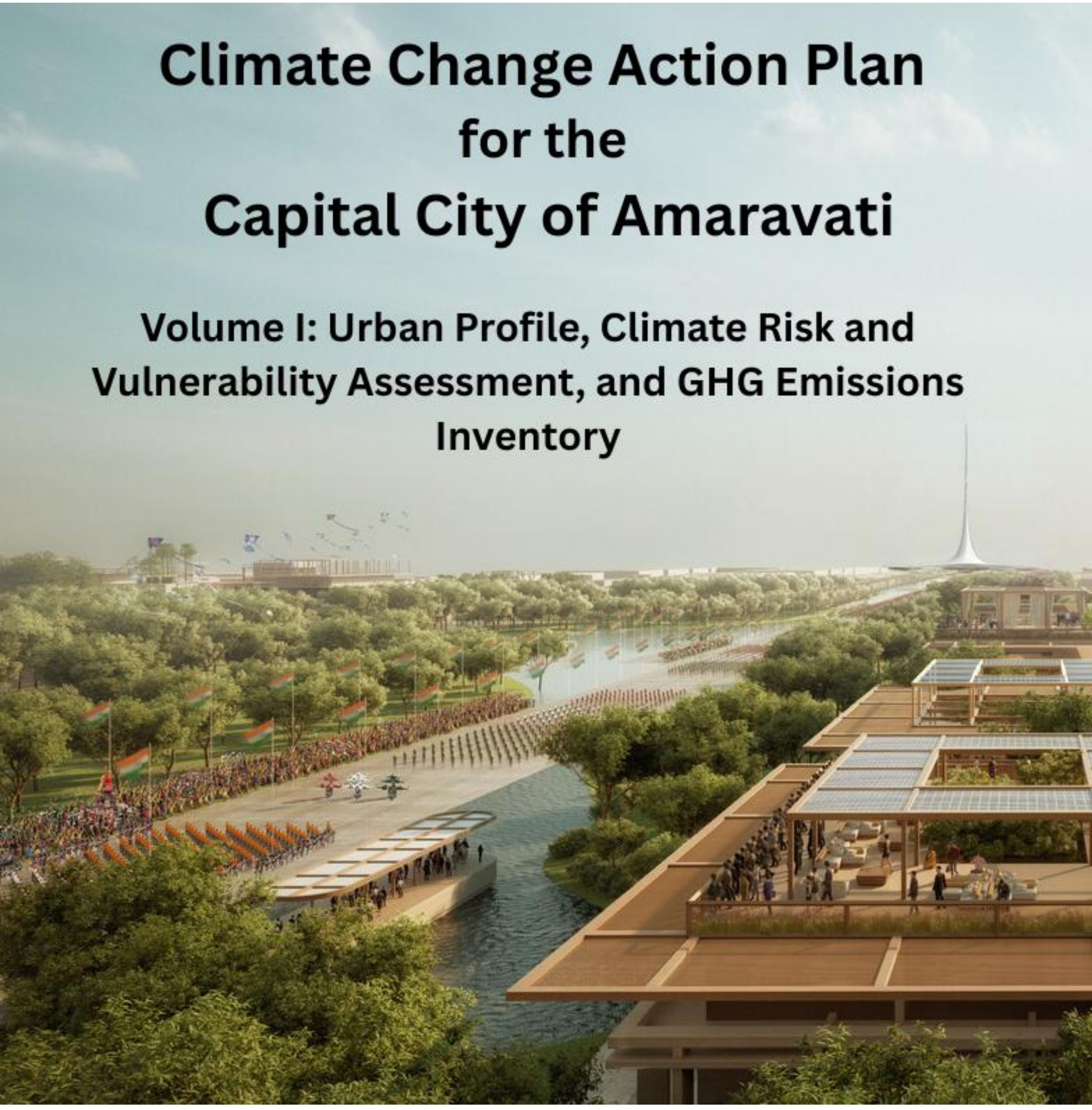
Climate Change Action Plan for the Capital City of Amaravati

Volume I: Urban Profile, Climate Risk and Vulnerability Assessment, and GHG Emissions Inventory



AMARAVATI
THE PEOPLE'S CAPITAL

ICLEI
Local Governments for Sustainability
SOUTH ASIA

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Acknowledgement

Developing the Amaravati City Climate Change Action Plan (CCAP) for Andhra Pradesh Capital Region Development Authority (APCRDA) marks a significant step towards developing a climate-resilient and net-zero capital city over the coming decades. This plan represents a united effort to address the impacts of climate change and enhance Amaravati's resilience. APCRDA has engaged ICLEI - Local Governments for Sustainability, South Asia, for the preparation of a comprehensive city-level CCAP for Amaravati city. This collaborative effort has been instrumental in shaping the CCAP, bringing in internationally accepted climate action planning approaches that enhance its scope and feasibility, helping lay out ambitious yet attainable targets. Heartfelt gratitude is extended to all the departments and staff within APCRDA, as well as to all the stakeholders who contributed towards developing this plan. APCRDA is committed to leading by example, implementing the strategies outlined in this plan, and continuing the collaborative efforts to build a climate-resilient, net-zero and inclusive Amaravati for present and future generations.

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Disclaimer:

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List of Abbreviations

A2O	Anaerobic–Anoxic–Oxic
AAGR	Annual Average Growth Rate
AAQMS	Ambient Air Quality Monitoring Systems
ADCL	Amaravati Development Corporation Ltd
AFOLU	Agriculture, Forestry, and Other Land Use
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APADCL	Andhra Pradesh Airports Development Corporation Ltd.,
APCRDA	Andhra Pradesh Capital Region Development Authority
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Limited
APGENCO	Andhra Pradesh Power Generation Corporation Limited
APIIC	Andhra Pradesh Industrial Infrastructure Corporation
APSPCL	Andhra Pradesh Solar Power Corporation Private Limited
APSPDCL	Andhra Pradesh Southern Power Distribution Company Limited
APSRTC	Andhra Pradesh Road Transport Corporation
APTRANSCO	Transmission Corporation of Andhra Pradesh
AR4	IPCC Fourth Assessment Report
ATC	Area Traffic Control
AVL	Automated Vehicle Location
AYUSH	Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy
BESS	Battery Energy Storage System
BRT	Bus Rapid Transit
BUR	Biennial Update Report submitted to the UNFCCC
C&D	Construction and Demolition
CBD	Central Business District
CCAP	Climate Change Action Plan
CCUS	Carbon Capture, Utilization, and Storage
CEA	Central Electricity Authority

CETP	Common Effluent Treatment Plant
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon-dioxide
COP	Conference of the Parties
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environmental Engineering Organisation
CRC	Climate Resilient CITIES
CSMC	Central SCADA Monitoring Centre
DAS	Distribution Automation Systems
DBR	Design Basis Report
DCS	District Cooling Systems
DPR	Detailed Project Report
DSM	Demand Side Management
ECBC	Energy Conservation and Building Code
E-E	External-External
E-I	External-Internal
EIA	Environment Impact Assessment
EV	Electric Vehicles
FAR	Floor Area Ratio
FGDs	Focused Group Discussions
GHG	Greenhouse Gas
GIS	Gas Insulated Substations
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GPRS	General Packet Radio Service
GWP	Global Warming Potential
GRIHA	Green Rating for Integrated Habitat Assessment
GWT	Ground Water Table

HDPE	High-Density Polyethylene
HPCL	Hindustan Petroleum Corporation Limited (HPCL)
ICMR	Indian Council of Medical Research
IDF	Intensity-Duration-Frequency
I-E	Internal - External
IGBC	Indian Green Building Council
I-I	Internal - Internal
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
IOCL	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IPT	Intermediate Public Transport
ISLS	Intermediate Sewage Lifting Stations
ITS	Intelligent Transport Systems
kW	Kilo Watt
kWh	kilo watt Hour
kV	Kilo Volt
LCC	Life Cycle Cost
LEED	Leadership in Energy and Environmental Design
LPCD	Litres per capita per day
LPG	Liquefied Petroleum Gas
LPS	Land Pooling Schemes
LST	Land Surface Temperature
LTO	Landing and Take-Off
MBBR	Moving Bed Biofilm Reactor
MCF	Methane Correction Factor
MCS	Main Control Station

MGS	Micro Grid Stations
MLD	Million Litres Per Day
MPS	Main Pumping Station
MRF	Material Recovery Facilities
MRT	Mass Rapid Transit
MSL	Mean Sea Level
MTMC	Mangalgiri-Tadepalli Municipal Corporation
MUZ	Multi-Utility Zones
MW	Mega Watt
N_2O	Nitrous Oxide
NAAQMS	National Ambient Air Quality Standards
NAPCC	National Action Plan on Climate Change
NATCOM	National Communication submitted to the UNFCCC
NDWI	Normalized Difference Water Index
NGO	Non-Government Organization
NMT	Non-Motorised Transport
NSSO	National Sample Survey Office
OFC	Optical Fiber Cable
O&M	Operations and Maintenance
PHC	Primary Health Centre
PIS	Passenger Information Systems
PLC	Programmable Logic Controllers
PM	Particulate Matter
PNG	Piped Natural Gas
RCP	Representative Concentration Pathways
RDF	Refuse Derived Fuel
RE	Renewable Energy
RTO	Road Transport Officer

SAPCC	State Action Plan on Climate Change
SBR	Sequence Batch Reactor
SCADA	Supervisory Control And Data Acquisition
SCS	Secondary Control Stations
SHG	Self-Help Group
Solar PV	Solar Photovoltaic
STP	Sewage Treatment Plant
SWM	Solid Waste Management
tCO_2e	Tonnes of Carbon Dioxide Equivalent
STP	Sewage Treatment Plant
T&D	Transmission and Distribution
TMC	Thousand Million Cubic Feet
TOD	Transit-Oriented Development
TPD	Tonnes Per Day
TR	Tons of Refrigeration
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterruptible Power Supply
VMS	Variable Message Signs
VTPP	Vijayawada Thermal Power Plant
WTE	Waste to Energy
WTP	Water Treatment Plants
ZLD	Zero Liquid Discharge

1 Introduction

1.1 Background

1.1.1 Climate Change – A Global Challenge that requires ambitious action

Climate change is the most formidable challenge faced by humanity today. The rate of climate change is accelerating, and its impacts are felt across societies, ecosystems and the environment. Addressing these impacts requires a comprehensive understanding of historic trends and potential future scenarios, leading to ambitious strategies and actions for climate resilience.

Global average temperature has increased by approximately 1.2° Celsius[1] since the late 19th century, exacerbating weather extremes and impacting ecosystems worldwide. Concurrently, sea levels have increased by about 20 centimetres since 1900, due to melting caused by warmer seawater, threatening coastal communities and habitats.[2] IPCC projects that global warming could reach or exceed 2.0°C within the 21st century, if emissions continue unchecked, posing catastrophic risks to food systems, water availability, and global supply chains[3]. The compounded damage to infrastructure and livelihoods will disproportionately affect low-income regions, especially in the Global South. A comprehensive general description of these phenomena reveals an urgent need to adopt not only immediate measures to mitigate greenhouse gas (GHG) emissions, but also to design innovative strategies that promote resilience against climate-related threats.

The effects of climate change are not distributed evenly; rather, they disproportionately affect vulnerable populations, amplifying existing inequalities and compounding socioeconomic vulnerabilities. The World Bank has estimated that climate change could push 100 million additional people to extreme poverty by 2030, underlining the urgency of addressing climatic change impacts. Communities that depend on natural resources for their livelihoods are exceptionally vulnerability to climate change impacts.

1.1.2 Imperative: City Climate Action

The IPCC's Special Report on Global Warming of 1.5°C[4] highlights the essential role of cities and urban centres in advancing climate action. As hubs of population, economic activity, and infrastructure, urban areas are uniquely positioned to scale up mitigation and adaptation measures that can collectively shape the global trajectory toward limiting warming to 1.5°C. With over two-thirds of the world's population expected to live in urban settings by 2050[5], the urgency of embedding climate resilience into urban planning frameworks has

[1] NASA: 2020 Tied for Warmest Year on Record, NASA Analysis Shows. Available at: 2020-tied-for-warmest-year-on-record-nasa-analysis-shows.

[2] Intergovernmental Panel on Climate Change (IPCC). (2023). Ocean, Cryosphere and Sea Level Change. In Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1211–1362). chapter, Cambridge: Cambridge University Press.

[3] IPCC: Climate change widespread, rapid, and intensifying. Intergovernmental Panel on Climate Change (IPCC). (2023). Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

[4] IPCC Special Report - Global Warming of 1.5 °C. Available at: https://www.ipcc.ch/sr15/ (accessed: 15th May 2025)

[5] United Nations Department of Economic and Social Affairs, "68% of the world population projected to live in urban areas by 2050, says UN", 16 May 2018, Available at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html (accessed: 15th May 2025)

never been more evident. In recognition of the global imperative for accelerated action, India announced its target to achieve net-zero emissions by 2070 at the 26th Conference of the Parties (COP26) in Glasgow. This long-term commitment is aligned with broader sustainable development objectives and places increased emphasis on integrating low-carbon strategies into urban development pathways. Local governments, therefore, emerge not only as implementers but as critical enablers of national and global climate ambition.

