developed the “advanced locality management” (ALM), which is a voluntary group constituted by a group of residents and commercial establishments for undertaking specific civic initiatives, such as waste segregation, processing and minimization, maintenance of green and open spaces and rainwater harvesting. It is similar to resident welfare associations formed in other cities across the country. The activities that are a part of ALMs are carried out in conjunction with BMC officials, including ACs, DMCs and AMCs.

Powers and capacities: The BMC works on implementation, maintenance, policy formulation and finance related to city provisions, such as water supply, sanitation, storm water drainage, sewerage, solid waste, roads, open spaces and public health. However, in the sectors of energy, regional transport, air quality and forest and mangrove conservation and restoration, the capacities of the corporation are limited.

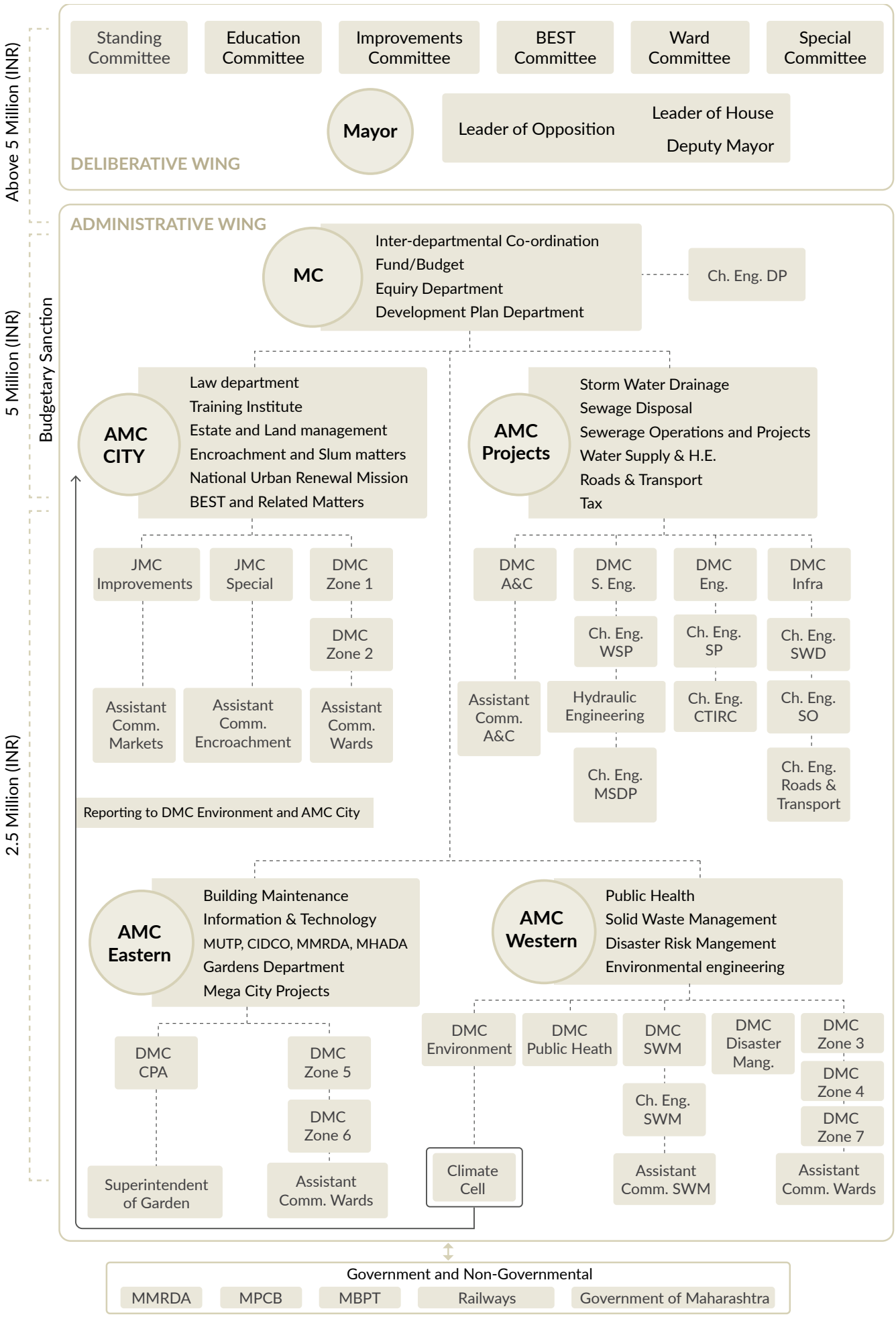


Figure *41: Organizational structure of the Brihanmumbai Municipal Corporation (BMC)*

Institutional Barriers

- BMC's institutional and governance structure is designed to carry out its functions related to key infrastructure, services and maintenance needs of the city. The central agency and ward level administration are focused on ensuring the timely implementation of sectoral and local administrative requirements of the city. However, to meet the complex and inter-connected challenges of climate change, strong inter-departmental coordination is required to achieve appropriate and desirable outputs.
- BMC is in charge of ensuring infrastructure implementation and service delivery across sectors such as water supply, sanitation, storm water drainage, sewerage, solid waste, roads, open spaces and public health. The effective implementation of MCAP will require the mainstreaming of climate actions in the existing priorities of the departments, project plans and future proposals.
- Several sectoral priorities, such as decarbonizing of the energy grid, large-scale forest and mangrove restoration, and a move to low carbon and accessible transport, fall in the jurisdiction of Central and State agencies, limiting the scope of BMC in influencing planning, decision-making and monitoring. For example, energy is supplied in the city by the State Energy Department, with several sub-entities entrusted with generation, transmission, distribution and tariff regulation. If the city plans to expand its renewable energy supply, it will need to work in conjunction with the State government as well as various sub-entities. Similarly, for making travel seamless while moving towards low-carbon transport, BMC will need to work with multiple external agencies responsible for different mediums and aspects of transport.

The Goals and Actions Proposed in the MCAP Fall in the Purview of Different Departments, as Listed in Table 28 Below:

Table 28: Existing list of line departments and other agencies as per priority action areas

Energy & Buildings

(A) The function of energy generation and distribution lies with DISCOMS. There are four public and private DISCOMS operational in Mumbai.

(B) The Building Approvals Department enforces building byelaws that determine light-ventilation standards, building materials, open space requirements and offset norms in all buildings across land use.

(C) The DP Department enforces land use zoning guidelines and Development Control Regulations.

Sustainable Mobility

(A) Public transport in Mumbai is operated by various agencies. BEST operates buses, MMRDA operates the metro and mono rails. Western Railway and Central Railway manages the respective Suburban Railway lines.

(B) RTO is under the Transport Ministry that is headed by the Transport Commissioner. The RTO is the regulatory authority for vehicle licenses, taxi and autorickshaw licenses and vehicle regulations, scrapping of old vehicles among other responsibilities.

(C) The State Transport Authority oversees licensing and enforces vehicle safety norms.

(D) Private bus and taxi fleet operators are key stakeholders

(E) Traffic police regulates traffic flow, road safety and on-street parking

(F) BMC's Road & Traffic Department builds and maintains roads, plans and enforces traffic management regulations, and undertakes O&M and revenue collection from off-street public parking lots.

(G) Off-street parking norms are set by the DP Department as part of the Development Control Regulations (DCRs).

(H) Mumbai Parking Authority is being formed to oversee all parking norms, enforcement and revenue collection.

Sustainable Waste Management

(I) BMC's SWM Department provides a daily door-to-door garbage collection service across Mumbai.

(J) This Department manages the garbage dump yards in the city, sets segregation, recovery and recycling policies, and enforces segregation norms in private buildings and commercial development.

Urban Greening & Biodiversity

(A) BMC's Garden's Department develops and maintains public spaces and is responsible for tree planting on avenues and in urban forests.

(B) There is a biodiversity committee set up to protect and conserve Mumbai's flora and fauna.

Urban Flooding & Water Resource Management

(A) BMC's Hydrology Department is responsible for water supply, water conservation and rainwater harvesting measures at the building level.

(B) DP Department sets building byelaws for rainwater harvesting and other water conservation and percolation systems to manage flood water on private plots.

(C) Storm Water Drainage Department builds infrastructure (along roads, rivers and coasts) to manage flood water and ensures flood risk mitigation.

(D) Mumbai Sewage Disposal Project (MSDP) builds, operates and maintains sewage treatment plants and ensures wastewater treatment.

Air Quality

(A) Air pollution is monitored by MPCB, SAFAR and BMC stations.

(B) Air quality measures are planned by BMC's Environment Department under the NCAP and enforced by MPCB.

(C) The associated projects to increase ambient air quality are implemented by the respective Departments, such as Garden (increasing greening), State Transport (improved traffic management) and SWM (C&D waste and other solid waste).

Given the institutional set-up of the city and its limitations, there is a need for a dedicated department within BMC that would be responsible for the implementation of MCAP, timely updates to the inventory, assessments and revision of the CAP. In this context, BMC has decided to expand the Environment Department to the Department of Environment and Climate Change. This department will be responsible for ensuring science-based planning and decision-making, encouraging innovation and tracking progress of key targets and outcomes of the MCAP.

Stakeholder Consultations for MCAP at BMC | By Prutha Vaze

6.2 Proposed Department of Environment & Climate Change

The Department of Environment is the nodal coordinating agency for the MCAP, alongside other related projects and initiatives such as MVA, Women for Climate, Cities4Forests, NCAP and sustainable development projects under the 15th Finance Commission fund. It is, therefore, important to create a climate action cell within the Environment Department. However, the Environment Department is currently not empowered to mediate/ coordinate across other departments, advise on key amendments to statutory regulations and liaise with parastatal agencies as per the city's needs. The existing department is an environment protection and enforcement body to control pollution, rather than a planning department to implement the MCAP.

The Department of Environment will be expanded and strengthened and renamed as the Department of Environment and Climate Change following official protocol. It will continue to report to AMC City, designated as the Nodal Officer for MCAP and be headed by the DMC, Environment & Climate Change. This department will be supported by the State Government of Maharashtra, and the Maharashtra Council for Climate Change. Additionally, a group of honorary advisors (which can be expanded as the plan progresses) will support the Department of Environment and Climate Change for the effective implementation of the MCAP. This department is created with five objectives:

1. To introduce new technical capacities within the corporation that is currently staffed with professionals who are trained to execute engineered projects;
2. To introduce innovation – use of SMART technologies, locally-led solutions, artificial intelligence and machine learning (AI/ML)-based service delivery and urban management – in meeting climate targets;
3. To coordinate across departments within the corporation and mainstream climate resilience in existing and proposed projects;
4. To develop stringent guidelines for new infrastructure or building projects that align with climate goals and encourage line departments to use these for project approval and to ensure regulatory enforcement;
5. To monitor MCAP progress, close data gaps, evaluate outcomes and report on targets at city and local levels

Considering the nature of work carried out in the city, the existing institutional arrangement of the corporation is based on addressing engineering and technical aspects. Given the context of climate uncertainties and an evolving environment of risks and challenges in the city, it is prudent to introduce more planners, social scientists and data analysts to meet these challenges. Officials with diverse qualifications can introduce holistic solutions that integrate traditional service sectors to meet the objectives of the Climate Action Cell (CAC). Figure 42 illustrates the proposed institutional structure of the CAC.