India is urbanizing at an unprecedented pace. By 2036, it is expected that more than 40% of country’s population will be living in urban areas, which offers both advantages and disadvantages in the context of climate change[6]. Projections also suggest that by 2050, the urban population will have doubled compared to 2018 levels, adding more than 400 million people to the cities[7]. This increased urbanization is expected to lead to an increase in energy demand, transportation requirements as well as infrastructure development demands, which will result in increased GHG emissions. Additionally, urbanization will also bring along the encroachment on natural ecosystems which will likely have huge impact on the local biodiversity and their capacity to act as carbon sinks, thus adding to the climate change impacts.

Against this backdrop, it is clear that Indian cities must take centre stage in the national climate strategy. Through comprehensive planning, improved infrastructure, and integrated development models, cities can lead India’s push toward a low-carbon and resilient future and inspire other nations in the Global South.

Urban development and climate actions should no longer be treated as separate goals. Many national programmes are now moving in this direction. Initiatives such as the Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat Missions and the National Clean Air Program demonstrate the government's commitment to promoting sustainable urban development and addressing environmental challenges. At a more strategic level, the National Action Plan on Climate Change (NAPCC) offers thematic missions that cities can align with. The National Mission on Sustainable Habitat 2.0, for instance, encourages cities to reduce their carbon footprint through smarter building codes, improved public transport, and better waste management systems. Other NAPCC missions like the National Solar Mission, Green India Mission, and Electric Mobility Mission provide the national-level push that cities can connect with through local projects.

Cities can significantly contribute to India’s climate ambitions by embedding climate considerations in infrastructure design, integrating green and blue spaces in land use planning, scaling clean energy and mobility, and prioritising inclusive governance. A collaborative, multiple stakeholder engagement approach that includes government agencies, the private sector, civil society organizations and local communities becomes essential.

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[6] Financing India’s urban infrastructure needs: Constraints to commercial financing and prospects for policy action, World Bank Group. Available at: http://documents.worldbank.org/curated/en/099615110042225105/pdf/P17130200d91fc0da0ac610a1e3e1a664d4.pdf (accessed: 15th May 2025)

[7] World Urbanization Prospects, 2018, United Nations Department of Economic and Social Affairs. Available at: https://population.un.org/wup/assets/WUP2018-Report.pdf?utm_source=chatgpt.com (accessed: 15th May 2025)

1.1.3 Climate Action at the State level in Andhra Pradesh

With an extensive coastline, rapidly growing urban centres and presence of varied ecosystems, Andhra Pradesh is highly vulnerable to climate change. The state's agriculture, water availability, and coastal livelihoods are already experiencing the impacts of rising temperatures, erratic rainfall, rising sea level, and increasing cyclones. Recognising these risks, the Government of Andhra Pradesh is revising the State Action Plan on Climate Change (SAPCC), which aligns with India's NAPCC. The SAPCC presents sector-specific interventions for energy, transport, urban development, water resources and biodiversity. The plan stresses on the need to integrate climate resilience into policy development and implementation.

Andhra Pradesh's SAPCC postulates stronger inter-departmental coordination and has opened pathways for mobilizing technical and financial support from national and international agencies. The state has piloted district-level vulnerability assessments and initiated urban climate planning in key cities. The SAPCC has laid the groundwork for a climate-resilient Andhra Pradesh by integrating climate action within the state's broader vision of sustainable development.

Andhra Pradesh has developed the Swarna Andhra 2047 vision,[8] envisioning water security, equal access to water, sanitation, and hygiene (WASH) facilities, creating clean living environments across the state, and moving towards net-zero emissions by 2047. This will be achieved by leading in green hydrogen production and decarbonizing sectors that emit high levels of GHGs, thereby promoting sustainable development. Key innovations such as carbon capture, utilization, and storage (CCUS), solar energy storage, and green ethanol, are central to this plan. The state intends to establish a Central Climate Knowledge Centre and partner with universities and research institutions to disseminate knowledge and advance technology. Additionally, Andhra Pradesh aims to achieve local energy self-sufficiency through the implementation of smart grids, extensive rooftop solar deployment, and energy democratization, ensuring affordable, sustainable, and reliable energy for households and industries. To support these efforts, the state has also introduced the Andhra Pradesh Integrated Clean Energy Policy 2024[9] to implement measures to realise these goals and has established a Climate Change Cell within the state's Environment department.

1.2 Amaravati's Sustainability Vision

Amaravati, the capital city of Andhra Pradesh, is being developed with a strong focus on environmental sustainability and planned urban growth. The city's broader vision is to grow not just a world-class capital city for the State, but as a symbol of planned, future-ready urban centre in India. The city envisions to synthesize best features of urban planning, sustainability, and effective governance to create an inclusive, highly liveable, and world-class urban ecosystem.

To meet the city's overall vision, it is envisaged that Amaravati's physical infrastructure will meet global standards, with efficient utilities that are environmentally friendly, and technologically driven. The city's current development plans include dedicated zones for open green spaces, preservation of water bodies, and mixed-use development designed to minimise travel demand and energy consumption. Additionally, there is a push for non-motorised and public transport, energy-efficient infrastructure, and the use of clean

[8] Swarna-Andhra 2047
[9] Andhra Pradesh Integrated Clean Energy Policy 2024

and renewable energy where possible. Environmental considerations such as flood protection, wastewater reuse, and urban cooling have also been built into the land use strategy to ensure long-term resilience.

The above initiatives are part of a larger strategy to enable Amaravati support Andhra Pradesh's climate objectives while addressing the state's urbanisation demand. As the development of city progresses, the vision remains on creating a sustainable, functional and inclusive capital city that support's Andhra Pradesh's journey toward climate-resilient sustainable development.

2 City profile

2.1 About the city

Amaravati, the capital city of newly bifurcated Andhra Pradesh state (2014)[10], is being developed by the government of Andhra Pradesh as a Smart City that meets global standards of urban living. This capital city is designed to serve as an economic hub, generating diverse job opportunities for local residents and focusing on enhancing skills to meet the demands of various industries. It aims to attract high-tech and knowledge-based industries, ensuring that job offerings are competitive on a global scale.

Sustainability and efficient resource management are priorities in Amaravati's development strategy. These principles have been integrated into the city's master plan, helping to preserve its clean and green environment while fostering a vibrant community that honours the region's rich cultural heritage. Central to Amaravati's planning is the provision of affordable and high-quality housing for its residents, ensuring that the city meets the diverse needs of its population.

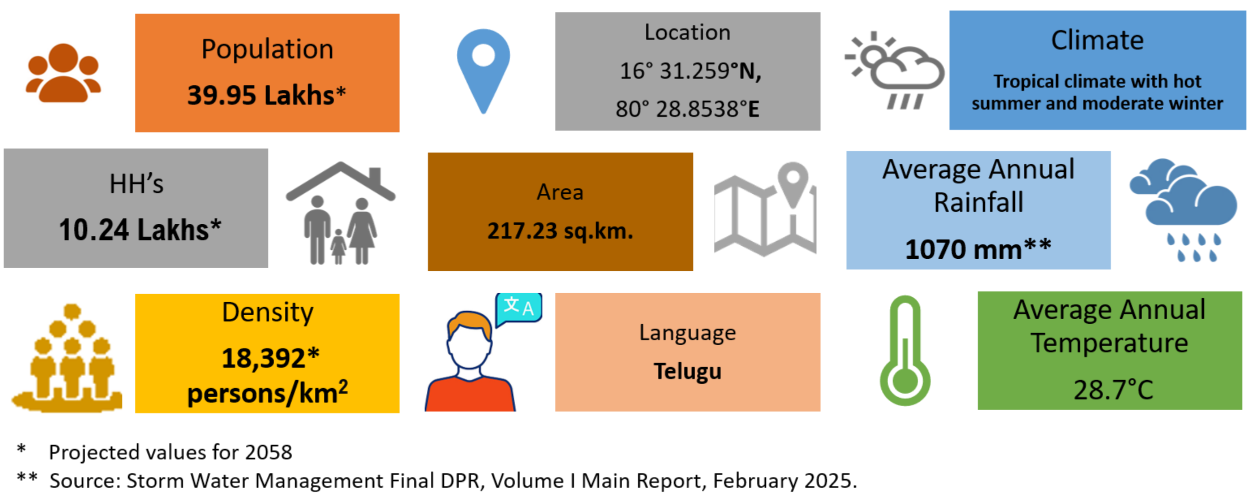

Figure 2-1 Snapshot of Capital city Amaravati

2.2 Location

Amaravati is situated on the banks of the Krishna River, near Vijayawada and 20 km from Guntur. The capital city area includes 29 existing villages, with a total population of 106,000 persons according to the 2011 Census. It spans an area of 217.23 square kilometres and encompasses parts of Thullur, Mangalagiri, and Tadepalli mandals in Guntur District.

[10] As per Andhra Pradesh Reorganisation Act of 2014, state of Andhra Pradesh is bifurcated into Telangana state and the residuary Andhra Pradesh state

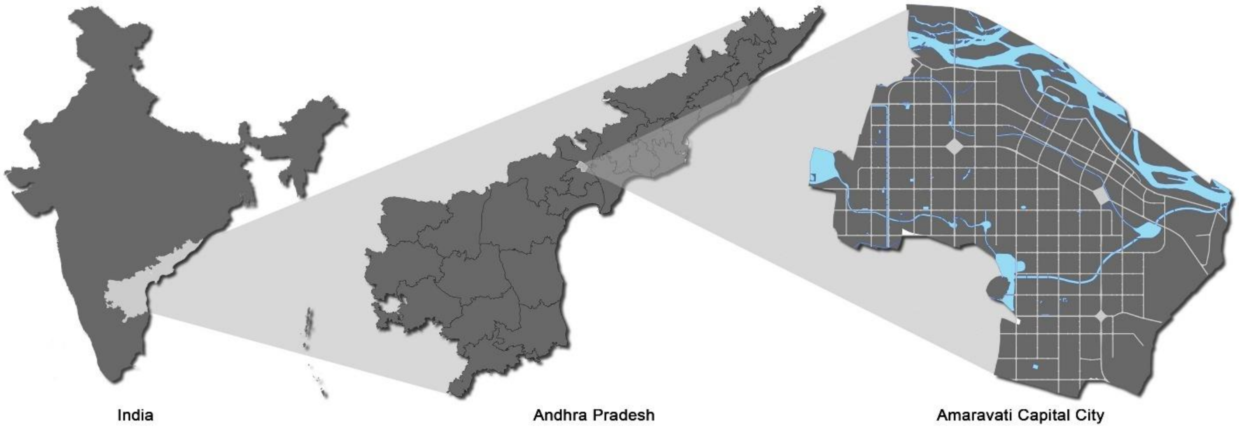

Figure 2-2 Location map of Capital city Amaravati

Under the unique Land Pooling Scheme (LPS), 17,000 acres of land owned by farmers and others have been incorporated into the capital city for development.