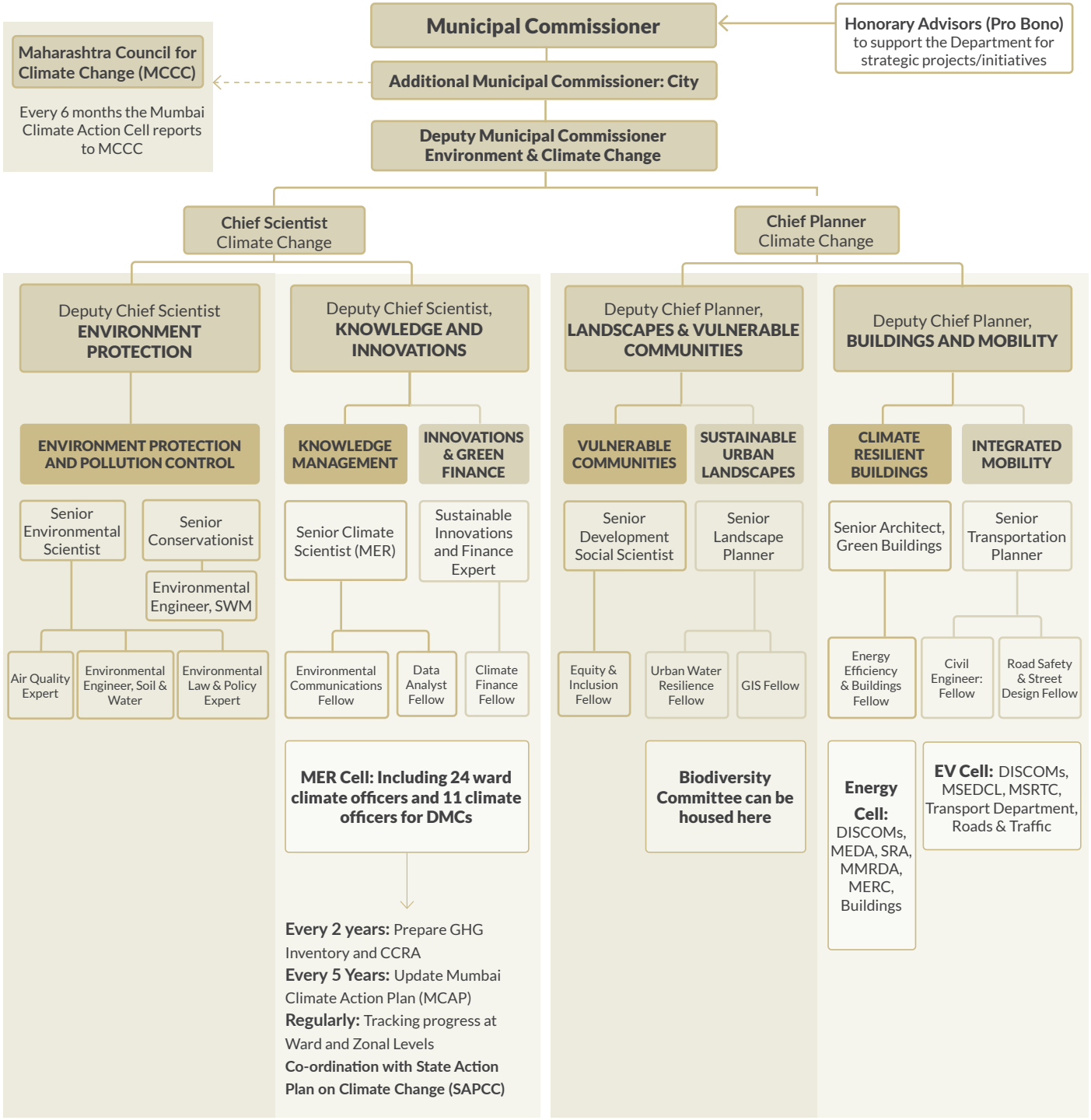


Figure 42: Proposed climate action cell

In addition to the existing function of environment protection and pollution control, the CAC will have **six Chief and Deputy Chief positions and six senior professional positions leading other functions.** The Cell will be headed by a Chief Scientist and a Chief Planner. Two Deputy Chief Scientists who will report to the Chief Scientist will be responsible for environment protection and pollution control, knowledge management and innovations and green finance. Two Deputy Chief Planners reporting to the Chief Planner will be responsible for sustainable urban landscapes, vulnerable communities, climate-resilient buildings and integrated mobility. They will be supported by six experienced professionals – Senior Climate Scientist, Sustainable Innovations & Finance Expert, Senior Landscape Planner, Senior Development Scientist, Senior Architect and Senior Transportation Planner. These senior professionals will be supported by junior professionals having expertise in urban water resilience, GIS, civil engineering, climate finance, data analysis, equity & inclusion, energy efficiency & green buildings, road safety & street design and environmental communications. Table 29 presents a summary of the functions of the Department of Environment & Climate Change (CAC).

Table 29: Staffing Plan in Climate Action Cell

Staffing Plan: Roles and Responsibilities

Environment Protection and Pollution Control

- The Department will work towards improving information on **air pollution** through robust consistent monitoring.
- The Department will monitor and reduce water pollution and work towards restoring aquatic ecosystems (with MSDP).
- The Department will monitor and work towards preventing soil and groundwater pollution by reducing landfilled waste and remediation and scientific management of existing landfills (with SWM Dept).
- The Department will work towards synergizing the MCAP with other initiatives such as MVA and NCAP.
- The Department will be responsible for conducting environment impact assessments and coordinating with MPCB.

Sustainable Urban Landscapes

- The Department will address heat and flood risk mitigation through NBS and other hybrid infrastructure, design and planned landscape projects.
- The Department will address water and soil pollution and environmental degradation through NBS.
- The Department will recommend changes in existing pollution control norms and better solid waste management, sewage operations and disposal.
- The Department will coordinate with other departments of BMC – Storm Water Drainage, Hydraulic Engineering, Gardens Cell, Solid Waste Management, Sewage Operations and Sewage Disposal.

Climate Resilient Buildings

- The Department will address demand-side solutions for energy conservation by meeting Mumbai's energy efficiency goals for all buildings by 2030.
- The Department will introduce DCR amendments, enforce green building norms for new buildings, and introduce guidelines and trainings to ensure passive architecture and passive cooling is integrated and enforced as part of building approvals.
- The Department will coordinate with Development Planning and Building Approvals within BMC and DISCOMS and other stakeholders.

Integrated Mobility

- The Department will address the mobility needs of city residents and workers with an integrated approach, ensuring land use and DCR recommendations wherever appropriate.
- The Department will identify priority "issues" or goals/targets laid out in MCAP and coordinate across all parastatal agencies to ensure a human-centred approach to mobility planning in the city.
- The Department will adopt AI/ML technologies to increase efficiency, increase access and equity in underserved neighbourhoods, and influence travel behavior.
- The Department will introduce finance tools to ease the transition to EV or clean fuel technologies by ensuring easy low-interest loans, etc. to assist IPT operators and freight to transition to low-carbon vehicles.

Vulnerable Communities

- The Department will commission community resilience assessments in vulnerable areas to understand the needs of residents.
- The Department will work closely with ACs and ward-level climate action officers to develop community resilience action plans at the local area level, address infrastructure and service delivery gaps and downscale DRR protocol to best fit community needs.
- The Department will work closely with SRA, MHADA and other planning agencies influencing housing design and allocation to ensure resilient infrastructure is built.
- The Department will work closely with the informal or formal labor groups employed in high-risk or vulnerable workforces (such as auto/taxi drivers exposed to heat risk and construction labor) and unhoused populations to address their adaptation needs.

Innovations & Green Finance

- The Department will maintain a repository of solutions, technologies and tools to integrate the right solutions with the right projects or plans within the cell (similar to the GoI's AGNI mission that brings local solutions to meet local needs).
- The Department will work with other departments within the CAC and across BMC to identify needs and challenges and connect the right solutions.
- The Department will work towards leveraging green finance to increase the overall finance pool, attract cutting-edge innovations and help channelize CSR/philanthropic funding and public private partnerships.
- The Department will also host a sustainability tech-fest to promote solutions and technologies to meet Mumbai's climate and equity goals.

Knowledge Management

- The Department will be responsible for the creation of the MER Cell, which will monitor the progress of MCAP implementation to meet targets, evaluate outcomes and report on KPIs.
- The Department will have 24 climate action officers (one for each ward) and 11 climate action officers (one for each DMC office) to track progress and report this in the central Monitoring Information System.
- This division will work closely with the DMC-Environment, AMC-City, and MC office to prepare a budget plan for each financial year, based on intended targets and progress made.
- The MER Department will lead the biennial GHG inventory and climate risk assessment update (next scheduled for 2023), and prepare an MCAP progress report every five years.

Reporting

Aligning the MCAP with the State Action Plan on Climate Change is critical to overcome the institutional barriers in the implementation process. It is also essential for the Department of Environment & Climate Change to report to the Maharashtra Council for Climate Change once a year to track the progress and request support for further implementation, especially in sectors such as transport and energy. Further, depending on the requirement, either AMC City or DMC Environment along with either Chief Officer Environment & CC and/ or respective vertical head can report to the Maharashtra State Steering Committee for Climate Change.

The MCCC is chaired by the Chief Minister of the State, co-chaired by the Deputy Chief Minister, and consists of ministers from the Government of Maharashtra Cabinet. It is meant to further climate change adaptation in the state, and can support BMC in meeting the vision/goals of the MCAP. At the state-level, the MCAP will also inform the revision of the SAPCC and be a lighthouse for other cities in the state that are part of the Race to Zero campaign. The State Steering Committee on Climate Change is responsible for supporting the implementation and periodic evaluation of the State Action Plan and the Climate Change Innovation Program initiated by Government of India. It will provide timely guidance and review on Climate Change related work in the state, and help secure funding and green finance for climate change related issues/initiatives at the national and international level. This Committee is chaired by the Chief Secretary to the Government of Maharashtra, and comprises of Principal Secretaries from different departments. It will also support BMC in furthering the vision of the MCAP.

Shot at Marine Drive | By Satyajeet Mazumdar

6.3 Creating a Climate Budget for Mumbai

Currently the procedures for formulating the Municipal Budget in BMC are initiated within respective Municipal Departments, headed by the DMCs in the Administrative Wing. Budget amounts of INR 2.5 million and less is approved by DMCs, budget amounts of INR 2.5-5 million are approved by AMCs and budget amounts more than INR 5 million require an approval from the Standing Committee of the Deliberative Wing of BMC.

Figure 43 shows budget estimates by department and type of projects, based on the 2020-21 BMC budget plan. (Only those departments/projects have been extracted here that align with potential climate action projects). Identifying the existing governance structure and budgetary allocations by departments will help align climate actions with specific departments for the CAC to coordinate.

Department	Budget Allocated (in Thousands INR)
Roads & Traffic	19 million
Garden & Recreation	3.8 million
Development Plan	7.9 million
Mechanical & Electrical	1.2 million
Storm Water Drains	11.6 million
Transport	3.8 million
Solid Waste Management	26.1 million
Disaster Management Cell	0.5 million

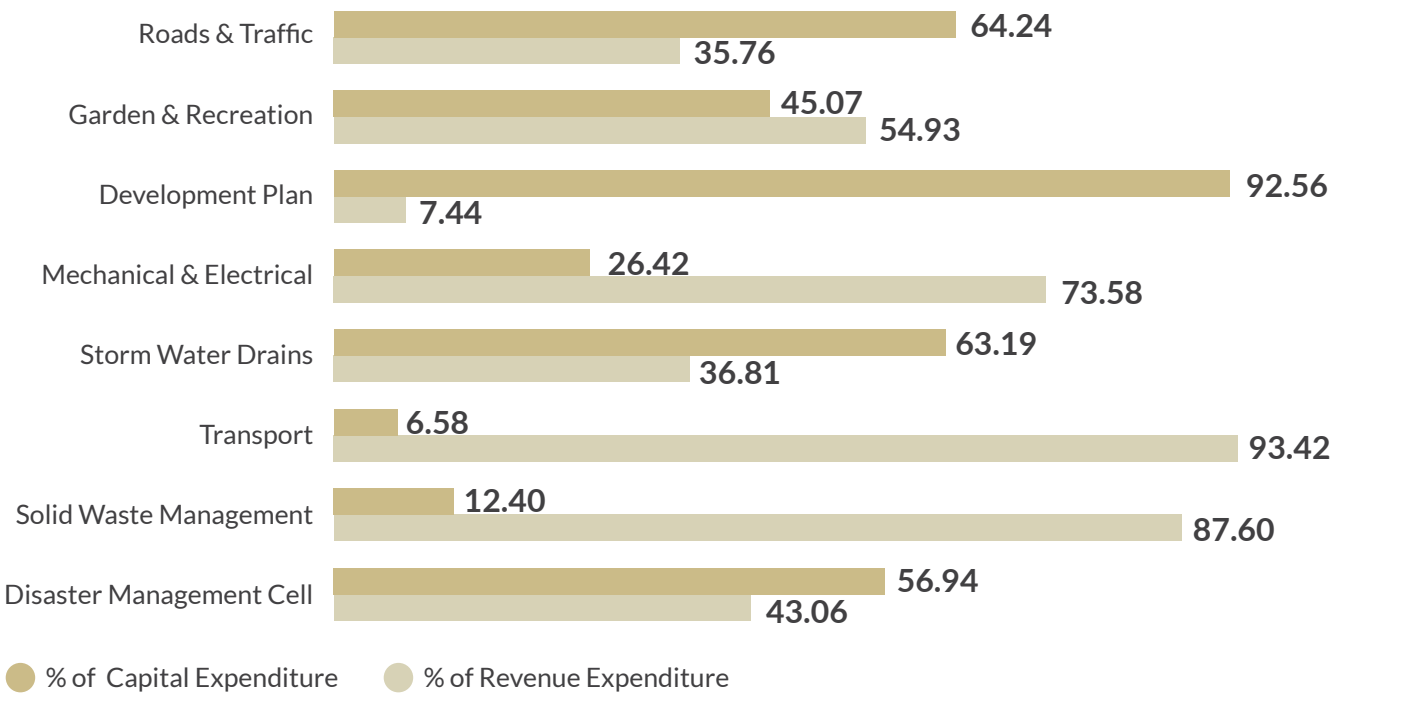


Figure 43: *Department-wise percentage of estimated cost of project works in BMC (Source: Budget Estimates of BMC, 2020-21)*

Need for a Climate Budget

Mumbai is one of the 11 cities participating in the climate budget pilot program of C40, which is being led by the City of Oslo. Indicative financial resources have been identified in the plan, and a proposed budget of INR 10 million has been set aside to create the CAC and identify projects for implementation over the next financial year. This includes BMC's budget; funds under Majhi Vasundhara, other state and centrally sponsored schemes and programs such as Swachh Bharat Mission – Urban, AMRUT, FAME II and NCAP; sector-specific agency budgets such as MEDA, which is the state designated agency (SDA) to improve RE, EE and ECBC in Maharashtra; green bonds; funds from 15th Finance Commission; international developmental funds such as GCF; CSR funds; and multilateral finance. The climate budget will build on the technical analysis that was undertaken while developing the GHG inventory, future emission scenarios and strategies suggested in the plan.

A climate budget is essential for Mumbai to ensure that dedicated financial resources are available to implement MCAP 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 BMC and prioritize activities that are directly under BMC's control, the CAC and the climate budget will ensure 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 2022-23 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 Monitoring, Evaluation, Reporting and Learning (MERL) process laid out in Chapter 7.

Oslo is leading C40 Cities' Climate Budget Pilot

Since September 2021, C40 has been supporting and connecting a group of cities interested in investigating, developing, implementing and improving the use of a climate budget to tackle GHG emissions. Led by the city of Oslo, the pilot includes Barcelona, Berlin, Los Angeles, Milan, Montreal, Mumbai, Stockholm, Paris, Rio de Janeiro and Tshwane. These cities will explore different approaches to climate budgeting in their unique contexts.

Mumbai Local Train | By Animesh Bhargava

Shot at Brabourne Stadium, CCI | By Mukta Salunkhe

Chapter 7: Tracking Progress

The implementation of a climate action plan should be followed by continuous Monitoring, Evaluation, Reporting and Learning (MERL) of its progress. MERL allows for actions to be tracked, evaluated and reported in an organized manner to promote accountability in implementation and make improvements based on the learnings. Monitoring is essential for tracking the progress of actions through continuous, systematic data collection, evaluation is important for assessing the impact of actions, while reporting and learning enable transparency and data-driven accountability amongst various stakeholders.

7.1 Monitoring

There are seven verticals in the Department of Environment & Climate Change in BMC. One of these is Knowledge Management which will house the MERL cell, with a team of 24 climate officers (each representing the 24 administrative wards) and 11 departmental MER analysts, each linked with one DMC office within BMC. The MERL cell will be led by the Chief Scientist who will report to the DMC-Environment and the AMC-City. The MERL cell will conduct a biennial update of the GHG inventory and the climate risk assessment. Once in five years, it will monitor the progress of MCAP against the targets set in the plan, report on a list of key performance indicators and communicate progress against indicators and develop a system to reflect learnings against the key objectives and principles of the MCAP. BMC will create the MERL cell in the current year, i.e., 2022 and set up a committee to update the GHG inventory in 2023.

To track progress, key performance indicators (KPIs) have been identified, which relate to the outcome indicators for each of the six priority action areas.

Energy and Buildings

Table 30: Key Performance Indicators for priority actions

Action Area	Key Performance Indicators
Increasing renewable energy in the grid	No. of MW renewable energy capacity installed within city boundaries, percentage of renewable energy in the grid mix Percentage of low-income population with electrical service supported by renewable energy
Energy-efficient infrastructure	Energy savings in buildings per year (MWh per annum) Percentage of monthly income spent on energy costs
Green buildings	No. of ECBC-compliant buildings
Passive design and thermal comfort	Amount of MWh energy demand for cooling in buildings (in low- and high-income areas) Availability of climate-resilient affordable housing

Sustainable Mobility

Action Area	Key Performance indicators
Public transport	Annual no. of public transport trips per capita (disaggregated by gender and income level), percentage of mode share Percentage of population within 500m walk of public transportation option (e.g., bus, metro, light rail)
Non-motorized transport	No. of km of walking and cycling infrastructure, % of mode share
Cleaner fuels	% of CNG or electric vehicles in the city, decreasing total annual fuel consumption from transport
Sustainable freight	% of low-carbon road freight Percentage of monthly income spent on transportation/delivery costs

Sustainable Waste Management

Action Area	Key Performance indicators
Waste minimization and reduced disposal	Waste generated per capita (kg/person/year) % of waste diverted away from landfills
Decentralized waste management	% of solid waste that is recycled, ward-level segregation rate (%), no. of green jobs created, percentage of population with regular solid waste collection at home
Dumpsite remediation and scientific disposal	Area of waste disposal site recovered/reclaimed (m^2), surface of urban land that is contaminated

Urban planning, green cover and biodiversity

Action Area	Key Performance indicators
Increasing green cover and permeable surfaces	Per capita green space (in high- and low-income areas), annual tree census, per capita open space (in low- and high-income areas), volume of water retention capacity created (m^3), percentage of residents within a 5-minute walk to a park
Heat resilience	Mean land surface temperature (across wards with different income levels), no. of heat prone wards (disaggregated by income level), percentage of urban area that is asphalt or building
Biodiversity conservation	City biodiversity index

Air Quality

Action Area	Key Performance indicators
Improved air quality	Annual average for daily PM2.5, PM10, NO_2, SO_2, O_3 (ozone) concentration in µg/m^3, emissions (CO_2, PM2.5, NO_2) in key areas of the city (e.g., near hospitals, schools, care homes or low-income neighborhoods)
Data and monitoring	No. of monitoring stations installed per year, % of area/population covered by monitoring and modelling systems, no. of days above WHO pollutants recommendations
Health management	Mortality and morbidity rates due to air pollution (disaggregated by gender and income level)

Urban flooding and water resources management

Action Area	Key Performance indicators
Flood and disaster resilience	% of population trained to respond to the hazard risk, no. of flood risk zones, % of heavy rainfall leading to floods Percentage of population with access to early warning systems
Water conservation and access	% of water recycled, % of households with piped connection, % of households receiving treated water, non-revenue water loss

Data Management

During the process of developing MCAP, various data gaps came to light, which challenged the extent of correctness and representation of several recent sectoral challenges. Socio-economic data and demographic differences at ward level were extracted from Census of India 2011, knowing that conditions would have changed over the past decade. Information on the impact of climate change on jobs, livelihoods and housing security were referenced from reports and articles in the media due to lack of government data. Sector-specific data was accessed from government reports. For example, travel behavior and modal splits data was referenced from the Comprehensive Mobility Plan prepared in 2016, and, therefore, modal splits for the base year 2019 onwards were not available.

Monitored data used for the risk assessment – for air pollution, coastal risks and weather data – was irregular or available intermittently for some stations, restricting the correctness of models and the ability to estimate the projected risks that can influence accurate climate-resilient infrastructure projects. The MCAP process also revealed that Mumbai's planning authorities – BMC, MMRDA, SRA, MHADA and Mumbai Port Trust (MbPT) – do not integrate climate risks and weather-related information in their planning processes. As a coastal city, Mumbai must include coastal risk analysis in planning decisions; however, the Indian National Centre for Oceans Information Services (INCOIS) tide gauge data is not used by any department or agency. Instead, Mumbai Maritime Board's (MMB) modelled tide height data is used to predict high-tide timings and issue storm surge warnings during extreme weather events. Modelled data has limited accuracy in predicting future risk projections. It is, therefore, recommended that BMC integrate monitored data into planning and decision-making. The C40 cities climate data management framework (C40 Knowledge Hub, 2021) can be a starting point to evaluate the data maturity of the city and effectively monitor progress.

7.2 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 31. The evaluation process will involve all relevant BMC departments and administrative officers – BMC's CAC-MER Cell and Heads of Departments, City Engineers, and Assistant Commissioners – to evaluate the success of on-ground implementation activities. The process will be participatory, involving external stakeholders and impacted communities, such as community-based organizations (CBOs), NGOs, and research agencies, to improve MCAP's impact on improving the lives of vulnerable communities and ensuring inclusivity.

This process will help the city assess the inclusivity of actions and the equitable distribution of impacts. The results of the evaluation process will be published and reported to various stakeholders for enhanced transparency and participatory review. This, along with the updated climate risk assessment and GHG inventory, can be used to revise the baselines, targets and trajectories in MCAP to accelerate action.

Table 31: Sample reporting template for energy sector actions

Goal 1: Increasing the Proportion of Renewable Energy to 50% by 2030 and 100% by 2050 in Mumbai's Energy Mix

Amending building byelaws to promote integration of RE systems, such as mandatory solar water heater and rooftop solar for all building typologies, and defining thresholds in a way that buildings meet more than 25% of their energy needs from RE systems

Output Indicator	Target (date)	Current progress (date)	Source
% of energy in buildings met through RE	25% (2030)	15 % (2025)	Energy audit of municipal buildings (provide document)

Develop a GIS-based Mumbai solar map and framework, which can allow users to plan a PV installation on their roof and gather information regarding possible costs and potential savings

Output Indicator	Target (date)	Current progress (date)	Source
Development of map	Develop a GIS-based solar map and framework (2025)	In draft stage, available in the public domain for feedback (2025)	Draft report (source)

Develop a strategic renewable energy roadmap for Mumbai on how to achieve 100% RE target by 2050

Output Indicator	Target (date)	Current progress (date)	Source
% of RE in the grid	25% (2025)	15% (2025)	MEDA annual statistics 2025 (link)

7.3 Reporting

The climate cell, responsible for monitoring MCAP, will also ensure that the GHG inventory as well as the climate risk assessment is updated every two years, to understand the city- and sector-wide impacts of CAP implementation. These inventories will also monitor and report on residual emissions in meeting the 2050 net zero target. Every three years, the MER Cell (part of the Department of Environment & Climate Change) will prepare an MCAP progress report, evaluating three levels of indicators – 1) at an aggregate city level, as per table 30; 2) as per KPIs (from Table 31); and 3) as per outcome indicators listed across every action in the sectoral action plans (Refer Chapter 5). Table 32 presents a list of indicators proposed for aggregate city-level progress assessment; these can be revised and updated as per the department's decisions. Additionally, the MER cell will also prepare an updated MCAP every five years to keep the city focused on its intended net zero target for 2050.