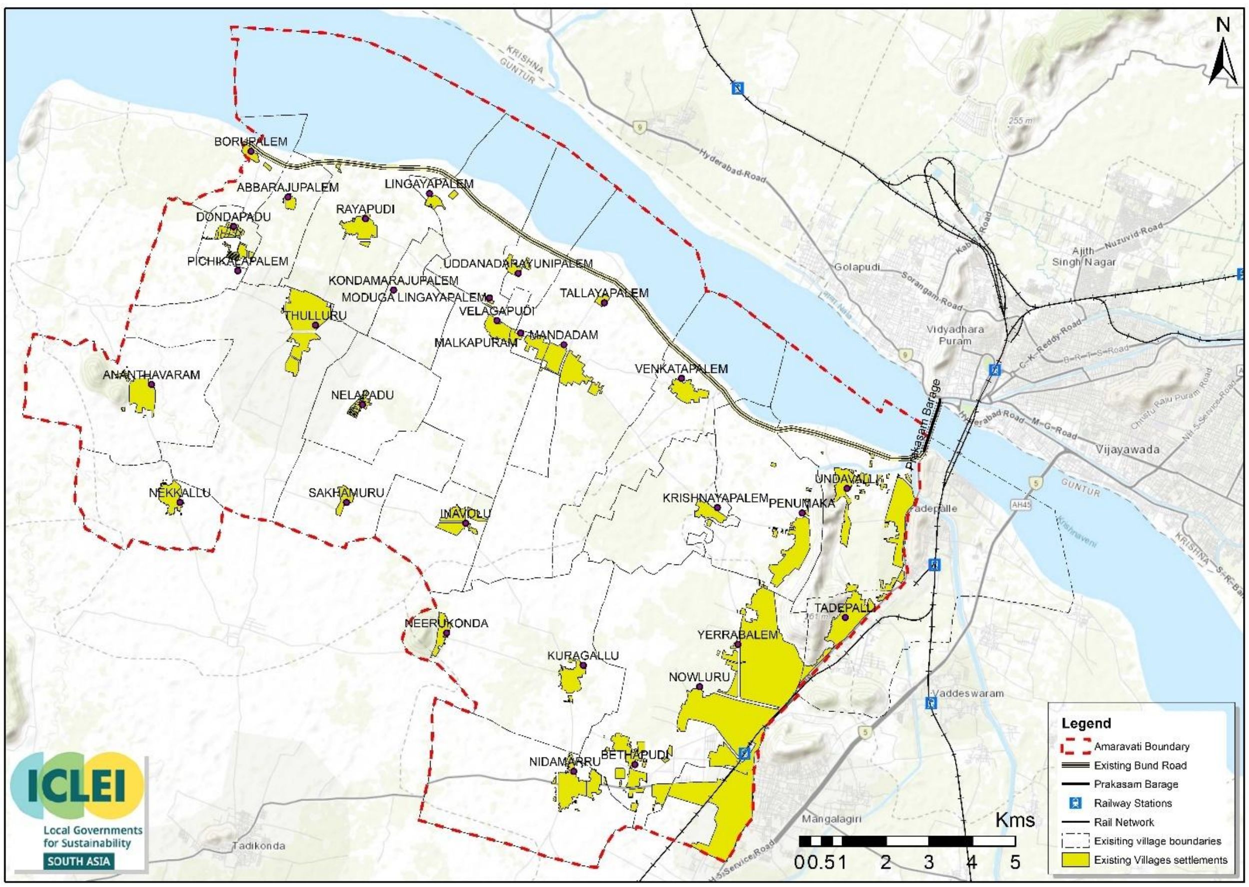

Figure 2-3 Existing settlements in Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA

2.3 Connectivity

The new greenfield city is adjacent to the city of Vijayawada and in close proximity to Guntur. Major cities within a 380 km radius include Chennai, Bengaluru, Hyderabad, Visakhapatnam, and Tirupati. The city is well connected via air, road, rail and waterways.

Road:

National Highway (NH) 16 (previously known as NH 5) is an important national highway that connects Amaravati with Chennai, Visakhapatnam, Bhubaneswar, and Kolkata. NH 9 connects Amaravati to Hyderabad and Pune in north-west and Machilipatnam towards south. Additionally, the Andhra Pradesh Capital Region Development Authority (APCRDA) has proposed an Inner Ring Road within its jurisdiction, along the perimeter of Amaravati. This ring road will serve as a bypass for regional traffic and enhance accessibility to the new capital and the surrounding villages and towns[11].

Rail:

Mangalagiri railway station is located within the jurisdiction of the capital city. Vijayawada is a prominent railway junction located 3 km away from Amaravati. Other prominent railway stations nearby include Krishna Canal (at a distance of 1 km), Guntur (at a distance of 30 km), Tenali (at a distance of 30 km), and Gudivada (at a distance of 45 km). A DPR for a new railway line of 56 kilometres, connecting Errupalem and Namburu via Amaravati, has been submitted to the Railway Board, and its execution is expected to begin soon[12].

Air:

Amaravati is accessible via the Vijayawada International Airport, which is located 35 kilometres away. The Andhra Pradesh Airport Development Corporation Ltd. (APADCL) has proposed a greenfield international airport for Amaravati and has begun the process of preparing a prefeasibility study and a techno-economic feasibility report[13].

Sea:

Andhra Pradesh, being a coastal state in India, boasts multiple ports that facilitate global trade and commerce. The upcoming Machilipatnam Port, expected to be completed by December 2026, is the nearest port to Amaravati, located about 100 km away. Other port in proximity includes Kakinada Port (253 km), Krishnapatnam port (321 km), Visakhapatnam (363 km) and Chennai (455 km). Furthermore, additional ports

[11] Inner Ring Road & Extensin of Capital city roads to IRR Master Plan, APCRDA Available at: https://crda.ap.gov.in/APCRDAdocs/Downloads/MasterPlans/Report%20-%20English.pdf (accessed: 15th May 2025)

[12] The Times of India, "New rly line proposed to improve connectivity", 4 October 2024, Available at: https://timesofindia.indiatimes.com/city/vijayawada/amaravati-to-get-new-56-km-railway-line-for-enhanced-connectivity/articleshow/113947775.cms#:~:text=A%20new%2056-kilometre%20railway%20line%20proposed%20between%20Errupalem,and%20improve%20connectivity%20in%20Andhra%20Pradesh%27s%20capital%20region. (accessed: 15th May 2025)

[13] RFP: Selection of Consultant for conducting Prefeasibility Study & Preparation of Techno-Economic Feasibility Report (TEFR) for Development of Greenfield International Airport in Amaravati in the state of Andhra Pradesh for Amaravati international Airport, APADCL, March 2025. Available at: https://www.apadcl.com/tender_docs/1741266343Airports-Adv-01.pdf (accessed: 15th May 2025)

have been proposed across the state[14], which will further enhance opportunities for intra and cross-boundary trade.

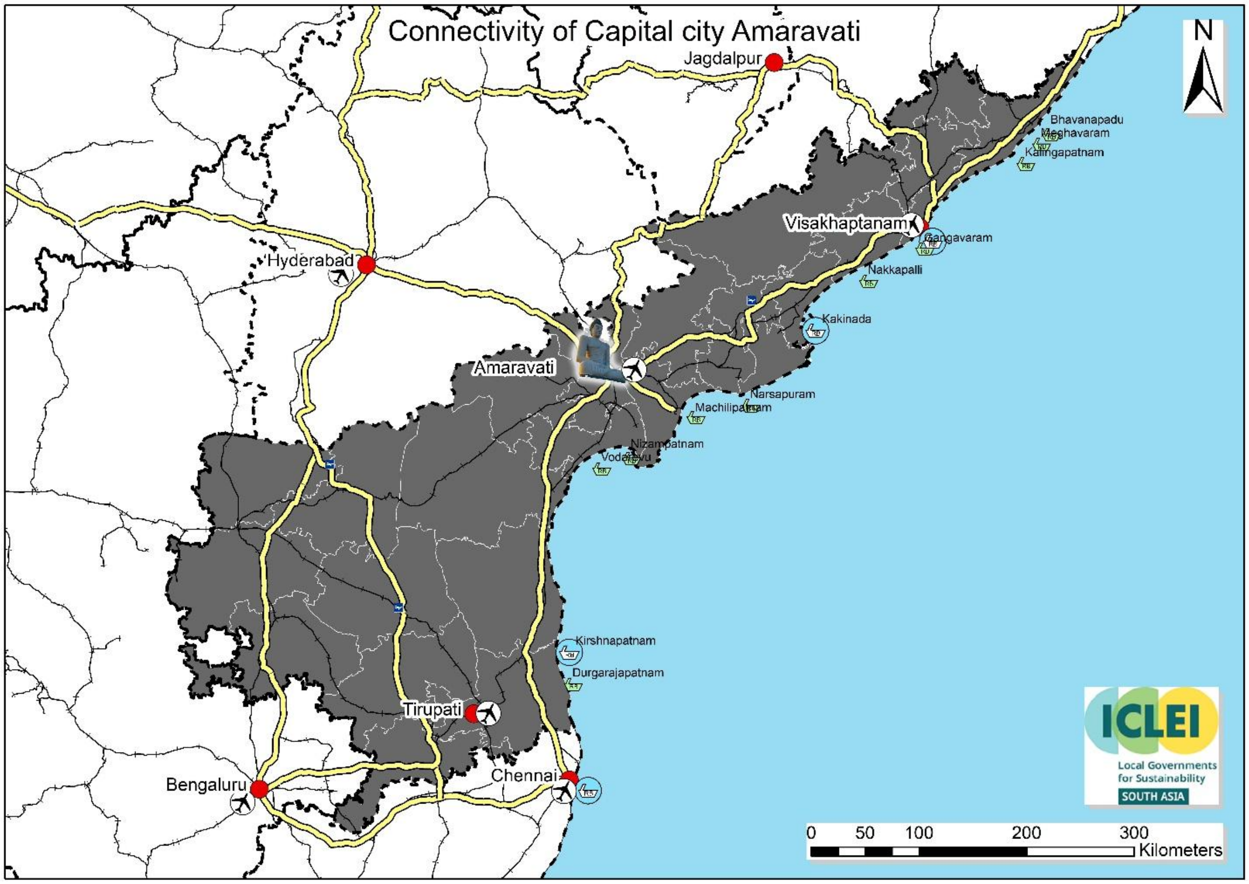

Figure 2-4 Regional Connectivity

[14] The New Indian Express, "Andhra Pradesh govt eyes global tie-ups to develop ports", 13 November 2024. Available at: https://www.newindianexpress.com/states/andhra-pradesh/2024/Nov/13/andhra-pradesh-govt-eyes-global-tie-ups-to-develop-ports (Accessed: 15th May 2025)

2.4 Demography

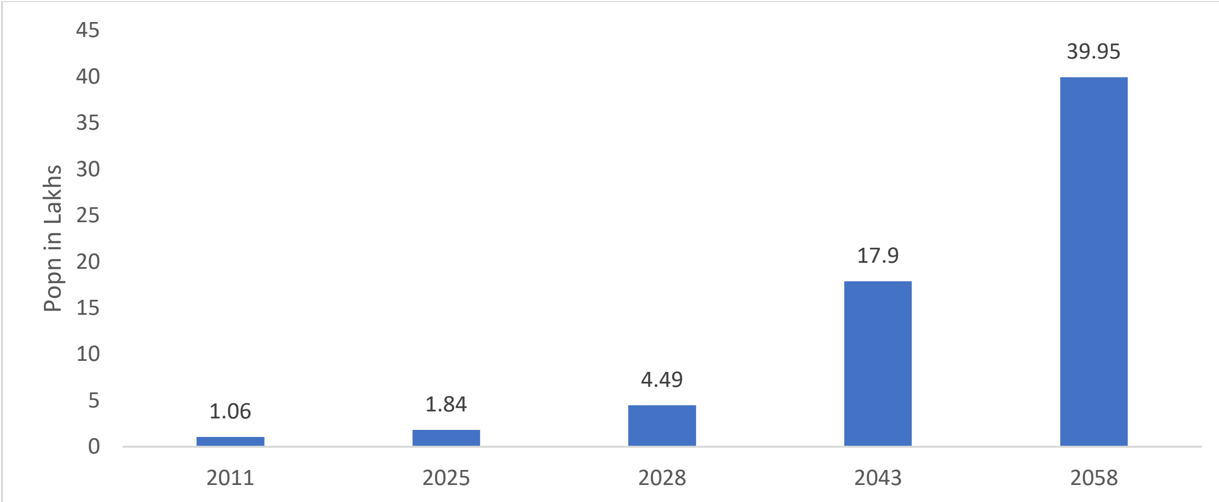

Figure 2-5 Population projected for Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA

According to the 2011 Census, 1.06 lakh persons reside in Amaravati, spread across 29 village settlements. By 2058, the fully developed city is projected to accommodate a population of 39.95 lakhs[15], with a gross density of 18,392 people per square kilometre. It is estimated that there will be approximately 10.24 lakh households living in Amaravati by 2058[16].

2.5 City Administration

Government of Andhra Pradesh, through an Official Act (No. 11 of 2014) constituted the Amaravati Development Corporation Limited (ADCL) & Andhra Pradesh Capital Region Development Authority (APCRDA) for creating the new capital; they are responsible for planning, coordination, execution, supervision, and management of the capital region development area.

The World Bank and the Asian Development Bank are supporting the first phase of Amaravati's development to create a transparent and effective city management framework that fosters citizen involvement in urban planning and development. The construction of the trunk infrastructure is currently underway, encompassing road networks, public transportation systems, measures for flood prevention and wastewater management. These developments are being implemented by integrating innovative, environmentally friendly technologies and design practices.

2.6 Planned Economic Development

Amaravati city is envisaged to be a hub for economic development and job-creation, with non-polluting, high-value manufacturing and service industries, creating 20 lakh jobs over 25 years with a GDP contribution

[15] Projected population as informed by APCRDA, 2025.
[16] Household size of 4 is considered based on Vijayawada 2011 Census.

of INR 1.5-2 lakh crores.[17] The city is planned to house industries such as electronics, food processing, fashion and apparel, tourism, higher education, and healthcare. It is anticipated that economic development within Amaravati will also boost the regional economy, livelihoods and quality of life.