Table 32: Proposed indicators for aggregate city-level progress assessment

Department
1. Total GHG emissions reduced – aggregate reduction across all actions in MCAP, which would result in emission reduction
2. Total green jobs created – aggregated green jobs created across all actions in MCAP
3. Total lives saved in vulnerable communities – estimated lives saved in risk-prone areas where adaptation actions are implemented
4. Overall community health improved – qualitative assessment of improved health in vulnerable/exposed communities
5. Total biodiversity gained – aggregate species increased (returned) or protected in the local areas of the city by implementing MCAP actions

* 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 (who are not technically qualified.

7.4 Conclusion

In the face of rising global temperatures and more frequent extreme weather events over recent decades, BMC has intensified its focus on combatting climate change and increasing the climate resilience of Mumbai. To this end, MCAP serves as a roadmap that outlines the city's strategies and actions to tackle this pressing global and local crisis.

MCAP builds on policies and plans developed at city, regional, state and national scales and aligns with the goals at global (SDGs) and regional (MVA) levels. The Development Plan 2034 was an integral planning document that provided the basis for MCAP analysis and future planning recommendations. The Department of Environment & Climate Change will continue to work with the DP Department towards policy reforms and regulatory amendments to mainstream climate actions within BMC's planning ethos. Other key policies and plans reviewed as part of the gaps assessment are presented in Annexure 2.

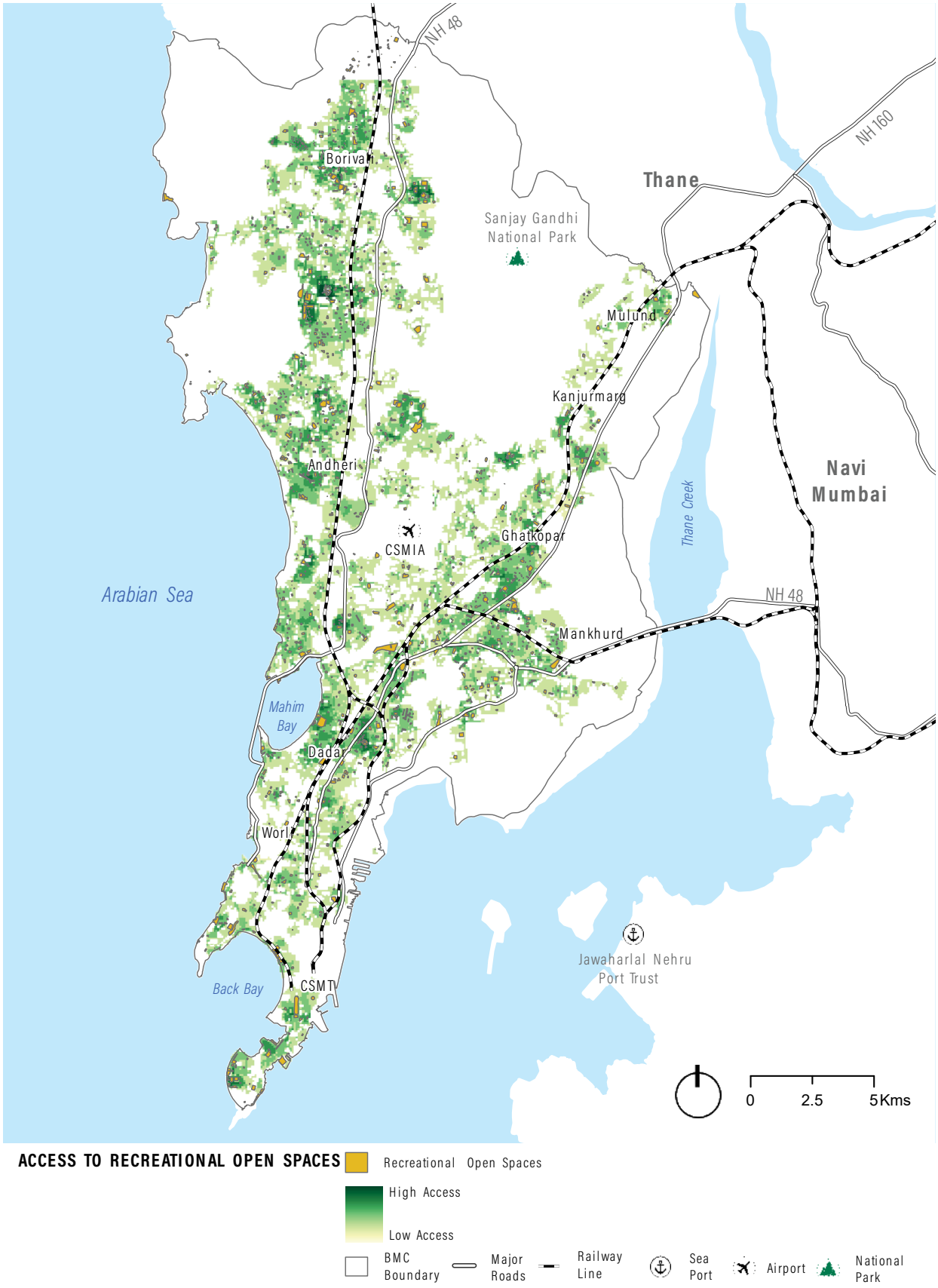
The MCAP process adopted a consultative and collaborative approach built on the contributions of several experts, CBOs, research institutions and private consultants. The process involved participation within BMC's departments and administrative wings at the zonal level, and in the future, will include suggestions and feedback from local political leaders to downscale climate actions to the local level. Annexure 3 includes a list of CBOs, NGOs, think tanks, consultants and research institutes that are invested and working in Mumbai and who can be engaged and consulted during the progress reporting and learning process of MCAP.

Finally, the success of MCAP is also dependent on the residents of Mumbai and their willingness to adopt sustainable choices in their daily lives to help achieve several MCAP targets. RWAs, ALMs, civil society groups and private investors are encouraged to participate, deliberate and catalyse the success of Mumbai's first ever climate action plan.

Shot in Worli | By Sahil Kanekar

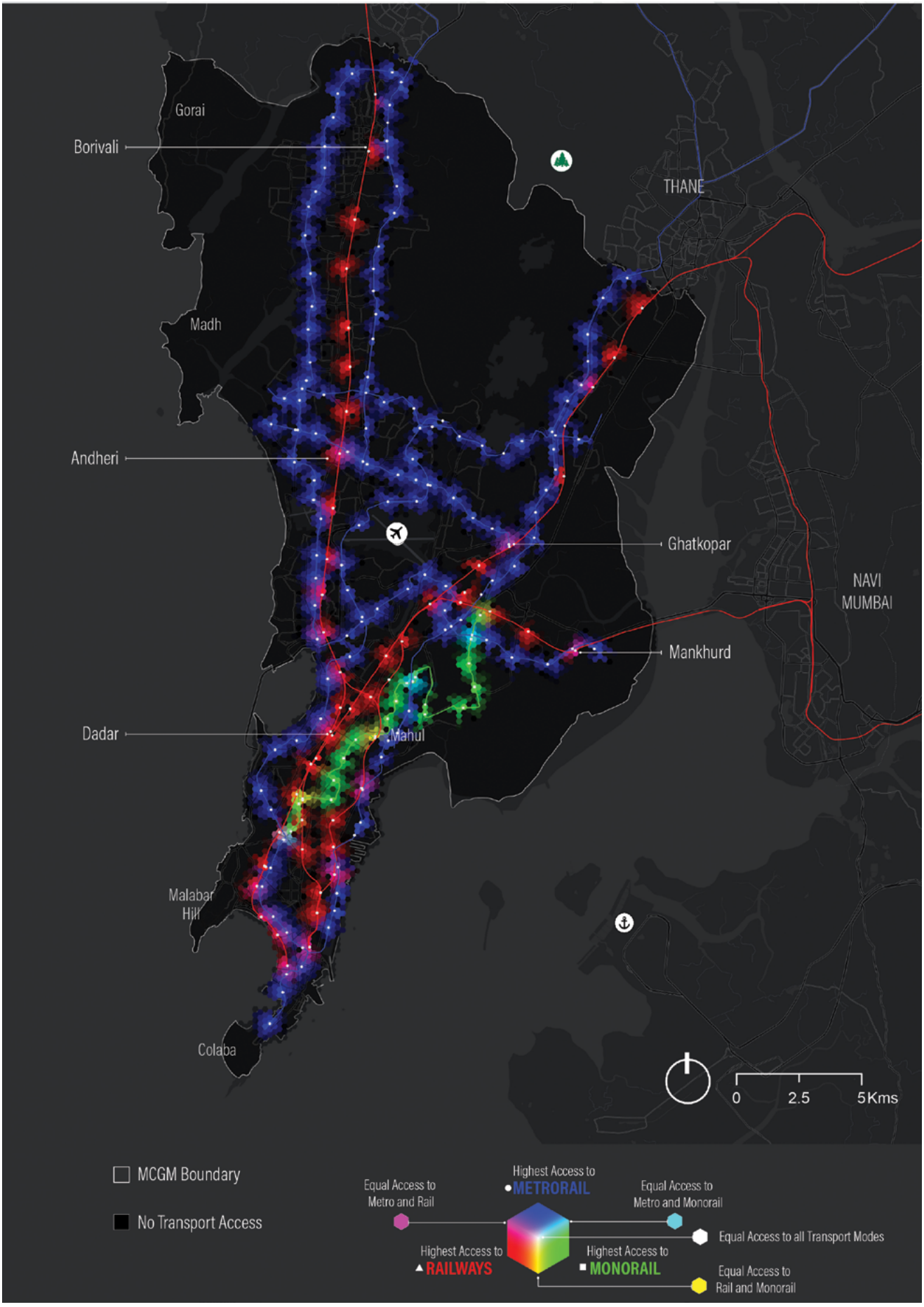
ANNEXURE 1

Annex 1.1: Figure 44 Map representing access to recreational open spaces within 1km walking distance