Economic Activities and Sectoral Growth

Amaravati's economic strategy revolves around a chosen set of high-value sectors. The city is planned to become India's leading hub for food services and organic food manufacturing; and a centre for innovative agro-tech research and development. Electronics manufacturing will initially focus on assembly, evolving over time to include electronics design and fabrication. The apparel and fashion sector, which will benefit from the robust regional textile industry, is also being encouraged. Integrated industrial parks are planned that will bring together upstream (e.g. spinning, dyeing, weaving) and downstream (e.g. textile manufacturing and dyeing processes) manufacturing units. The city will also house institutions of higher education, tourism and health services. Planned economic activity will be supported by world-class infrastructure and serviced by integrated logistic networks that include more than 115 km of public transport corridors, well connected regional road and rail networks, quick access to the airport and well-developed ports in proximity.

2.7 Physiography

2.7.1 Topography

The general topography of the city slopes from south-west to north-east, towards Kondaveeti Vagu (stream), which finally flows into the River Krishna, upstream of Prakasam Barrage. Toward the West, Ananthavaram village is at an elevation of 55 m above Mean Sea Level (MSL) and Venkatapalem village toward the East is at an elevation of 19 m. Nekkallu village in the South is at an elevation of 38 m and Kara Katta to the North has an elevation of 20 m.

The topography is predominantly flat in the central portion of the city, with a slight slope to the south-east. Western part of the capital city slopes towards the central portion. Central portion of the capital city shows mild slope towards north-east and exhibits an undulating terrain.

All the streams in the capital city area originate from South, South-west draining toward the North-East and discharge finally into the Krishna River. The northern side of Pala Vagu slopes towards the vagu/stream in some locations. The southern side of Kondaveeti Vagu slopes towards the vagu at different locations.

[17] Amaravati Project Edition : 04, APCRDA, February 2019. Available at: https://crda.ap.gov.in/APCRDADOCS/DataModuleFIles/Reports/01~Amaravati%20Project%20Report%20Edition%20No4%20Status%20Feb%202019.pdf (accessed: 15th May 2025)

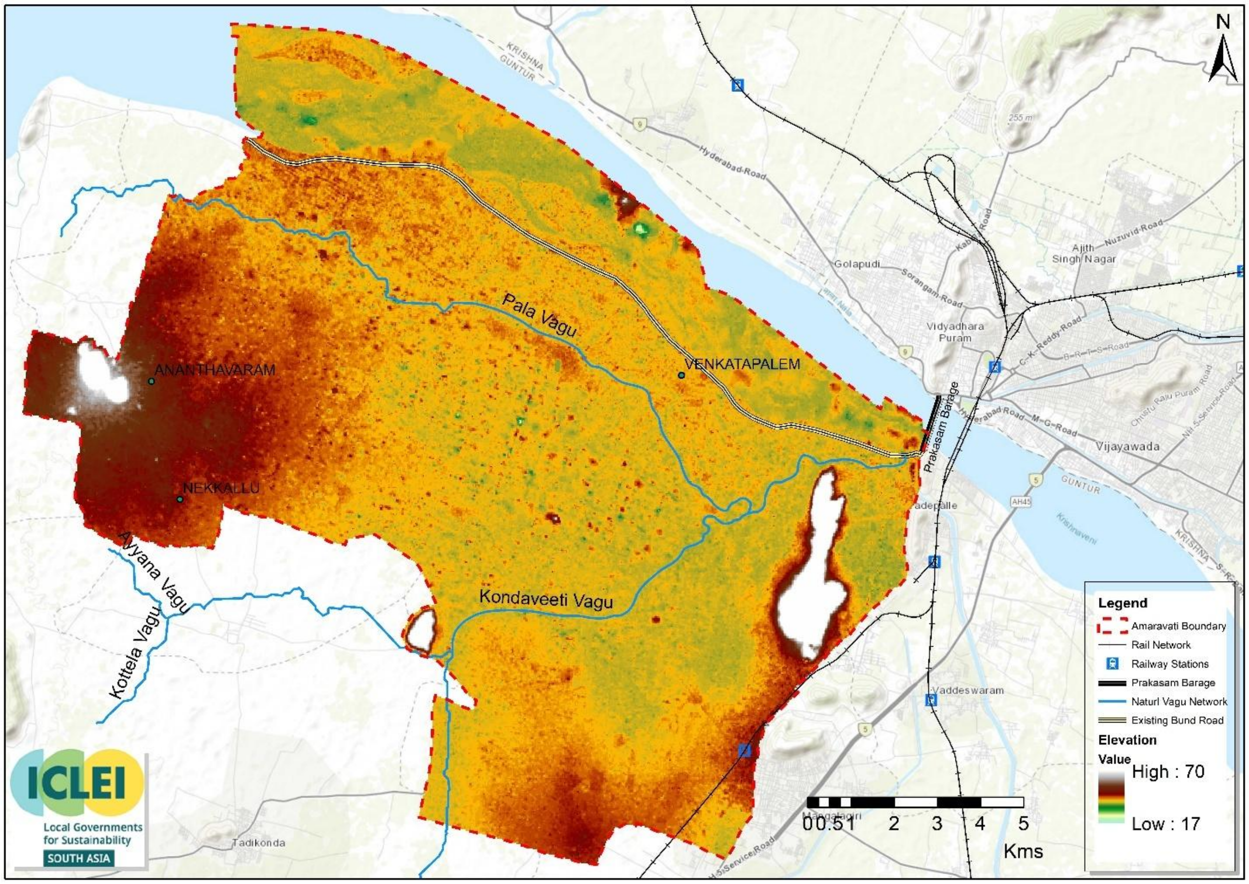

Figure 2-6 Topography of Amaravati

2.7.2 Existing Environmental Features

- **Green Cover and Forests:** Amaravati comprises a total forest area of 3,165 hectares, including, water bodies Kondapalli, Mangalagiri, and Tadepalli reserve forests. Agricultural fields, forests, and groves present in the region provide ecological services. Preservation of these green areas and environmental features is key to preventing heat island effect and retaining biodiversity.
- **Hilly terrain:** Hills such as Kondaveedu, Mangalagiri, and Undavalli are present, acting as ecological and visual landmarks; it is envisaged that the city will integrate and will be built around these hills.
- **Water Bodies:** Amaravati is endowed with the Krishna River and several other water bodies spread across 2,160 hectares, with a long riverfront of over 22 km. The Krishna River, along with a network of canals and tanks, forms the region's primary blue infrastructure. These water bodies are critical for irrigation, drinking water, flood control, and recreation.
- **Flood Zones:** Certain areas along the Krishna River and its tributaries are flood-prone.

2.7.3 Soil

Black Cotton, Alluvial and Clayey-loam soils are predominantly found along the Krishna Riverbank. Within the capital city area, black cotton soil is the most widespread. The capital city area has layers of stacked up clayey and silty soil underlaid by medium sand and clay.[18] Silty-clayey soils, loamy soils and sandy clayey/gravelly clayey soils are also observed.

Soil characteristics influence the thermal profile of the city, that is, its warming and heat retention. Black cotton, which is predominant in the city, soil has high thermal conductivity[19] and diffusivity. Due to this thermal characteristic of soil, barren land absorbs heat faster than other surfaces during daytime and releases heat faster and cools down during night-time. Soil conditions are largely suitable for urban construction but require proper stormwater drainage planning.

2.7.4 Ground Water Table

The depth of ground water table is observed to be between 2 to 5 m in the northern part of the capital city (near River Krishna). In comparison, ground water levels are in the range of 5 to 10m in western and southern parts of the city. To preserve the existing aquifer conditions, it is envisaged that ground water extraction in Amaravati will be subject to government regulations.

2.8 Land Use Planning

Amaravati is envisioned as Andhra Pradesh's "People's Capital" – a world-class, smart city with the state-of-the-art infrastructure and global standards followed by developed cities and countries. It aims to be an economic hub generating high-value jobs (knowledge/tech, finance, education) while capitalizing on the region's heritage and culture and offering affordable, high-quality housing and a green, livable environment.

2.8.1 Planning Strategies and Approach for Land Use

The Master plan aims to address 6 key goals through an Urban Sustainability Framework namely:

1. Creating Jobs
2. Attracting Investments
3. Provision of good quality housing
4. Nature and Environment
5. Flood Management
6. Heritage and Culture

Several goals and strategies are framed based on these 6 goals,

- **State of the art Infrastructure:** Transit-oriented development (TOD) and high-density mixed use along transit axes, 225 km of public transport corridors by 2050, prioritizing high public transport mode share, and strategic first and last mile connectivity integration with approximately 593 km of major roads by 2050.
- **Jobs & Homes for all:** Generate more than 20 lakhs jobs to sustain population of 39.95 lakhs by 2058 and create quality and affordable housing catering to the needful low and medium-income groups

[18] Water supply revised DPR 2025, ADCL

[19] Thermal conductivity of black soil 2 Days after Saturation (DAS) is 8.61 W m−1K−1 (1.4 Mgm-3 Compaction level) and 14.02 W m−1K−1 (1.2 Mgm-3 Compaction level) and 6 DAS is 3.88 (1.2 Mgm-3 Compaction level) and 5.73 (1.4 Mgm-3 Compaction level) (Pramanik & Aggarwal, 2013).

- **Green and Clean:** Mandate retaining the green network (forests, hills) as well as waterfront, and utilize these natural features to create a regional green network and make it accessible to the inhabitants.
- **Quality Living:** Create universal and accessible amenities and infrastructure including transit, healthcare facilities, education, public spaces, among others.
- **Efficient Resource Management:** Adopt nature-based solutions and develop sustainable flood management system, adopt 3R principles of Reduce, Recycle and Reuse and maximize use of renewable energy, develop smart energy grid, and attain global certification on climate responsive green buildings and infrastructure.
- **Identity and Heritage:** Preserve all historic and culturally important sites and create conservation awareness, promote cultural activities at strategic locations, and integrate existing villages to reflect and promote region's culture.

The Capital City's development and land use plan has been designed considering the traditional Indian approach of 'Vastu Shastra' which ensures climate responsive urban planning while conserving existing flora and fauna and maintaining health and wellbeing of inhabitants throughout the year.

The plan proposes 3 important axes which serve as potential corridors within the city, namely: civic axis for administrative functions, recreation axis housing a number of parks and open spaces, and waterfront axis along the river front lying between the civic and recreational axis. This axis shall house the city's downtown area with a vibrant waterfront commercial district that will create a distinctive skyline for the Amaravati city; with 'Brahmastan' (Silent Centre) at its centre.

The plan defines goals and strategies prioritizing Transit-oriented development (TOD), high-density mixed use with slum-free housing; cutting-edge public transport [Bus Rapid Transit (BRT)/Mass Rapid Transit (MRT)] and connectivity (including a high-speed rail link); strict sustainability principles following "reduce-recycle-reuse" approach for waste management, maximizing the use renewable energy, and a green, "walkable" urban form with parks and amenities within every neighbourhood integrating region's identity of heritage and culture. The master plan envisages nine thematic sub-cities including the Government city, Justice city, Finance city, Education & knowledge city, Health city, Sports city, Cultural city, Electronics city and Tourism city, that have been strategically planned across Amaravati.

2.8.2 Spatial Structure

The city is organized around multiple urban centres linked by high-capacity transit. A waterfront Central Business District (CBD) along the Krishna River is envisioned as the commercial/cultural heart, featuring mixed-use towers, cultural institutions and high-end housing. Two other transit nodes – the Eastern Gateway (airport corridor) and the Government Core (assembly, secretariat, judiciary) – anchor mixed-use developments and high-density jobs.

A Township model, as shown in Figure 2-7 has been adopted for the proposed capital region using the strategy of hierarchical distribution of population, land uses, open spaces, and infrastructure, while also integrating and upgrading existing village neighbourhoods through the provision of essential civic amenities, aligning with future urban settlements.

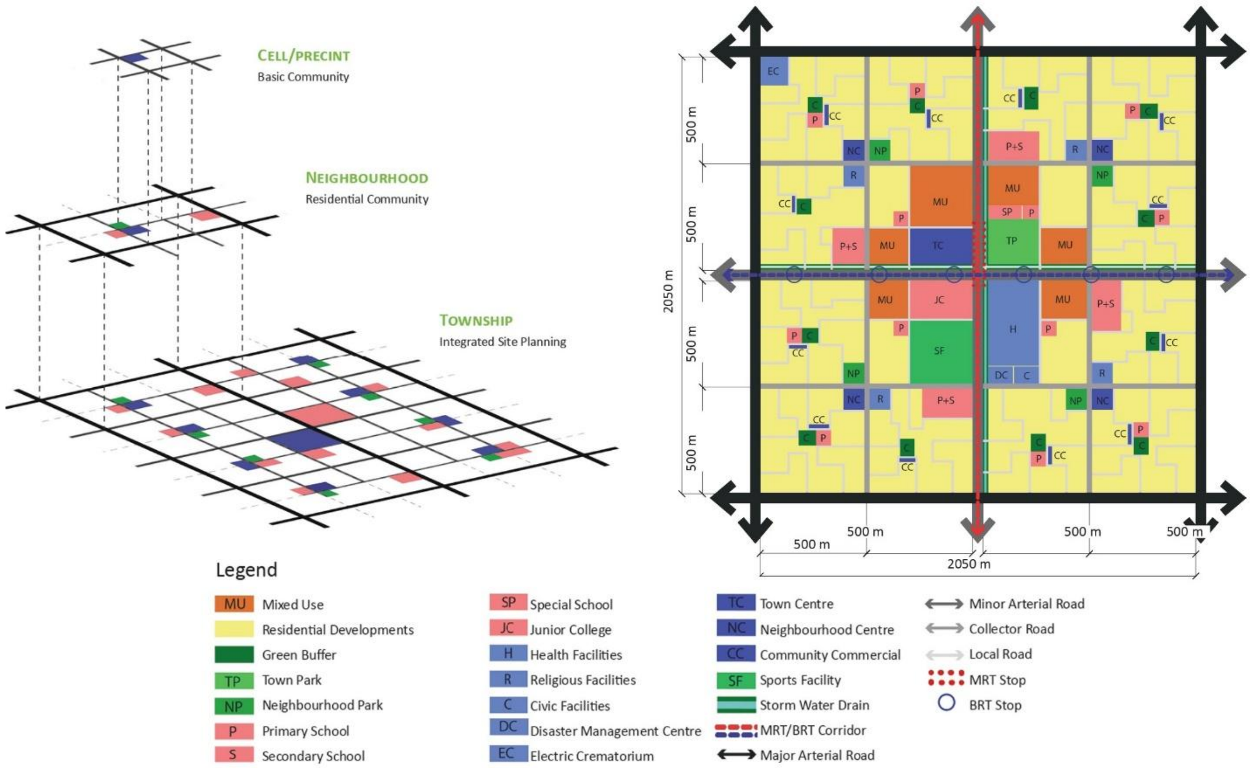

Figure 2-7 Capital City Amaravati Township Model
Source: Amaravati Capital City Master Plan Report

Each township is planned in “Cells” of 500x500 meters each, with a potential for up to 4,550 dwelling units. Each “cell” represents a small community with greenery, playground and no-vehicle zones. The proposed township model also integrates a number of employment nodes such as commercial offices, light industries and business parks in close proximity to residential developments, connected by public transport.

2.8.3 Zoning Approach

As shown in Figure 2-8, land parcels are designated by intended land use.

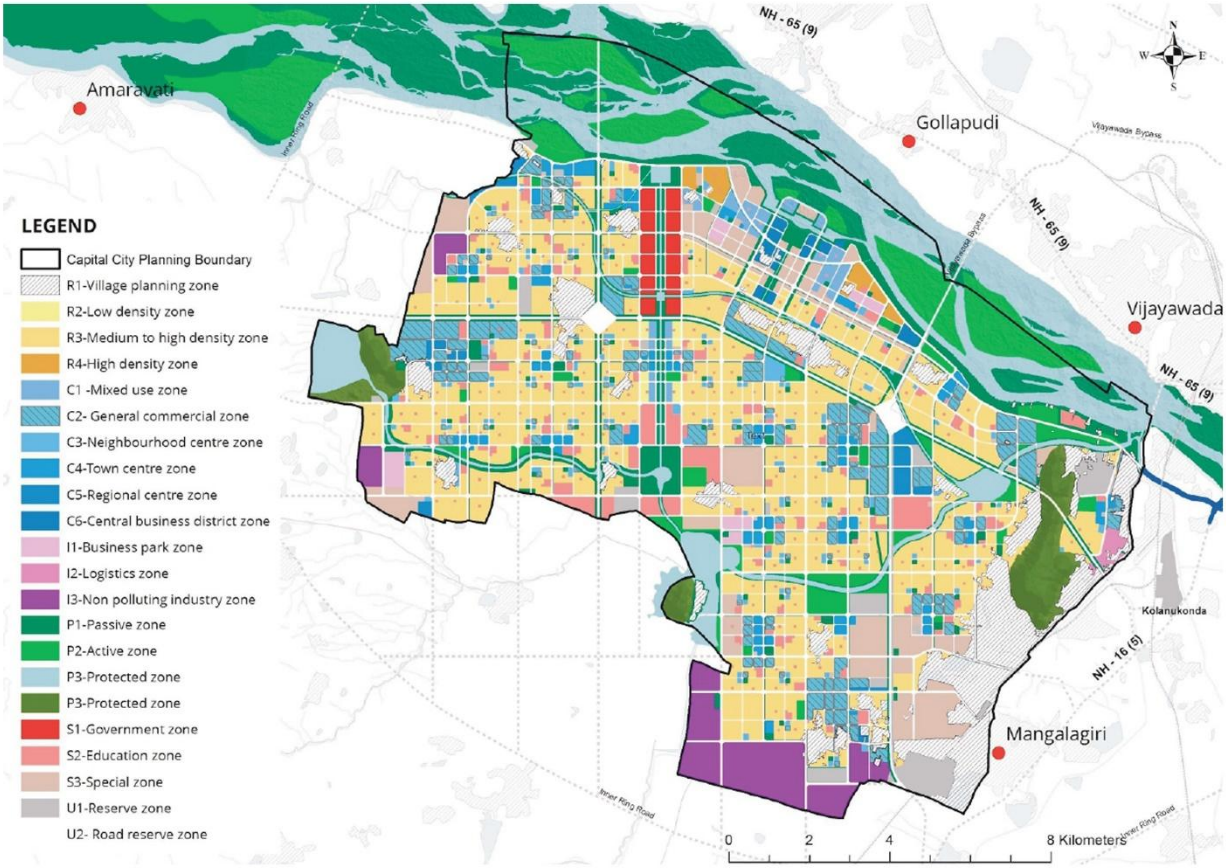

Figure 2-8 Capital City Amaravati Master Plan 2050
Source: Amaravati Capital City Master Plan Report

Table 2-1 Land use allocation as per Master Plan 2050

Land Use	Percentage of Area	Area in Hectares
Residential	32%	6,951
Commercial	11%	2,389
Industrial	4%	869
Parks and Open spaces	29.5%	6,397
Institutional	10.5%	2,280
Infrastructure	13%	2,823

Source: Capital City Master Plan Report

- **Residential (R) zone:** The residential zone comprises four subzones R1 to R4 that include existing settlement zones (integrating existing villages), low-rise, low-density developments, medium to high density (single to multifamily dwelling units), and high-density apartment zones, planned along the riverfront within the central business district.
- **Commercial (C) zone:** Multiple commercial zones, C1 to C6, allocate space for town centres, neighbourhood shops and business parks. Special mixed-use “C2- community commercial zones” permit small-scale retail and offices within residential areas. The Central business district zone, C6, represents a high-rise commercial zone in the downtown area to create an iconic city centre. About 7.84% of commercial land has been allocated for mixed use development.

- **Institutional (I) zone:** Comprises land parcels for strategic government institutional projects like the Legislative Assembly, Secretariat, State Departments and other government offices.
- **Infrastructure Reserve:** To enable the government in securing land for strategic infrastructure and transportation projects. It includes large scale transport utilities like bus terminal, metro depot as well as large scale infrastructure utilities like water treatment plants (WTPs), sewage treatment plants (STPs), and electrical substations.
- **Industrial zone:** It is proposed to house clean and non-polluting industries along with IT/ITeS corridors, financial and R&D clusters within Amaravati. A mega food processing park and electronic manufacturing cluster are also envisaged. The Industrial zone is further categorized into 3 zones: 1) Business Park Zone 2) Industrial Zone 3) Logistics Zone

2.8.4 Heritage and Tourism

Cultural heritage forms an integral part of the master plan. Existing religious and historical assets are planned to be protected and showcased.

- **Tourism Circuit:** A religious and heritage circuit is planned linking temple sites within Amaravati, the planned Buddha Statue, Undavalli Caves, Vasudhara Falls and other attractions. Interpretation facilities and museums will highlight the region's 2,200-year Buddhist heritage.
- **Temple Hub:** Amaravati is planned as a "Temple Tourism" hub, leveraging and connecting existing village temples. A heritage zone with village walkways that integrate living temples and community sites is planned.
- **Eco-tourism:** Natural features (river islands, Kondapalli/Undavalli hills) are to be developed as eco-cultural nodes. Flood zones have been identified and designated for non-intensive land uses such as parks and open space.
- **Identity:** Iconic architecture (e.g. legislative complex, convention centre) and public art will reflect local history and create a memorable skyline. The plan enforces conservation of historic village cores even as they gain infrastructure, ensuring development "respects and supports the rich cultural and religious heritage".

2.8.5 Environmental Integration

The framework for Amaravati's sustainable development focuses on integration of existing natural systems—land, water, vegetation, and air—into the urban fabric, ensuring ecological balance, resilience to climate change, and quality of life for residents. The master plan has set a goal to "create a clean, healthy vibrant city with well protected environment which supports a sustainable society and economy"

The primary objectives are:

- Preserving the region's natural assets valuable to the public
- Minimize environmental degradation during urbanization based on scientific well-informed decisions and be the authoritative advocate for the environment

- Promote climate-sensitive infrastructure and design including the climate responsive buildings adhering to the global standards such as GRIHA and LEED, at least 10% of urban farming, decentralized wastewater management, solid waste management, constructed wetlands

The APCRDA has defined various strategies and measures to conserve the diverse environmental features of the region. The key strategies include:

- **Green-Blue Network:** A comprehensive system of parks, green corridors, and water bodies is planned to promote ecological continuity and improve stormwater management. A large open green space is planned at the city centre housing a large water reservoir, will collect the rainwater from the various city canals, and channelize the water to other water bodies.
    - Primary green spaces spanning about 3,165 hectares (Ha) are planned along the existing canals and water bodies to serve as city's main ecological corridors
    - 505 Ha of secondary green spaces are planned through the townships connecting the various town and neighbourhood parks mostly aligned to the arterial roads. These are passive recreational spaces, jogging trails and non-motorized transport corridors across the city.
- **Infrastructure and land use regulation:** Environmentally sensitive zones—including wetlands, riverbanks, and forests are protected through land use restrictions and designated conservation zones. Recreational facilities of about 560 Ha such as stadiums, multi-purpose halls, sports hubs, theme parks, golf courses are proposed close to the green-blue network.
- **Krishna River Protection:** Strategies are proposed to conserve the river and its catchment area. Projects that leverage the river's ecosystem services are planned. A network of water taxis is also proposed to connect eco-tourism attractions on the cluster of islands on river Krishna. Strict land use and zoning regulations are in place to protect the river.
- **Pollution Management**: Guidelines are in place to manage air, water, and noise pollution. These include buffer zones near industrial areas, sewage treatment systems, and clean energy promotion.

2.8.6 Climate Resilience and Sustainable Development Strategies

The Master Plan also defines sustainable development strategies that are to be adopted across Amaravati.

- **Promotion of Green buildings and infrastructure:** All public and private developments are encouraged or mandated to meet green building certifications. Renewable energy-based solutions such as solar, wind, and biomass energy will be adopted and promoted to reduce lifecycle emissions from built-up infrastructure.

  Mandatory provisions such as rainwater harvesting systems, decentralized wastewater treatment and reuse will be integrated in the building regulations.
- **Stormwater and Flood Management:** To manage flood in flood prone areas various strategies are designed including infrastructure such as retention ponds, recharge wells, and improved drainage systems to manage monsoon run-off.
- **Urban Forest and Tree Cover:** Large-scale tree plantation and preservation of existing vegetation will be prioritized to mitigate urban heat and maintain air quality.

2.9 Disaster Management

Abutting the Krishna River and its flood plain, Amaravati is susceptible to riverine flooding during the rainy season. A robust disaster and vulnerability assessment was conducted and preventive and mitigative measures are suggested in the Environment Management Plan prepared as part of the Environment Impact Assessment (EIA) conducted in 2015.

A Disaster Management Plan was also proposed as part of the EIA, including guidance on the formation of 'Disaster Management Committee', to monitor, steer and mitigate potential disasters.