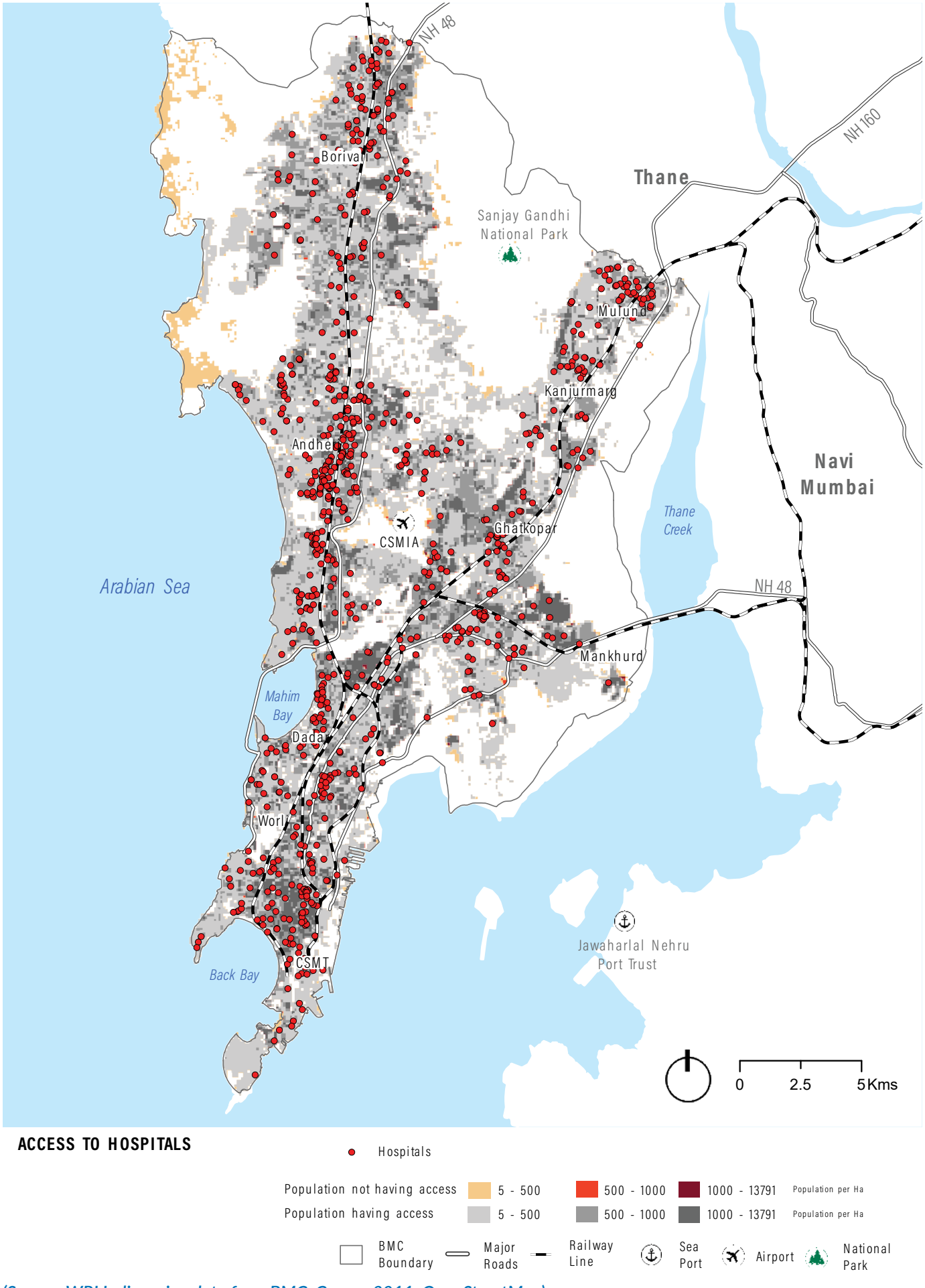
(Source: WRI India; using data from BMC, OpenStreetMap)

Annex 1.2: Figure 45 Map representing access to (existing and proposed) mass transit stations within 1km walking distance



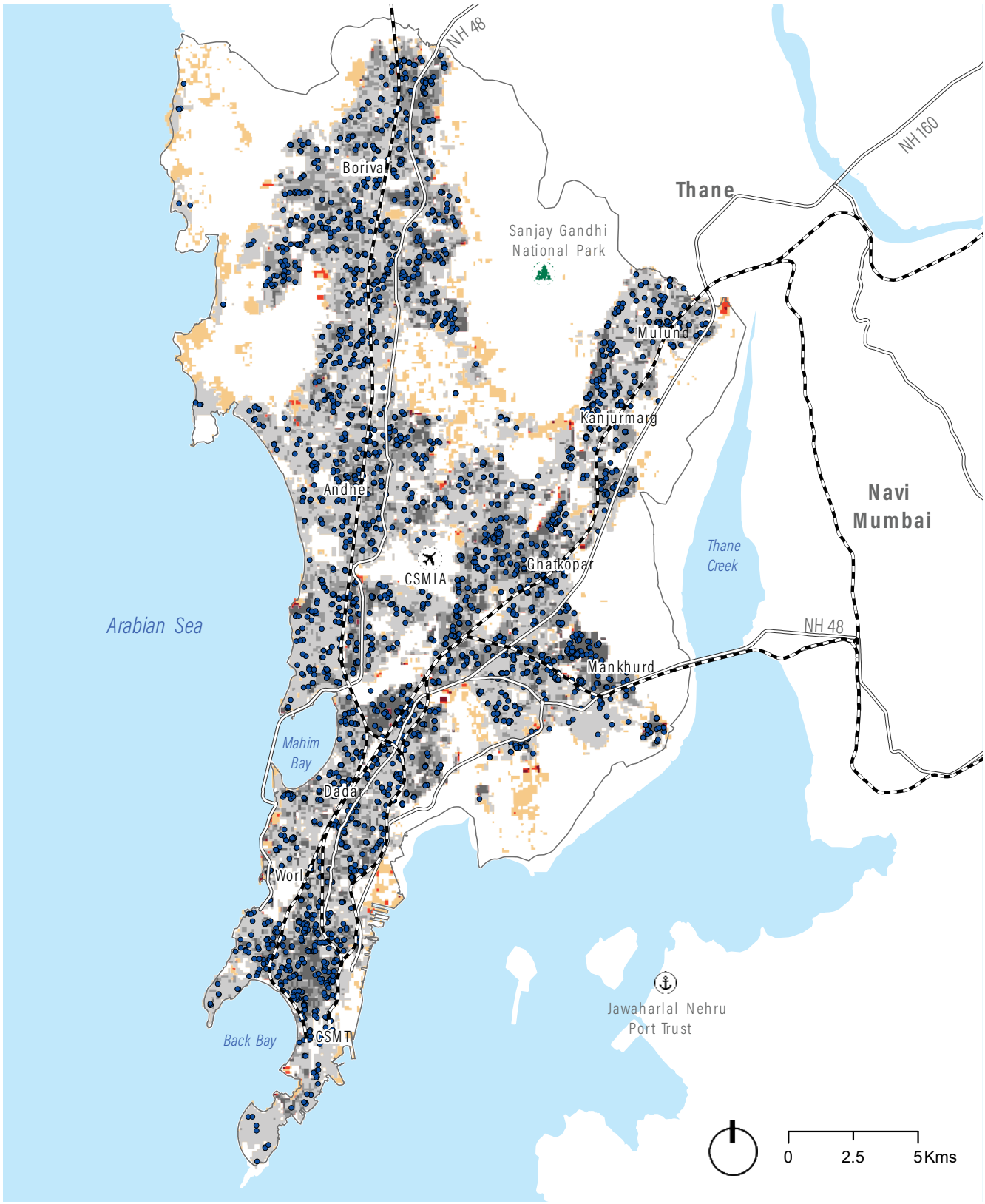
(Source: WRI India; using data from BMC, MMRCL, OpenStreetMap)

Annex 1.3: Figure 46 Map representing access to healthcare by population density



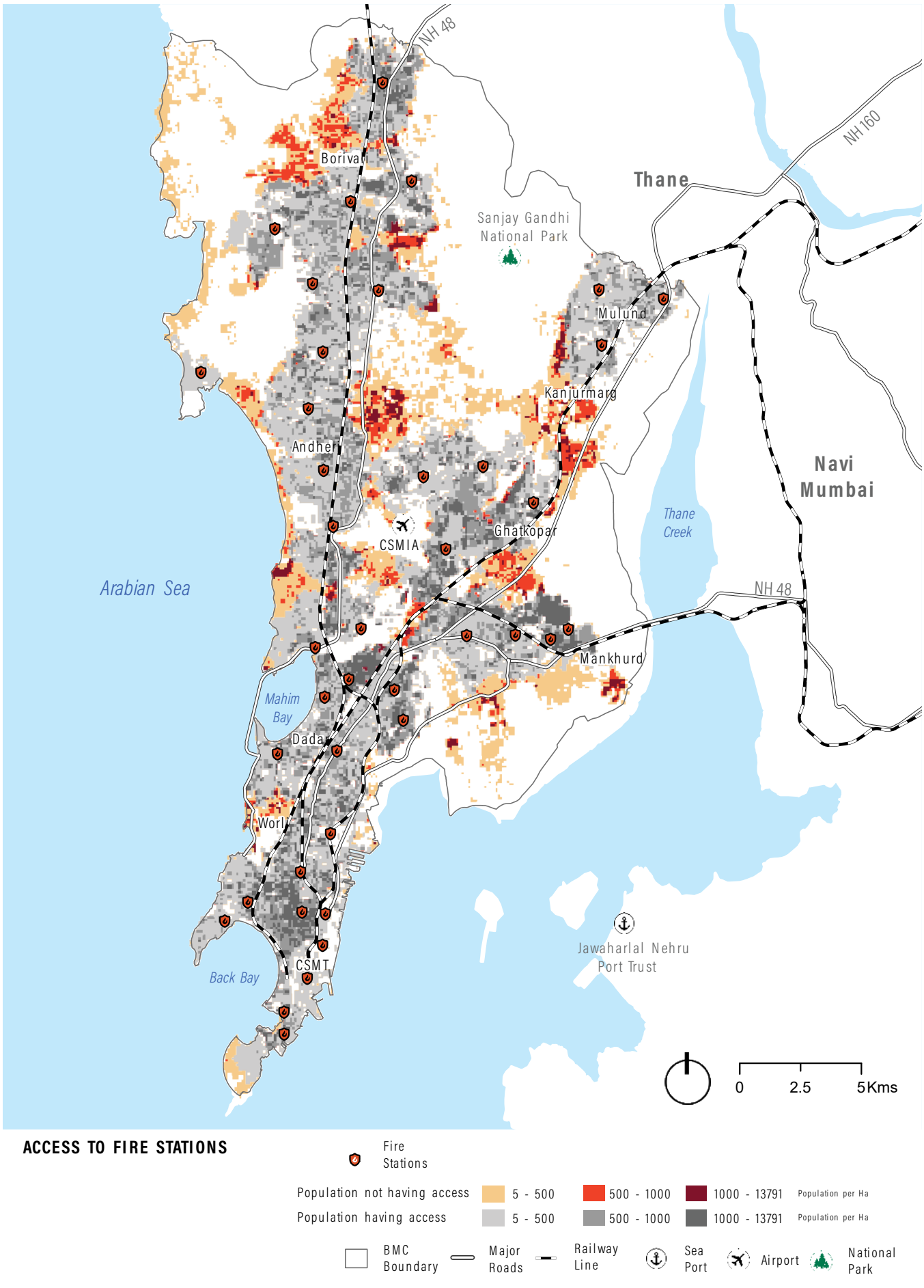
(Source: WRI India; using data from BMC, Census 2011, OpenStreetMap)

Annex 1.4: Figure 47 Map representing population living within 1km walking distance of educational institutions



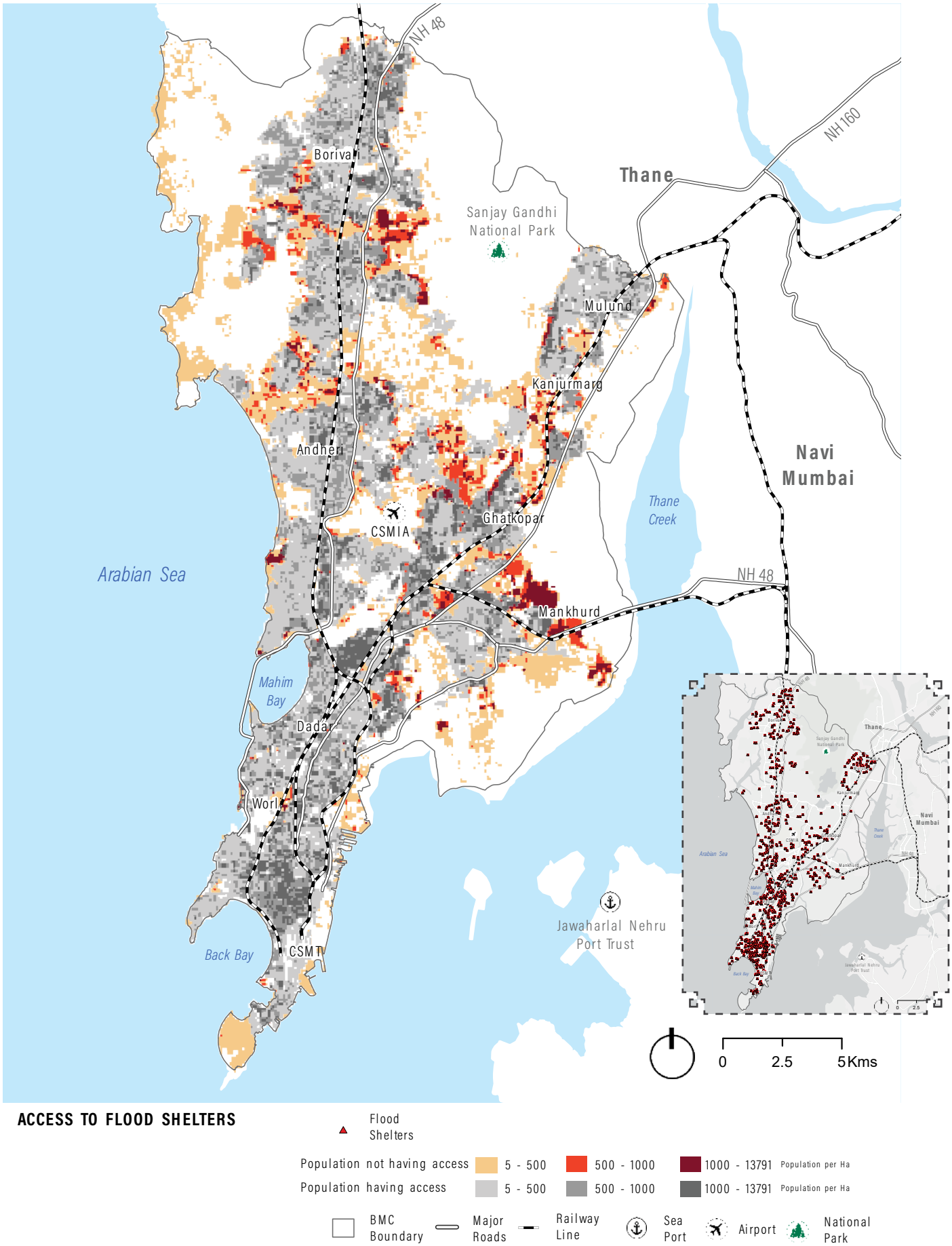
(Source: WRI India; using data from BMC, Census 2011, OpenStreetMap)

Annex 1.5: Figure 48 Map representing access to fire services within 5-minute response time across Mumbai



(Source: WRI India; using data from Google API, Census 2011)

Annex 1.6: Figure 49 Map correlating access to flood shelters with population density within 1km walking distance



(Source: WRI India; using data from BMC, Census 2011)

ANNEXURE 2

City-level Policies and Plans Reviewed During Gap Assessment

Cross-sectoral

1. Greater Mumbai Draft Development Plan (2014-2034)
2. Development Control Regulations for Mumbai Metropolitan Region (2016-2036)
3. Environmental Status Report of Brihanmumbai Municipal Corporation (annually)

Energy and Buildings

1. Energy Department, Government of Maharashtra
   - A. Net Metering Policy, 2015
   - B. Energy Conservation Policy, 2017
   - C. Renewable Energy Generation Policy, 2020
   - D. Green Tariff Policy, 2021

Sustainable Mobility

1. Brihanmumbai Municipal Corporation
   - A. Pedestrian first footpath guidelines, 2014
   - B. Comprehensive Mobility Plan, 2016
2. Transport Department, Government of Maharashtra, State Urban Transport Policy, 2017
3. Environment and Climate Change Department, Government of Maharashtra, Electric Vehicle Policy, 2021

Sustainable Waste Management

1. **Department of Environment and Climate Change, Government of Maharashtra**
   - A. Solid Waste Management Rules, 2016
   - B. Plastic Waste Management Rules, 2018
2. **Ministry of Environment, Forest and Climate Change, Government of India**
   - A. Construction and Demolition Waste Management Rules, 2016
   - B. E-Waste (Management) Rules, 2016
   - C. Hazardous and Other Wastes (Management and Transboundary Movement), 2016
   - D. Bio-Medical Waste Management (Second Amendment) Rules, 2019
   - E. Plastic Waste Management Amendment Rules, 2021
3. **Swachh Bharat Mission, Ministry of Housing and Urban Affairs, Government of India (2014 onwards)**
4. **Brihanmumbai Municipal Corporation**
   - A. Swachh Mumbai Prabodhan Abhiyan, 2013
   - B. Mumbai Solid Waste Management Plan (under development)

Urban Planning, Green Cover and Biodiversity

1. **Forest Department, Government of Maharashtra, Maharashtra Tree Protection and Conservation Act, 1975 – amendment in 2021 to include trees older than 50 years as heritage trees**
2. **Brihanmumbai Municipal Corporation**
   - A. Biodiversity Committee, 2020
   - B. Garden Policy (under development)

Urban Flooding and Water Resources Management

1. **Brihanmumbai Municipal Corporation**
   - A. Water Charges Rules and Sewerage & Waste Removal Rules, 2015
   - B. Mumbai City & Suburban Disaster Management Plan
   - C. Eco-housing program
2. **Ministry of Environment and Forests, Government of India, Environment (Protection) Act, 1986 for guidelines of water quality and common effluent treatment plants standards**
3. **Urban Development Department, Rainwater Harvesting norms under the Maharashtra Regional and Town Planning Act, 1966**

Air Quality

1. Maharashtra Pollution Control Board, Environment and Climate Change, Revised Action Plan for Control of Air Pollution in Non-Attainment Cities of Maharashtra - Mumbai, 2019

2. Ministry of Environment, Forest and Climate Change, Government of India

   A. National Clean Air Programme, 2019

   B. Bharat Stage Emission Standards, 2000 onwards

ANNEXURE 3

Stakeholder Consultations Conducted in the Process of Developing MCAP

External consultations

In these consultations, representatives from various research organizations, NGOs, community organizations and the private sector participated. The names of the participants are listed below:

Waste

Stakeholder Organizations Represented

- Jyoti Mhapsekar, Stree Mukti Sanghatana
- Monisha Narke, R U R Greenlife
- Kedar Sohoni, Founder, Green Communities Foundation
- Pramod Dabrase, Director, Centre for Sustainable Environment and Development Initiatives

Sustainable Mobility

Stakeholder Organizations Represented

- Ashok Datar, Chairman, Mumbai Environmental Social Network
- Zohra Mutabanna, Senior Urban Planner - Associate, IBI Group
- Sonal Shah, Founder, The Urban Catalysts
- Antony Samy, Co-Convenor, Aamchi Mumbai Aamchi BEST
- Shashank Rao, Leader, Autorickshaw Union
- Prachi Merchant, Senior Urban Planner, Tata Institute of Social Sciences
- Maxson Lewis, Managing Director, Magenta - ChargeGrid

Urban Greening and Biodiversity

Stakeholder Organizations Represented

- Stalin D., Director, Vanashakti
- Sucharita Roy, Head - Planning & Building, Aga Khan Agency for Habitat, India
- Dr. Shubhalaxmi V., Founder & CEO, Ladybird Environmental Consulting LLP
- Samarth Das, Architect & Urban Designer, P.K. Das & Associates
- Pankaj Joshi, Trustee, Urban Centre Trust
- Pradeep Tripathi, Founder & Executive Director, Green Yatra
- Debi Goenka, Executive Trustee, Conservation Action Trust

Air Quality

Stakeholder Organizations Represented

- Gufran Beig, Former Chief Scientist, IITM Pune SAFAR Project
- Ronak Sutaria, Founder, Respirer Sciences Pvt Ltd
- Anumita Roy Chowdhury, Research and Advocacy and head of the air pollution and clean transportation programme, campaigns for clean air and public health, Centre for Science and Environment
- Vijay Anadkat, Fellow, WRI India
- Bhagwan Keshbhat, Founder, Waatavaran Foundation
- Nitai Mehta, Founder, Praja Foundation

Energy and Buildings

Stakeholder Organizations Represented

- Ashish Fernandes, CEO & Lead Analyst, Climate Risk Horizons
- Sunil Dahiya, Analyst, Centre for Research on Energy and Clean Air
- Dr. Sunita Purushottam, Mahindra
- Nilesh Kane, Tata Power

Urban Flooding and Water Resource Management

Stakeholder Organizations Represented

- Professor Kapil Gupta, Indian Institute of Technology Bombay
- Rhea Shah, Kamla Raheja Vidyanidhi Institute of Architecture and Environmental Studies
- Subhajit Mukherjee, Mission Green Mumbai
- Sitaram Shelar, Pani Haq Samiti
- Amita Bhide, TISS
- Roshni Nuggehalli, Youth for Unity and Voluntary Action (YUVA)
- Nikhil Anand, Associate Professor of Anthropology, University of Pennsylvania

Internal Consultations

The dignitaries and representatives from various departments of BMC as well as other organizations had participated in these consultations to streamline and finalize the sectoral goals, targets and actions identified. A list of these organizations is given below:

Departments within BMC	Other Agencies
• Storm Water Drains • Gardens & Tree Authority • Hydraulic Engineer • Coastal Road • Sewerage Operations • Deonar Abattoir • Parking Authority • Building Maintenance • Development Planning • Environment Department • Mechanical and El ectrical • Solid Waste Management	• Mumbai Port Trust • Mumbai Metropolitan Region Development Authority • Central Pollution Control Board • Maharashtra Pollution Control Board • MMRDA Monorail • Mumbai Metro One Private Limited • BEST • Reliance Metro • Adani Electricity • C40 Cities • Tata Power • Maharashtra State Electricity Distribution Company Limited • Magenta Group • Environment Department, GoM

Zonal Consultations

The ward level consultations saw representation from Assistant Commissioners, assistant engineers from the ward level and zonal Deputy Municipal Commissioners from three districts. The wards represented by the participants are listed below:

Western	P/S ward, K/W ward, K/E ward, R/N ward, R/C ward. Kandivali east west ward, H/E ward
Eastern	N ward, T ward, M/East ward, M/W ward
City	C ward, F/N ward, E ward, F/S ward, G/N ward, P/N ward, M/W ward

ANNEXURE 4

Data Check List

Sector	Department	Data Points
Water Supply	Hydraulic Engineering	**1.** Water demand of the city in MLD & LPCD **2.** Water supplied to the city in MLD & LPCD **3.** Sources of water supply and their capacity **4.** Future sources of water supply to cater to the projected demand and their capacity **5.** The water quality standard that is maintained while treating the drinking water **6.** % of HHs having piped water connection **7.** % of HHs having 24x7 water supply **8.** Total water put into the transmission and distribution system **9.** Total water sold **10.** Electricity required to supply 1,000 litres of water by municipal authorities **11.** Energy consumed Per MLD water supplied over a year **12.** Annual electricity consumption of water supply management **13.** The Mumbai Water Supply Management Plan (No Water Supply Management Plan; got the Expert Committee Report on 'Towards Equitable and 24x7 Water Supply for Greater Mumbai) **14.** Map and location of the WTPs and the city-wide Water Supply Network (GIS and PDF layer) (GIS Shape files are not there with HE dept.) **15.** Changes in number of distributions of WTPs and total units of electricity consumed for water supply management over the years (from 2010-2020) (only the power consumption data for May 2021 against the substations have been shared, the other years' data are remaining) **16.** Total number of waterbodies in the city (2015-2020) **17.** Total area of waterbodies (2015-2020) **18.** Plans to conserve waterbodies, 2021 and onwards **Questions** **1.** Has the city carried out a study indicating stock of existing water resources and its uses for various sectors with projections? (Yes/No) **2.** Does the city have water resource management plan with actions? (Yes/No)