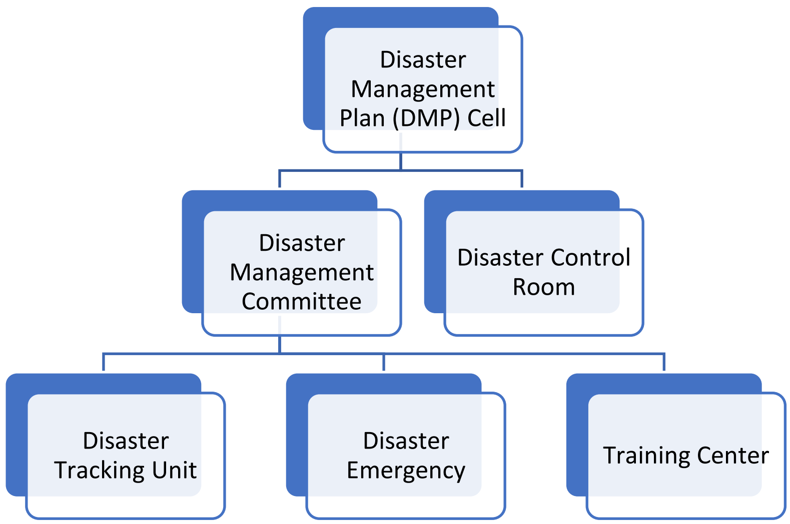

Figure 2-9 Organizational Structure for Disaster Management
Source: EIA & EMP of Amaravati Capital City, APCRDA, September 2015.

The proposed organizational structure for disaster management is shown in Figure 2-9.

Flood Management Plan: A detailed flood management plan was also prepared by the APCRDA based on the recommendations and assessments provided by National Green Tribunal (NGT) and EIA conducted thereafter. The plan provides details on past flooding occurrences and provides current situation as well as future projections. Flood mitigation measures including infrastructure planning, stormwater drains networks, canal networks, reservoirs, flood water pumping stations, among others, have been detailed out along with cost estimates. Refer section 3.3 for further details.

3 Urban System Gap Analysis

3.1 Water Supply

Existing Situation

The primary source of surface water in the capital city area is the Krishna River. The Rural Water Supply and Sanitation (RWSS) department is the nodal agency in the state for providing drinking water and sanitation facilities in rural areas. As of 2024, the RWSS department sources water from the Krishna River and treats it to provide 13 million liters per day (MLD)[20] of water supply to 25 villages and the Mangalagiri-Tadepalli Municipal Corporation (MTMC) areas falling within the Amaravati jurisdiction. The quality of piped water supplied meets the standards. . Village settlements also depend on groundwater extracted through borewells to meet their water requirements. For drinking water, some of the settlements in Harishchandrapuram and Venkatapalem buy RO water from NTR Sujala plants.

Proposed Water Supply

The water supply system for Amaravati is planned to meet the projected water demand of 925 MLD in 2058. The city's projected water demand has been estimated based on assessment of anticipated demographic growth and development and using Central Public Health & Environmental Engineering Organization (CPHEEO) norms. Residential water demand has been estimated using the projected population for 2058 and applying a standard water demand rate of 150 litres per capita per day (lpcd). Commercial and institutional demand is estimated based on the anticipated workforce population, with an estimated demand rate of 45 lpcd. For industrial areas, water requirements have been estimated at 35,000 litres per hectare per day. Floating population demand has been included at 5% of the total population, with 2.5% assumed to need 45 lpcd and the remaining 2.5% around 15 lpcd. In addition, system losses are factored in at 15%, which includes 10% for unaccounted-for water, 2% for transmission losses, and 3% loss at the water treatment plants (WTPs). Additionally, the water requirement from the three Startup Area zones has also been incorporated to project the water demand.

Table 3-1 Projected Water Demand in Amaravati over the Time Horizon 2028-2058

Year	Projected Water Demand (MLD)
2028	141
2043	412
2058	925

Source: ICLEI South Asia estimates based on Final DPR water supply, ADCL, 2025

A two phased approach is adopted to meet the city's water demand; phase I will cater to the demand until 2043 (2028-2043) and phase II will meet the demand until 2058 (i.e. from 2043-2058). Figure 3-1 provides an overview of the plan for Amaravati's water supply system from source to consumer.

[20] Estimated based on an average per capita water supply of 70 litres per capita per day (lpcd) by the Rural Water Supply and Sanitation Department, excluding groundwater sources

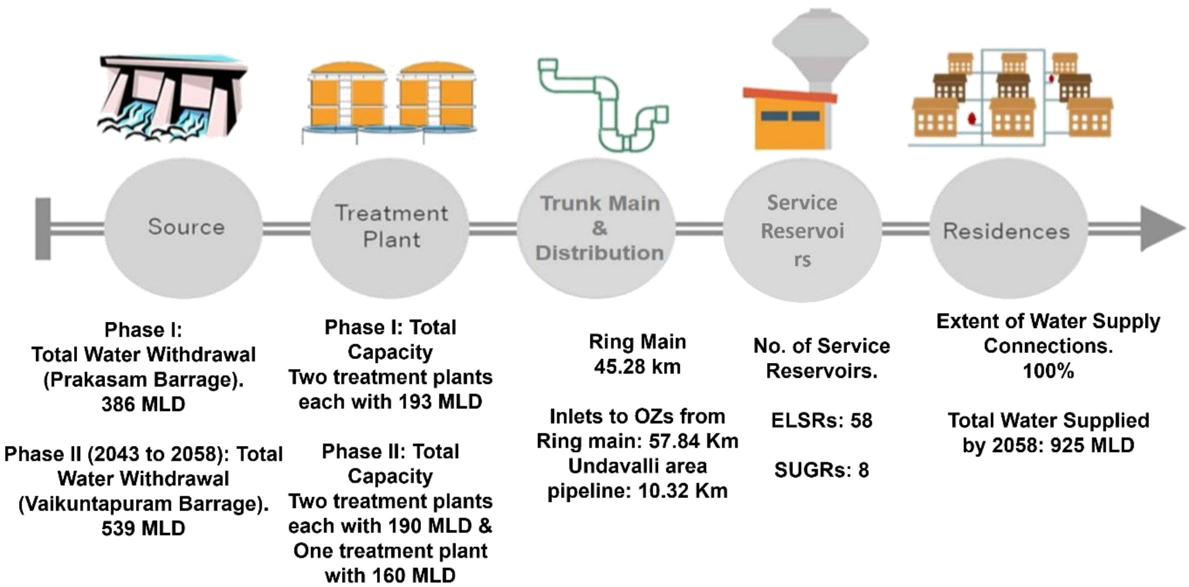

Figure 3-1 Water distribution from source to consumer in Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA.

3.1.1 Water Sources

The Krishna River is the primary water source for the city. Two intake wells have been proposed for water withdrawal. In Phase I, it is proposed to lift 386 MLD from Prakasam Barrage intake well to meet the city's water demand until 2043. In Phase II, the proposed Vykuntapuram Barrage, designed for a storage capacity of up to 10 thousand million cubic feet (TMC), will cater the additional projected water demand of 539 MLD by 2058.

For the initial 15 years from 2028 to 2043, water will be drawn from the backwater storage of Prakasam Barrage to cater to the demand of the city. In the second phase, from 2043 to 2058, the plan is to supply water from both the proposed Vykuntapuram Barrage and the Prakasam Barrage.

In addition, considering the long-term sustainability of water supply, diversion of water from the River Godavari on completion of the Polavaram project is also planned, which will help balancing water demand during peak season or during other conditions of exigency.

Table 3-2 Water Source Capacities Phase-wise

Phase	Source Location	Supply Capacity (MLD)	Key Infrastructure
Phase I (2028-2043)	Prakasam Barrage	386	Intake wells, pump house, raw water transmission mains
Phase II (2043-2058)	Vykuntapuram Barrage	539	Proposed barrage with storage facilities

Source: Final DPR water supply, ADCL, 2025

3.1.2 Water Treatment

The water treatment design for Amaravati adopts a modular and technologically advanced approach to ensure water quality meets the World Health Organization (WHO) standards. For Phase I, the WTP is planned at Venkatapalem, with a total designed capacity of 386 MLD, comprising two modules of 193 MLD each. The first phase treatment incorporates sophisticated technology for rapid and efficient clarification using plate settlers, complemented by rapid sand gravity filtration and efficient disinfection. This modular approach allows the future expansion or upgradation of water treatment capacity as the city grows.

In Phase II, treatment facility at Borupalem will be added, to handle the additional demand. This facility will comprise three modular units: two units with a capacity of 190 MLD each and a third unit of 160 MLD, designed to scale with the city's expanding demand. This phase will integrate innovative features such as zero liquid discharge (ZLD) for water reuse and enhanced automation through Supervisory Control and Data Acquisition (SCADA) systems. These integrations will help automate operational processes while also facilitating continuous monitoring and real-time adjustment of treatment parameters to maintain high water quality.

Table 3-3 Water Treatment Plant Capacities

Phase	WTP Location	Capacity (MLD)	Treatment Technology
Phase I (2028-2043)	Venkatapalem	386 (2 modules of 193)	Plate Settlers, Rapid Sand Gravity Filters, Disinfection
Phase II (2043-2058)	Borupalem	539 (2 modules of 190 and 1 module of 160)	Zero Liquid Discharge (ZLD), Advanced SCADA-based control

Source: Final DPR water supply, ADCL, 2025

3.1.3 Transmission and Distribution Network

Treated water will be supplied through a direct-pumping transmission and distribution network that guarantees round the clock supply, i.e. 24x7 supply. The system is engineered to minimize energy losses and maintain a consistent residual pressure at consumer endpoints. In Phase I, raw water will be conveyed via ductile iron and mild steel pumping mains with diameters in the range of 2000 to 2500 mm. The clear water will then be transmitted from the treatment plants via dedicated clear water mains—approximately 1.2 km in length in Phase I—to a ring main that extends across 45.28 km, thereby providing a central backbone for distribution.

The ring main will be a critical element of the network as it not only ensures rapid and equitable distribution of water to the various parts of the city but also provides multiple tapping points and connection zones. There will be 24 tapping points that serve as nodes that feed into 66 operational zones (OZs), which will further be supported by 58 elevated service reservoirs (ELSRs) and 8 semi-underground reservoirs (SUGRs) for flexible demand management. In Phase II, additional pipeline extensions and pumping mains are planned to reinforce the network's resilience, while the basic design of the ring main remains similar to that of Phase I.

Table 3-4 Transmission & Distribution Components

Component	Phase I	Phase II
Raw Water Pumping Main	Approximately 2.66 km	Approximately 7.50 km
Clear Water Transmission Main	Approximately 1.2 km	Approximately 3.29 km

Component	Phase I	Phase II
Ring Main	45.28 km	Same as Phase I (expanded as required)
Operational Zones (OZs)	66 zones	Expanded based on demand
Storage Tanks (ELSRs & SUGRs)	58 ELSRs + 8 SUGRs	Additional units as per demand

Source: Final DPR water supply, ADCL, 2025

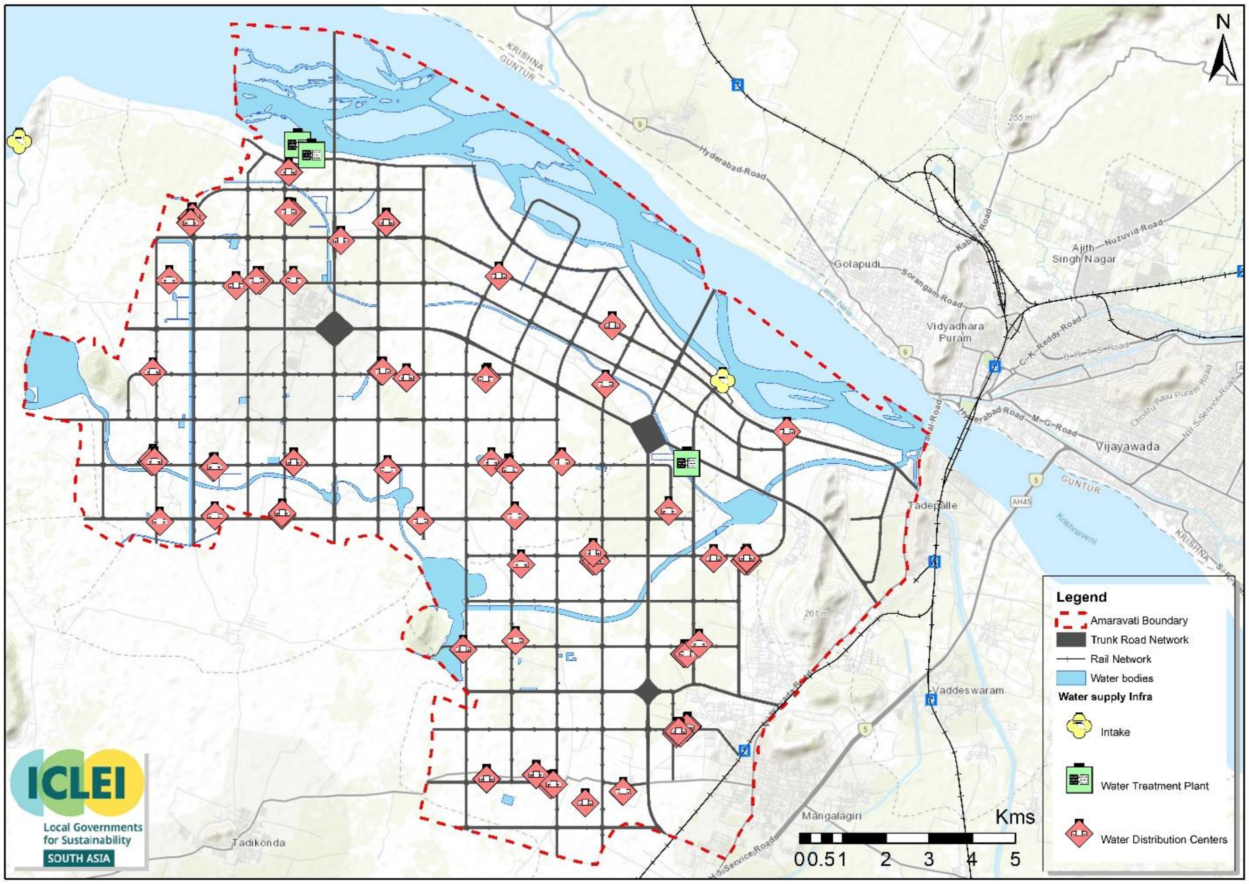

Figure 3-2 Proposed Water Supply infrastructure for Amaravati, 2058
Source: Prepared by ICLEI South Asia based on data received from APCRDA.