Sector	Department	Data Points
		3. Is the city on target to meet the future water demand (2035- 40)? (Yes/No) **4.** Has city considered climate change scenarios in estimating future water availability? (Yes/No) **5.** Has city conducted the Energy Audit including for water supply pumping stations and treatment plants? (Yes/No) **6.** What is the process of treatment of drinking water before releasing for transmission? **7.** How is the monitoring of the treatment of the water done? **8.** Does the City have a Water Supply Management Plan? (Yes/No) **9.** Does city prioritize rejuvenation and conservation of water bodies? **10.** Has city allocated any financial resources for rejuvenation and conservation of urban water bodies and open areas? **11.** Is the city reviewing and monitoring urban water bodies and open areas and maintaining rejuvenated/conserved water bodies and open areas?
Storm Water Drainage	SWD Planning Cell	**1.** Storm water drainage network – natural and artificial drainage network (with design details: length, volume, flow rates, outfalls, location of flood gates, etc.)
	SWD (O&M)	**2.** Length of covered drains and open drains **3.** Capacity of the present SWD network and how much should be the required capacity to accommodate flood-like situation **4.** Frequency of cleaning and desilting the nallahs, Mithi river and water bodies, and when is it done?
	SWD (M&E) Projects	**5.** Mapping of problem areas/sections within the storm water drainage network **6.** Map/spatial location of areas prone to water logging **7.** Map/spatial extent of flood-prone and affected areas **8.** Map/spatial extension of evacuation network paths (including road network map) **9.** Physical protective barriers to manage flooding/sea water intrusion: flood walls, embankments, dykes, MOSE gate, etc. **10.** % of widening and deepening of Mithi river that is completed **11.** GIS shape files of city-wide Storm Water Drainage Network with location of pumping stations and outfalls **12.** PDF files of city-wide Storm Water Drainage Network with location of pumping stations and outfalls **13.** Condition of the floodgates at the outfalls (number of floodgates and their maintenance condition)

Sector	Department	Data Points
		Questions **1.** How old is the present storm water drainage network? **2.** What is the process of cleaning and desilting of nallahs, rivers and waterbodies? **3.** Has city conducted a rapid flood risk assessment? (Yes/No) **4.** Has city prepared a flood risk mitigation plan? (Yes/No) **5.** Has city implemented the flood management plan? (Yes/No) **6.** Has city conducted a scientific hazard risk vulnerability assessment (HRVA) and included recommendations in the relevant plans? (Yes/No)
Sewerage and Sanitation	Sewerage Operations	**1.** Quantity of wastewater generated for the years 2010-2020 **2.** Process of treatment of wastewater and sewage **3.** Wastewater's source and its organic content – a. BOD (biochemical oxygen demand) concentration b. COD (Chemical Oxygen Demand) content **4.** Organic component removed as sludge **5.** Amount of methane recovered from the process of treatment of wastewater **6.** Treated wastewater recycled and reused in million litres per day **7.** Energy consumed per MLD of wastewater generated and treated **8.** Annual electricity consumption of wastewater management **9.** The City Sanitation Plan of Mumbai: i) Sewage Master Plan (1979-2005) and ii) MSDP (2005-2025) **10.** Number, location (map-wise) and capacity of proposed STPs and WWTFs **11.** Number and Location Map of existing STP and WWTFs **12.** City-level Zone Map based on the service coverage of each STP (GIS shape files) **13.** Map showing overall city-level Sewerage Network Map (GIS shapefiles) **14.** Process of treatment of wastewater and sewage **15.** Water quality standard maintained for treated sewage and waste water
	Sewerage Project	
	Mumbai Sewerage Disposal Project	
		Questions **1.** Where does the city re-use the wastewater? **2.** Has city conducted the Energy Audit including for wastewater pumping stations and treatment plants? (Yes/No) **3.** Does the city have any Sanitation Plan? (yes/no)

Sector	Department	Data Points
Solid Waste Managemen	Solid Waste Management Department	**1.** Total solid waste generated in Mumbai (annual average tonnes per day) – 2015 to 2021 <2010 – 2020> **2.** Based on the data submitted between 2015 and 2021, waste generation data has been decreasing in Mumbai – why/how is there a decrease? **3.** Waste generated by sector – residential buildings, commercial buildings & municipal buildings (2010 – 2020) **4.** Number of vehicles used for waste management by sector – residential buildings, commercial buildings & municipal buildings (2010 – 2020) **5.** Vehicle kilometres travelled by waste management vehicles (2010 – 2020) **6.** Fuel consumption (fuel sales data) for waste management vehicles (2010 – 2020) - petrol, diesel, CNG, biofuel, electricity **7.** Total waste processed through composting, waste to energy, biomethanisation RDF (total tonnes per annum) **8.** Total waste recycled, MRF – formal or informal (tonnes per annum) **9.** Total waste recovered and recycled (tonnes per annum) **10.** SCF/RDF utilized (tonnes per annum) **11.** Total Construction & Demolition (C&D) waste transferred to processing facility or designated dumping point (tonnes per annum) [No info available] **12.** Total C&D waste generated in city (tonnes per annum) [No info available] **13.** Total C&D waste transferred to processing facility which is converted to recycled products (tonnes per annum) **14.** Number, location and map of dumpsites/landfills in and around Mumbai **15.** Total waste sent to dumpsites/landfills (tonnes per annum) **16.** Type/condition of landfill/dumpsite (managed, unmanaged – deep, unmanaged – shallow, uncategorized) [Will make assumption] **17.** Waste composition (for calculating DOC) – fraction/percentage of waste by type (food waste, garden & park waste, nappies & sanitary waste, paper/cardboard waste, rubber & leather, textiles, wood, others) **18.** Methane recovered at landfill (flared or energy recovery) – Yes/No **19.** Quantity of waste treated through biological processes (composting/anaerobic digestion) **20.** Type of waste (wet/dry) **21.** Biological treatment type (composting/anaerobic digestion) **22.** Quantity of methane recovered from biological processing of waste

Sector	Department	Data Points
		23. Quantity of waste incinerated or burnt **24.** Type of treatment (incineration/open burning) **25.** Type of premises (stoker/fluidized bed – continuous incineration, semi-continuous incineration, batch type incineration) **26.** % of total domestic hazardous waste (menstrual waste/baby and adult diapers) collected (whether collected separately at source or received from MRF center) is treated, either by BMC or through third party managing biomedical waste (hazardous waste from hospitals, nursing homes/clinics/labs, etc. not considered) **27.** % of wet waste processed out of total wet waste collected **28.** % of dry waste processed out of total dry waste collected (excluding domestic hazardous waste) through MRF, RDF or W2E plants, etc. **29.** % of HH having individual toilet facilities [Directed by sewerage operations to SWM] **30.** % of HH catered by community toilets [Directed by sewerage operations to SWM] **31.** % of HH having soak pits [Directed by sewerage operations to SWM] **32.** % of HH practising open defecation [Directed by sewerage operations to SWM] **33.** Does the City have Waste to Energy Plants? (yes/ No), If yes, how many and their location map (MSDP directed the information to be taken from SWM department) **Questions** **1.** Does Mumbai have dedicated facilities for material recovery and SCF/Refuse Derived Fuel? (Yes/No) **2.** Does city practice scientific disposal of municipal solid waste? (Yes/ No) **3.** Does city landfill have Environmental Clearance (EC) from SEIAA or as applicable for the State? (Yes/No) **4.** Does the operation of landfills in Mumbai take place as per SWM Rules, 2016? (Yes/No) **5.** Has Mumbai planned for any scientific landfill/dumpsite closure along with post closure maintenance? (Yes/No) **6.** Has the city executed scientific closure of landfill/dumpsites and mitigation of landfill gas? (Yes/No) **7.** Has the city executed scientific closure, utilization of landfill gas and maintained the site post closure? (Yes/No) **8.** Has Mumbai converted any scientifically capped landfill/dumpsite into green space for public/multi-use after post maintenance period? (Yes/No) **9.** Is there any Dedicated storage and Collection Mechanism for C&D Waste in the city? (Yes/No)

Sector	Department	Data Points
		10. Is the city recycling & reusing Construction & Demolition waste? **11.** Has Mumbai undergone the Swachh Survekshan survey? If yes, please share report/findings **12.** Does the city have a solid waste management plan? (There is no SWM Plan) **13.** Is there a ban on the use, sale and storage of non-biodegradable plastic bags/products less than 50 microns, in compliance with plastic waste management rules 2016? **14.** Were there any initiatives undertaken in 2019-21 to reduce generation of dry/wet waste? If yes, share details **15.** Is there any on-site wet waste processing by non-bulk waste generators? **16.** How are Bulk Waste Generators managed? (i) doing onsite processing of wet waste generated, including kitchen and garden waste or organic waste or getting wet waste collected and processed by private parties authorized by BMC (ii) Handing over segregated dry waste to authorized waste pickers or waste collectors **17.** Does the capacity of dry waste processing facility/facilities match with the total dry waste collected in the city? **18.** What are the mechanisms in place to collect and process/reuse C&D waste as per C&D waste management rules, 2016? **19.** Has Mumbai considered remediation of all identified dumpsites, no legacy waste (dumpsite)/zero landfill city? **20.** Is the landfill in Mumbai a sanitary landfill?
Air Quality	Environment Dept	**1.** Ambient Air Quality levels for pollutants PM2.5, PM10, Ozone, NO_2, CO, SO_2, CO_2, NO_x, SO_x, NH_3 and C_6H_6 for the years between 2010-2020 (Only for the month of Nov 2020, Jan 2021 and Feb 2021 has been received) **2.** AQI values against different monitoring stations (2010-2020) **Questions** **1.** Number of Air Pollution/Quality Monitoring Stations and their locations **2.** Does city perform pollutant source identification and have a clean air action plan? **3.** Has clean air action plan been implemented? **4.** Is assessment of impacts of clean air action plan being done? **5.** Does the city monitor the basic pollutants (PM10, PM2.5, NO_x, SO_x as per Central Pollution Control Board Guidelines? (Yes/No) **6.** Does the city monitor the advance pollutants CO, VOC and O_3, etc. as per Central Pollution Control Board Guidelines? (Yes/No)

Sector	Department	Data Points
		7. Does the city demonstrate reduction trend/incremental improvements in compliance to NCAP targets? (Yes/No) **8.** Does city's air quality comply with National Ambient Air Quality Standards? (Yes/No)
Disaster	Disaster Management	**1.** Map/spatial location of areas prone to water logging **2.** Map/spatial extent of flood prone and affected area **3.** Map/spatial extension of evacuation network paths (include Road network map) **4.** Map/spatial location of landslide-prone and affected areas **5.** Study undertaken on landslides and slope failures in Mumbai **6.** CRZ Zones **7.** The latest Disaster Management Plan of Mumbai **8.** Types of calamities, their impact area, loss of lives and potential economic losses and loss of jobs (calamity-wise and sector-wise) from 2010-2020 (Only the peoples' lives lost data against the incidents are obtained) **9.** Different types of risks and their priorities **10.** BMC daily/ monthly rain gauge data (1969-2020) recorded against all the rain gauge stations of BMC **Questions** **1.** Has city conducted a rapid flood risk assessment? (Yes/No) **2.** Has city prepared a flood risk mitigation plan? (Yes/No) **3.** Has city implemented the flood management plan? (Yes/No) **4.** Has city conducted a scientific hazard risk vulnerability assessment (HRVA) and included recommendations in the relevant plans? (Yes/No)
	Mumbai Port Trust	**1.** Tide Level Data at one minute/hourly interval (2010-2020)
	Maharashtra Maritime Board	
	Indian Meteorological Department	**1.** Average Storm Surge Height (one minute interval/hourly interval) (2010-2020) (redirected to get the data from INCOIS) **2.** Frequency of Cyclones (2010-2020) **3.** Cyclonic pathways (2010-2020)

Sector	Department	Data Points
Climate	Indian Meteorological Department	**1.** Precipitation data from IMD – decadal trend since 1969 **2.** Temperature data from IMD – decadal trend since 1969 **3.** Humidity or dew point temperature data from IMD – decadal trend since 1969
Urban Planning	Developmental Planning Dept	**1.** Map of water bodies **2.** Map of open areas **3.** Map of green cover **4.** Existing land use management characteristics/land use map **5.** Total green cover in the city as a percentage of municipal area **6.** Total urban and peri-urban areas (including institutional lands) **7.** Population/Demography **8.** GDP of Mumbai and per capita income **9.** Total area of city **10.** Slum population in the city **11.** Metro rail network with stations **12.** Suburban railway network with station
Green Cover and Biodiversity	Garden and Tree Authority, Garden Cell	**1.** Map of open spaces (2020) **2.** Map of green spaces (2020) **3.** Location of trees and types (2020) **4.** Proposed green area increase after 2021, with upcoming projects and documents **5.** T otal green cover in the city as a percentage of total municipal area (2015-2021) **6.** Total mangrove cover in the city (2020) **7.** Total area of open forests [1] (2015-2021) **8.** Total area of scrub/grassland vegetation (2015-2021) **9.** Total area of wetlands (2015-2021) **10.** Total areas of urban and social forestry (improved & new) (2015-2021) **11.** Map of soil type and cover (2020) **Questions** **1.** Does the city prioritize conservation of open spaces? **2.** Has the city mapped open areas? What is the location of trees and types? **3.** Has the city allocated any financial resources for rejuvenation and conservation of open areas? **4.** Is the city reviewing and monitoring open areas and maintaining rejuvenated/conserved open areas? **5.** Has the city prioritized urban biodiversity management?

Sector	Department	Data Points
		6. Has the city established a city-level biodiversity management committee? **7.** Has the city conducted baseline assessment for urban biodiversity management? **8.** Has the city identified measures to increase the urban biodiversity with sufficient resources allocated for its implementation? If yes, has the city implemented the said measures?
Transport	**A.** Traffic department	**Data for 2020** **1.** Total road network map and length (data given in polygon form) **2.** Length of footpaths and cycle paths (km) **3.** Length of pedestrian pathways (km) **4.** Length of cycle lanes if any (km) **5.** Average vehicle kilometres travelled by cars, taxis – kaali peelis, autorickshaws, 2-wheelers, BEST buses **6.** Road congestion map/list **Questions** **1.** Is the city considering congestion pricing/new parking policies or any other measures to tackle congestion?
	A. The Brihanmumbai Electric Supply & Transport Undertaking **B.** Maharashtra State Road Transport Corporation **C.** Mumbai Bus Malak Sanghatana (private bus operators association) **D.** Cityflo (premium AC buses for office corporates)	**Data from 2010-2021 and onwards** **1.** Number of buses (segregated by clean fuels such as CNG, LPG, hybrid, biofuels, electric) in the city **2.** Number of privately operated buses (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city **3.** Electricity and fuel consumption for all the above buses **4.** Fuel efficiency and age of buses **5.** Number and distribution of EV chargers and/or battery swapping stations for buses **6.** Total public transport availability per 1000 people **Questions** **1.** Does the city have clean technology shared vehicles? **2.** Does the city have a robust public transport system? **3.** Does the city have any incentives for clean fuel public transport?
	A. OLA/Uber, Meru cabs, Mega cabs **B.** Ola research center **C.** Motor Vehicles Department – RTO	**Transport data (2010 – 2020) and 2021 and onwards** **1.** Number of taxis (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city **2.** Number of app-based cabs (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city

Sector	Department	Data Points
	D. Magenta Power | ChargeGrid | Mobility (charging infrastructure company) **E.** Strom Motors (startup in Mumbai for e-cars) **F.** Mumbai Metropolitan Region Transport Authority **G.** Mumbai Taxi Association	**3.** Number of app-based 2-wheelers (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city **4.** Number of auto rickshaws (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city **5.** Electricity and fuel consumption for autos, 2-wheelers, taxis and cabs **6.** Number of private 2-wheelers (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) **7.** Number of private, commercial, government 3-wheelers (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) **8.** Number of private, commercial, government 4-wheelers (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) **9.** Number of private, commercial, government multi axle vehicles (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) **10.** Total/average vehicle kilometres by the above modes
	A. Mumbai Metropolitan Region Development Authority **B.** Central Railways **C.** Western Railways **D.** Mumbai Metro Rail Corporation **E.** Mumbai Railway Vikas Corporation	**Data from 2014-2020 and 2021 onwards with year and proposed expansion** **1.** Fleet size of metro rail **2.** Fleet size of suburban rail network **3.** Fleet size of mono rail **4.** Daily ridership vs expected ridership of metro **5.** Daily vs expected ridership of suburban rail **6.** Daily ridership vs expected ridership of mono rail **7.** Electricity consumption for suburban rail, metro and monorail **Questions** Does the metro route have optimal last-mile connectivity initiatives or plans to increase last-mile access?
	A. Traffic department **B.** RTO	**Data from 2010-2020** **1.** Number of private vehicles (millions) (4-wheelers and 2-wheelers) **2.** Number of electric vehicles in the city (2-, 3- and 4-wheelers) **3.** Number of commercial app based 2-wheelers **4.** Total electricity and fuel consumption by private 4-wheelers and 2-wheelers **5.** Number of 3-wheelers (millions): commercial, private, govt, number of diesel vehicles, number of petrol vehicles, number of CNG/LPG vehicles **6.** Number of commercial taxis and cabs **7.** Number of private, government, diesel, petrol, and CNG/LPG 4-wheelers

Sector	Department	Data Points
		7. Total number of multi-axle (million), number of commercial multi axle, govt. multi-axle, number of diesel multi-axles and CNG/LPG-based multi-axles in the city (yet to receive from west RTO) **Questions** **1.** What are the initiatives in place or proposed for managing congestion? (congestion charges, parking policy, parking charges, low emission zones, etc.) **2.** What are the incentives in place to promote clean fuel private vehicles?
	A. Maharashtra State Road Development Corporation **B.** Maharashtra Maritime Board **C.** Mumbai Port Trust	**Data from 2010-2020** **1.** Number of ferries (segregated by fuel such as CNG, LPG, hybrid, biofuels, electric, diesel, petrol) in the city **2.** ROPAX fleet size: current and proposed **3.** Fuel/electricity consumption of ferry fleet **4.** Ridership for ferry **5.** List of ferry stations and routes
	Petroleum companies DISCOMs – BEST, TATA Power, Adani BMC Departments	**Data for GHG inventory (2010-2020)** **1.** Electricity consumption – on-road vehicles, off-road vehicles, railways, waterborne navigation, electricity consumption at charging stations (Received for metro, BEST buses, Central Railway) **2.** Fuel consumption (total fuel sales) data at the city-level – diesel, petrol, auto LPG, CNG, biofuel (specify kind of biofuel), aviation turbine fuel for on-road, off-road, railways, aviation and water navigation, by fleet (municipal, public, private, commercial, multiple) type
Cross Sectoral	Market Department	**1.** List of existing markets **2.** I nformation on ongoing projects **3.** Is there any NMT infrastructure construction at existing markets? **4.** What are the existing waste management systems at various markets? **5.** Fuel consumption by street vendors, hawkers – LPG, CNG, coal, firewood <not available>

Sector	Department	Data Points
Energy & Buildings	Chief Engineer (Building Maintenance, Building Proposal) Department	**1.** Total electric energy generated from all grid-connected renewable energy sources within the city (2010 – 2020) **2.** Total electricity consumption in the city (2010 – 2020) **3.** Total electrical energy supplied from all grid-connected renewable energy sources to the city (2010 – 2020) **4.** Total number of units lost due to T&D loss (2010 – 2020) **5.** Cumulative installed capacity (off grid + on grid) from renewable energy sources for self-consumption (2010 – 2020) **6.** Total connected load in the city (2010 – 2020) **7.** Building height **8.** Building footprint of Mumbai Percentage of buildings securing green building compliance, pre-certification, and final certification **9.** Total number of pre-certified buildings for the assessment period **10.** Total number of buildings approved for the construction for the assessment period **11.** Built-up area of green buildings certified for the assessment period **12.** Built-up area of all buildings completed for the assessment period **13.** Are all the buildings in the base year certified? (Yes/No) **14.** Total electricity consumption of green buildings certified till 2020 **15.** Total electricity consumption of all buildings completed in 2020 Level of compliance, implementation procedures and stakeholder co-operation in place for green buildings **16.** Is there any existing compliance procedure at state level? (Yes/No) **17.** Is there inclusion of latest National Building Codes (NBC 2016) and/ or Energy Conservation Building Codes (ECBC 2017) (commercial & residential) as notified in City Development Control Regulations (DCRs/ GDCRs), building rules/byelaws? (Yes/No)
	Mechanical and Electrical	**1.** Total number of and electricity consumption for public parks and gardens (2010 – 2020) **2.** Total number of and electrical energy consumption for municipal schools (2010 – 2020) **3.** Total number of and electricity consumption for municipal buildings (2010 – 2020) **4.** Total number of and electricity consumption for community halls (2010 – 2020) **5.** Total number of and electricity consumption for govt. hospitals/clinics (2010 – 2020)

Sector	Department	Data Points
		6. Total electricity consumption for fire services (2010 – 2020) **7.** T otal number of and electricity consumption for all streetlights (2010 – 2020) **8.** Total number of and electricity consumption for energy efficient streetlights (2010 – 2020) **9.** Total number of and electricity consumption for streetlights under smart street lighting automation (2010 – 2020) **10.** Total number of RE-powered streetlighting (2010 – 2020) **11.** Total number of and electricity consumption for WTPs (2010 – 2020) **12.** Total number of and electricity consumption for STPs (2010 – 2020) **13**. Map of streetlighting in Mumbai
	Mumbai Fire Brigade	**1.** Total electricity consumption for fire services (2010 – 2020) **2.** Total diesel consumption (2010 – 2020) **3.** Total petrol consumption (2010 – 2020) **4.** Total LPG consumption (2010 – 2020) **5.** Total CNG consumption (2010 – 2020) **6.** Mention name and quantity of any other fuel consumed (2010 – 2020)
	DISCOMs (TATA Power, Adani, BEST) MSEDCL	**Electricity consumption data (2010 – 2020)** ***Residential subsector*** Number of residential consumers (LT) Total number of units consumed by residential consumers (Kwh) Total number of units generated by renewable energy (Kwh) ***Commercial subsector*** Number of commercial consumers (LT) Total number of units consumed by commercial consumers (Kwh) Total number of units generated by renewable energy (Kwh) ***Municipal/Public facilities and buildings subsector*** Number of public streetlights and parks (LT) Total number of units consumed by public streetlights and parks (Kwh) Total number of units generated by renewable energy (Kwh) ***Industrial subsector*** Number of residential consumers (LT/HT) Total number of units consumed by residential consumers [LT/HT] (Kwh) Total number of units generated by renewable energy (Kwh)

Sector	Department	Data Points
	Mahanagar Gas, HP, Indane, Bharat Gas, Indian Oil, Petrol pump associations	**Fossil fuel data by residential, commercial, municipal/public facilities & buildings, industrial, energy industries subsectors (2010 – 2020)** Total coal consumption in city (in tons) Total diesel consumption in city (in KL) Total petrol consumption in city (in KL) Total kerosene consumption in city (in KL) Total PNG consumption in city (in kg) Total CNG consumption in city (in kg) Total LPG consumption in city (in kg) Total aviation turbine fuel/jet fuel consumption in city Total furnace oil consumption in city (in litres) Total fuel wood consumption in city (in tons) Total biodiesel consumption in city (in litres) Total solar energy consumption in city (in MWh) Total wind energy consumption in city (in MWh) Total hydro energy consumption in city (in MWh) Total nuclear energy consumption in city (in joule) Total waste to energy consumed in city (in MWh)

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