3.2 Wastewater Management

Existing Situation

Existing settlements, including around 46,224 households,[21] generate about 10.3 MLD[22] of wastewater in 2024. All the households are currently dependent on individual septic tanks . Desludging of the septic tanks is carried out by private operators . Instances of emptying collected fecal sludge into open fields and

[21] Estimated based on the average household size of 4

[22] Wastewater generation has been estimated based on the assumption that 80% of the total water supply (13 MLD), after accounting for losses, is discharged as wastewater

vagus/natural drains is in practice by a few desludging operators. During the active period of agriculture, some of the farmers were using this fecal waste as manure in the fields.

Proposed Wastewater Management

The wastewater management system in Amaravati is designed as a fully decentralized, zoned network aimed at providing comprehensive wastewater collection, treatment, and reuse or safe disposal. The city is divided into 13 sewerage catchments, including 12 for domestic wastewater and one dedicated zone for industrial effluents. Each zone is planned with its own Sewage Treatment Plant (STP) or Common Effluent Treatment Plant (CETP) to decentralize treatment operations and reduce the need for long-distance conveyance systems.

The system has been designed in alignment with CPHEEO 2013 guidelines on the Manual on Sewerage and Sewage Treatment Systems and incorporates gravity-based flow principles wherever possible. Amaravati's wastewater management system will be entirely separate from its stormwater network and will be implemented in two major phases to synchronize with urban development timelines.

3.2.1 Wastewater Generation

By the planning horizon year of 2058, Amaravati's projected water demand is estimated to be 925 MLD, based on anticipated residential, commercial, institutional, and industrial development. Correspondingly, the total wastewater generation is expected to reach 723 MLD[23]. These estimates are based on land use zoning, population density norms, and projected occupancy across the city area, as outlined in the master plan, and includes domestic, non-domestic and infiltrations from all planned activity zones.

Table 3-5 Projected Wastewater Generation in Amaravati, 2028-2058

Year	Projected Wastewater Generation (MLD)
2028	113
2043	319
2058	723

Source: ICLEI South Asia Analysis based on Final DPRs for Water and Wastewater, ADCL, 2025

3.2.2 Wastewater Network Infrastructure

The total length of the trunk sewer network is planned to be 1,035 km, covering the entire jurisdiction of Amaravati city. The network will comprise the following key components:

- 58 intermediate sewage lifting stations (ISLS)
- 1 main pumping station per zone
- Pipe diameters ranging from 200 mm to 1800 mm
- Design period: up to 2058, with an interim milestone in 2043

Table 3-6 Design Considerations of Sewerage Infrastructure in Amaravati

Parameter	Value
Total Area Covered	217.23 sq. km

[23] Wastewater generation for Amaravati has been calculated by assuming that 80% of the water supplied, after accounting for losses, is discharged as wastewater. To meet CPHEEO norms, an additional 10% of the estimated wastewater has been added to account for possible groundwater infiltration, resulting in the final wastewater generation figure.

Total Sewerage Zones	13 (12 STPs + 1 CETP)
Total Sewer Length	1,035 km
Number of Intermediate Lifting Stations (ISLS)	58
Design Period	30 years (up to 2058)
Diameter of Sewer Lines	200 mm to 1800 mm

Source: Final DPR Wastewater, ADCL, 2025

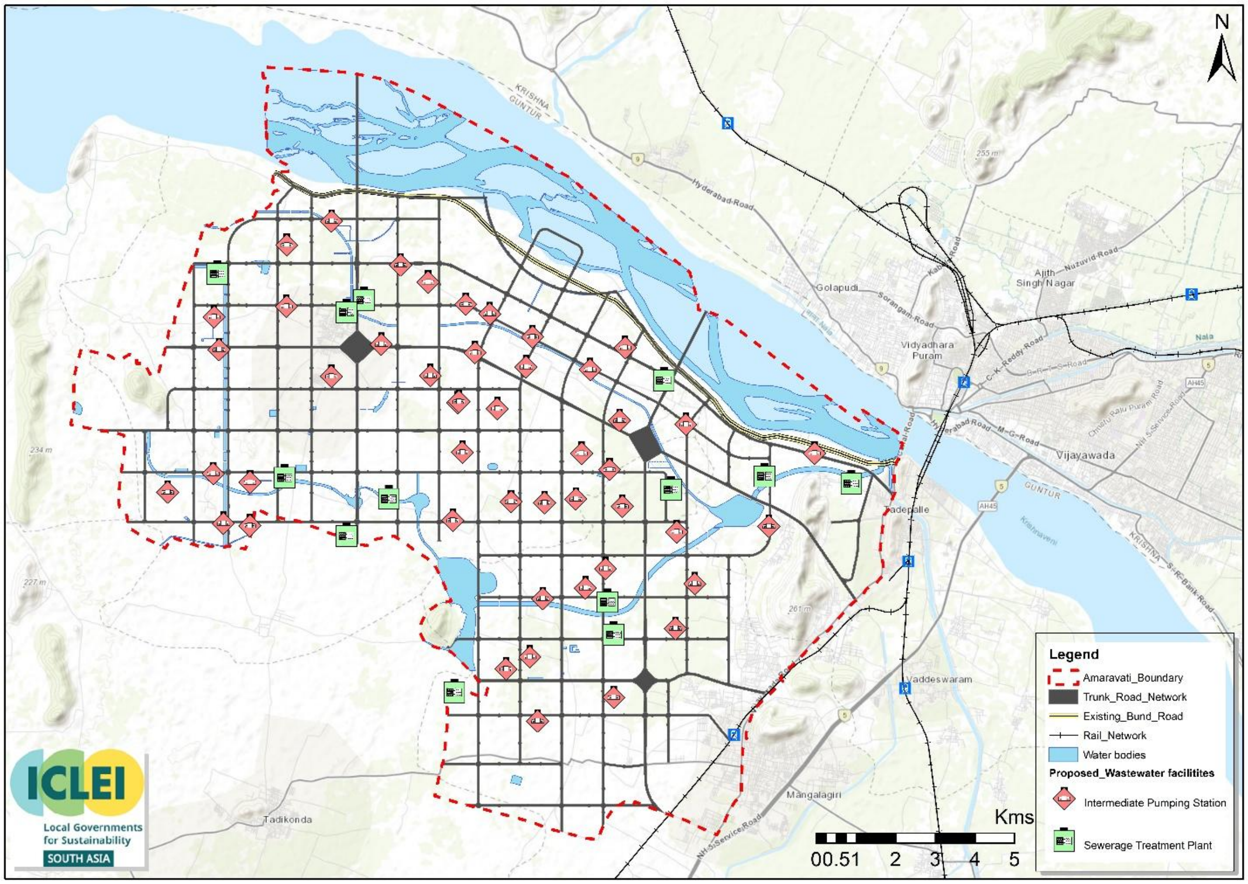

Figure 3-3 Proposed Sewerage infrastructure for Amaravati, 2058

Source: Prepared by ICLEI South Asia based on data received from APCRDA.

3.2.3 Treatment Plants and Technology Options

A total of 12 STPs and 1 CETP are proposed for treatment of Amaravati's anticipated domestic and industrial wastewater generation. The CETP is designated to be located in zone 12A, which houses industries. The STPs are proposed to be modular and designed for scalability. Deployment of the wastewater management infrastructure is structured into two phases:

- **Phase I (up to 2043)** will include the complete sewerage network, all intermediate sewage lifting stations, main pumping stations, and the initial modular capacities of all STPs (a total of 284 MLD) and CETP (35 MLD).
- **Phase II (2043–2058)** will focus on expanding the treatment capacities at each STP (to a total of 586 MLD) and CETP (53 MLD) to cater to projected wastewater generation.

Table 3-7 Zone-wise STP and CETP Treatment Capacities in Amaravati (Phase I and II)

Zone	STP/CETP	Phase I Capacity (MLD) (2043)	Phase II Capacity (MLD) (2058)
Zone 1	STP	16.8	33.6
Zone 2	STP	12.3	24.6
Zone 3	STP	37.2	74.4
Zone 4	STP	6.59	13.18
Zone 5	STP	37.14	74.28
Zone 6	STP	8.16	16.32
Zone 7	STP	18.02	36.04
Zone 8	STP	9.08	18.16
Zone 9	STP	46.54	93.08
Zone 10	STP	31.23	62.46
Zone 11	STP	8.32	16.64
Zone 12	STP	52.68	71.12
Total STP		**284.06**	**586.56**
Zone 12A	**CETP**	**35.56**	**52.69**

Source: Final DPR Wastewater, ADCL, 2025

The wastewater treatment capacity presented in Table 3-7 reflects estimates from an earlier planning scenario. The city envisions a modular approach to infrastructure development to meet future increases in demand, aiming to achieve 100% wastewater network coverage and treatment. Accordingly, the capacities presented are indicative and subject to change.

Amaravati's wastewater management strategy is organized across four key components: collection, treatment, treated effluent disposal, and sludge management. Based on a life cycle cost (LCC) analysis, three technologies have been recommended for the proposed STPs, including: sequencing batch reactor (SBR) technology, anaerobic-anoxic-oxic process (A2O), and moving bed biofilm reactor (MBBR). Final technology selection will depend on the intended end use of the treated wastewater and compliance with discharge norms.

3.2.4 Treated Wastewater Reuse and Disposal Plan

By 2058, total wastewater generation is projected to reach 723 MLD. 100% of the wastewater is expected to be treated through decentralised STPs installed on a modular basis to cater to the wastewater generation. Treated wastewater is intended for reuse in applications such as urban irrigation, landscaping, and district cooling, with an estimated requirement of 193 MLD[24]. The remaining treated wastewater of 386 MLD[25] will be discharged into the Palavagu and Kondaveeti Vagu navigational canals. Prior to both reuse and discharge, disinfection will be carried out using chlorine to ensure effluent safety, as the water discharged into vagus

[24] Wastewater DPR report for Amaravati city 2025

[25] 80% of the wastewater is the expected volume of wastewater after the treatment from STPs, which is 579 MLD. The remaining wastewater is the subtraction of the volume of wastewater from STPs (579 MLD) and treated wastewater for reuse (193 MLD)

will eventually reach the Prakasam barrage, which is the surface water source for Vijayawada, Guntur, and Amaravati.

3.2.5 Supervisory Control and Data Acquisition (SCADA) Integration

Amaravati's wastewater network will be fully SCADA-enabled, supporting 24/7 centralized monitoring through the Central SCADA Monitoring Centre (CSMC) located at Zone-1 STP. Equipment at each lifting station and STP will include:

- Programmable logic controllers (PLCs)
- Manual override systems
- Online monitoring of power consumption, flow, and energy recovery
- Redundant remote interfaces and UPS systems
- Data transmission via optical fiber cable (OFC) and GPRS

The system enables real-time monitoring, error logging and energy management through the Central Command and Control Centre which serves as the digital foundation of Amaravati's sewerage system.

3.3 Stormwater Management

Amaravati city falls within the catchment area of Kondaveeti Vagu and Pala Vagu (421 sq. km), the two major water streams flowing through the city. Located along the banks of the River Krishna, the capital city area is susceptible to riverine flooding.

The natural discharge flow of Kondaveeti Vagu and Pala Vagu into the River Krishna is obstructed by the existing bund, its regulating mechanism, and the operations of the Prakasam Barrage. The area surrounding the Kondaveeti Vagu is especially susceptible to pluvial flooding. In the prevailing conditions, the catchment area is susceptible to severe flooding and frequent inundations every year during the monsoon season, primarily due to the overflow of the Kondaveeti Vagu and its local streams, Kottela Vagu and Pala Vagu, which join the Kondaveeti Vagu at various points.

Existing Situation

The Amaravati city area currently lacks a dedicated stormwater drainage system. In villages with a surface wastewater network, the runoff flows through the surface wastewater network that connects with either Kondaveeti Vagu or Pala Vagu. In villages with no surface drainage network, runoff follows natural drainage network .

Annually, both Kondaveeti Vagu and Pala Vagu overflow during the monsoon season for about 4 to 5 days, disrupting connectivity between villages. The construction of a pumping station at Undavalli to lift runoff into the barrage during periods of higher water levels in the Prakasam barrage has significantly reduced flooding in the Kondaveeti Vagu catchment, which previously experienced backwater flooding. Instances of flooding have increased due to the failure in the timely execution of maintenance of vagus, such as desilting and hyacinth removal.[26]

[26] Information shared in focus group discussions were conducted by ICLEI South Asia in six villages of Rayapudi, Borupalem, Neerukonda, Velagapudi, Krishnayapalem, Penumaka and in the Babunaiahnagar colony of MTMC

Proposed Stormwater Drainage

The transition of land use from agriculture to an urban environment that will happen over the course of Amaravati's development can potentially increase peak runoff, early peak flow rate and higher runoff volumes downstream. The design and planning of the capital city area's stormwater drainage and flood mitigation infrastructure has been based on the future scenario in which the city is fully developed.

3.3.1 Proposed City-level Stormwater Drainage System

The city's proposed stormwater drainage system is being designed and built to withstand rainfall events with a return period of up to 1 in 100 years, minimizing the potential impact of flooding.

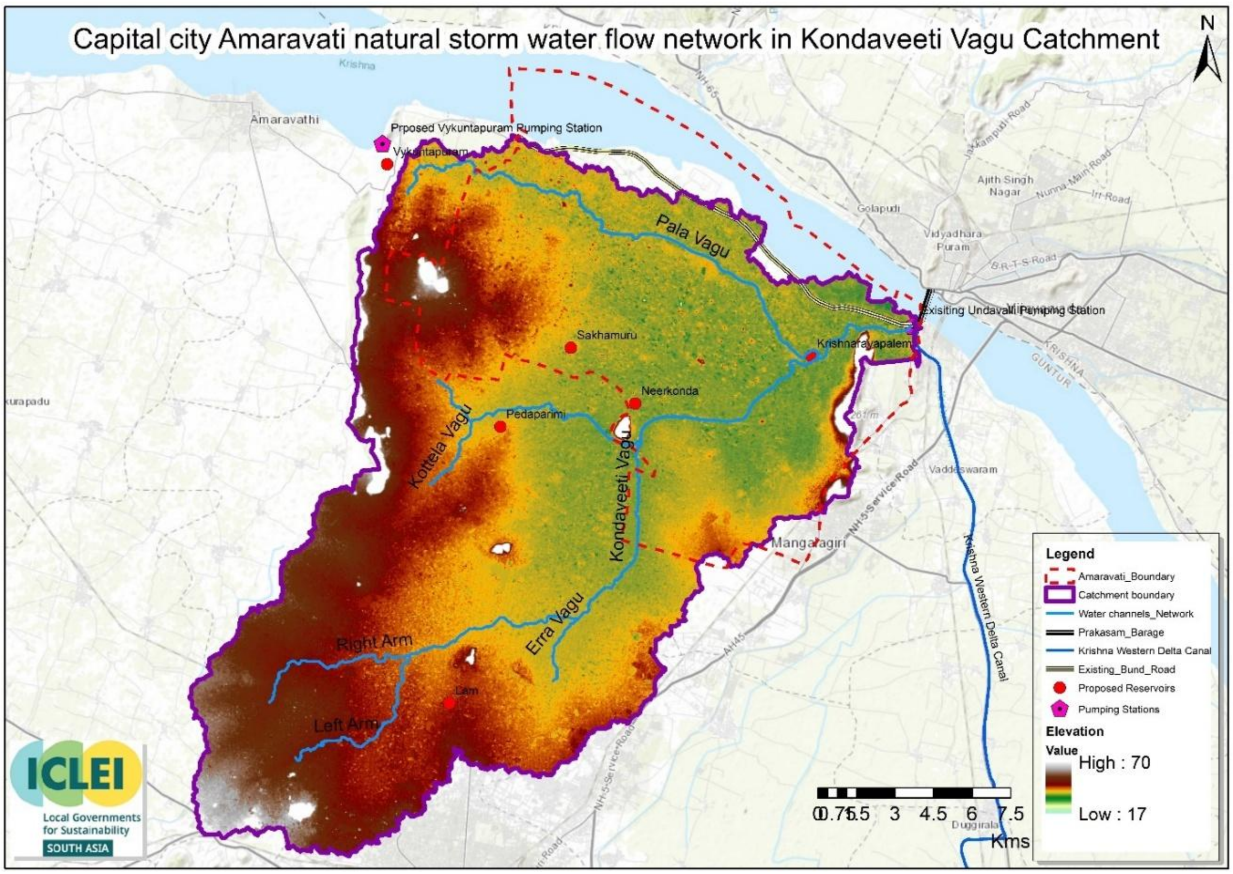

Figure 3-4 Kondaveeti Vagu catchment and natural drainage features

Source: Prepared by ICLEI South Asia based on data received from APCRDA.

Using IMD's historical rainfall data recorded at 15-minute intervals, intensity-duration-frequency (IDF)[27] curves have been developed for a 1-in-200-year return period rainfall event. This serves as the basis for designing the stormwater network in the city.

The underlying concept for planning the city-level storm water network is to align with the natural drain network following the Kondaveeti Vagu and Pala Vagu. Measures are in place to widen and deepen

[27] IDF curve is a tool in hydrology and urban drainage design that represents the relationship between Rainfall intensity, Rainfall duration and Rainfall frequency of such an event. These IDF curves are used to design stormwater infrastructure like culverts, drains, and detention basins.

Kondaveeti Vagu and its tributary drains to manage the stormwater runoff generated on completion of Amaravati's development. Additionally, the construction of five reservoirs is planned, three outside the capital city—Lam, Pedaparimi, and Vykuntapuram—and two within the capital city—Neerukonda and Krishnayapalem[28].

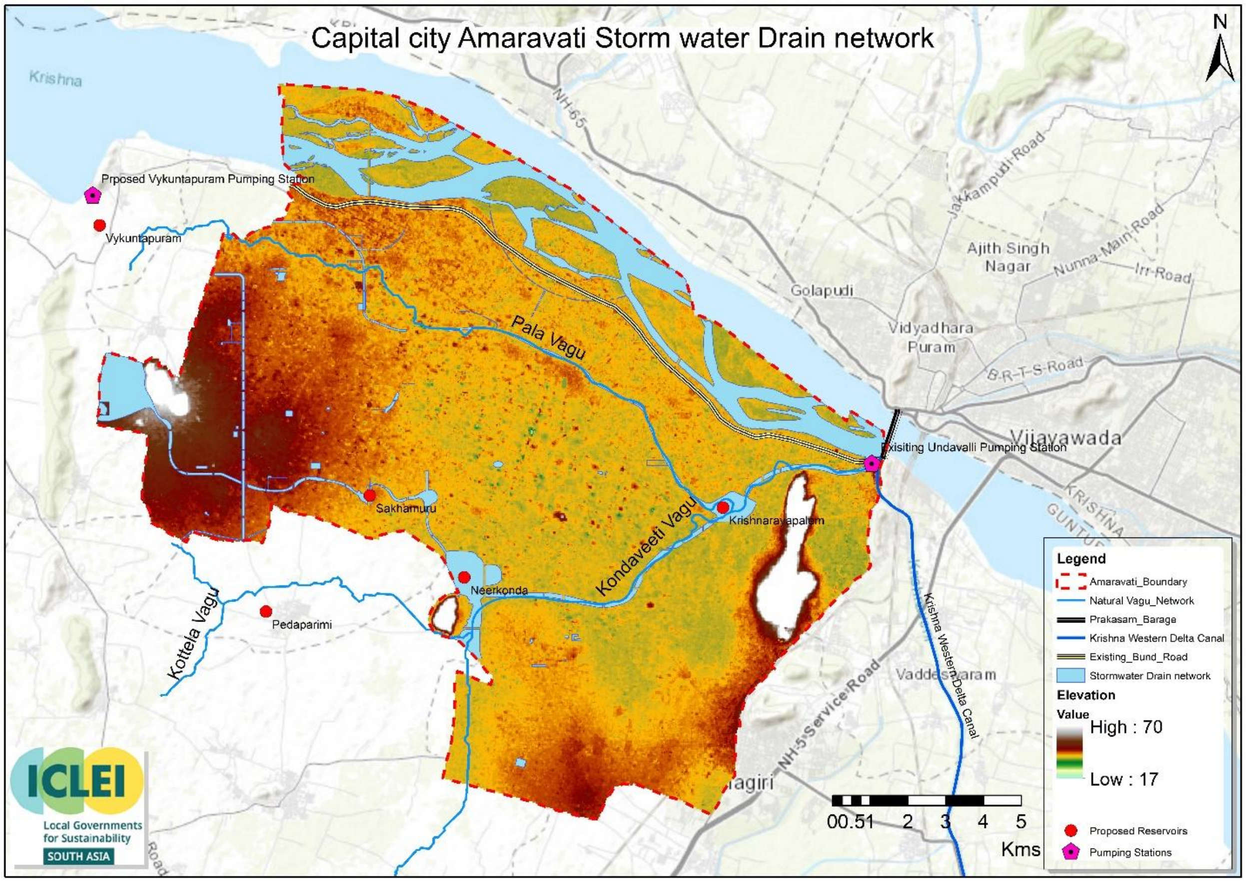

Figure 3-5 Proposed Reservoirs and Pumping Stations of Storm water infrastructure
Source: Prepared by ICLEI South Asia based on data received from APCRDA.

The city's stormwater management system is designed to align with the natural drainage patterns of Kondaveeti Vagu and Pala Vagu. Runoff from the upstream area of the Kondaveeti Vagu catchment (190 sq. km), reaching the Lam Reservoir, along with the runoff from the western catchment area of Kondaveeti Vagu will be channelled to the proposed reservoirs at Pedaparimi and Vykuntapuram via a gravity-based canal system, ultimately discharge 5,650 cusecs of runoff into the Krishna River, facilitated by pumping stations planned at Vykuntapuram.

The flood discharge from the downstream area of the Kondaveeti Vagu catchment, after the Lam Reservoir, follows the natural flow network of the Kondaveeti Vagu and reaches the outfall at the Undavalli sluice. A total of 4,000 cusecs of runoff from the Kondaveeti Vagu will be diverted through the existing escape

[28] DPR for Flood Management for Capital city Amaravati, June 2017.

regulator at the Undavalli Sluice to the Krishna Western Delta Canal. By enhancing the pumping infrastructure at the Undavalli, the remaining runoff will be discharged into the Prakasam Barrage.

3.3.2 Stormwater Drainage for LPS zones

The stormwater drainage network at the LPS level is designed for a rainfall with a return period of once in five years, which corresponds to a rainfall intensity of 46.75 mm/hr, in accordance with the standards set by the CPHEEO. The entire city is divided into six stormwater drainage basins, following the alignment of existing water bodies, natural drainage pathways, and proposed waterways, as illustrated in Figure 3-6. The stormwater runoff collected through the LPS infrastructure is directed into natural drainage areas and reservoirs at various locations, utilizing gravity flow[29].

Stormwater from the roofs and open areas of residential, commercial, and industrial developments is planned to be managed on-site, through downspouts and harvesting structures, reducing the volume of stormwater that enters the drainage system. Runoff from the roads enters the drainage network through horizontal grates located at specified intervals along the curbs. These grates will connect to drains below, which will allow fine silt and debris to settle in designated silt pits. This process will enable stormwater to flow freely through the system. Amaravati's stormwater drains will operate on gravity flow, from tertiary to secondary drains, with no requirement for any mechanical equipment.

The storm drains shall be located beneath the roads within a block, running along the carriageway to collect stormwater. Runoff collected flows into tertiary collector drains situated along all major arterial and sub-arterial roads, ultimately discharging into the vagu, either directly or through a secondary network of box drains. Stormwater drains will also be positioned beneath the cycle track along all trunk roads. The stormwater drainage network along the trunk roads measures 599 km, while that in the LPS zones and the Amaravati Government Complex measures 2,369 km.[30]

[29] Storm Water Management Final DPR for Phase I Infrastructure projects at Amaravati, February 2025
[30] Excluding LPS zone 8 and Zone 11

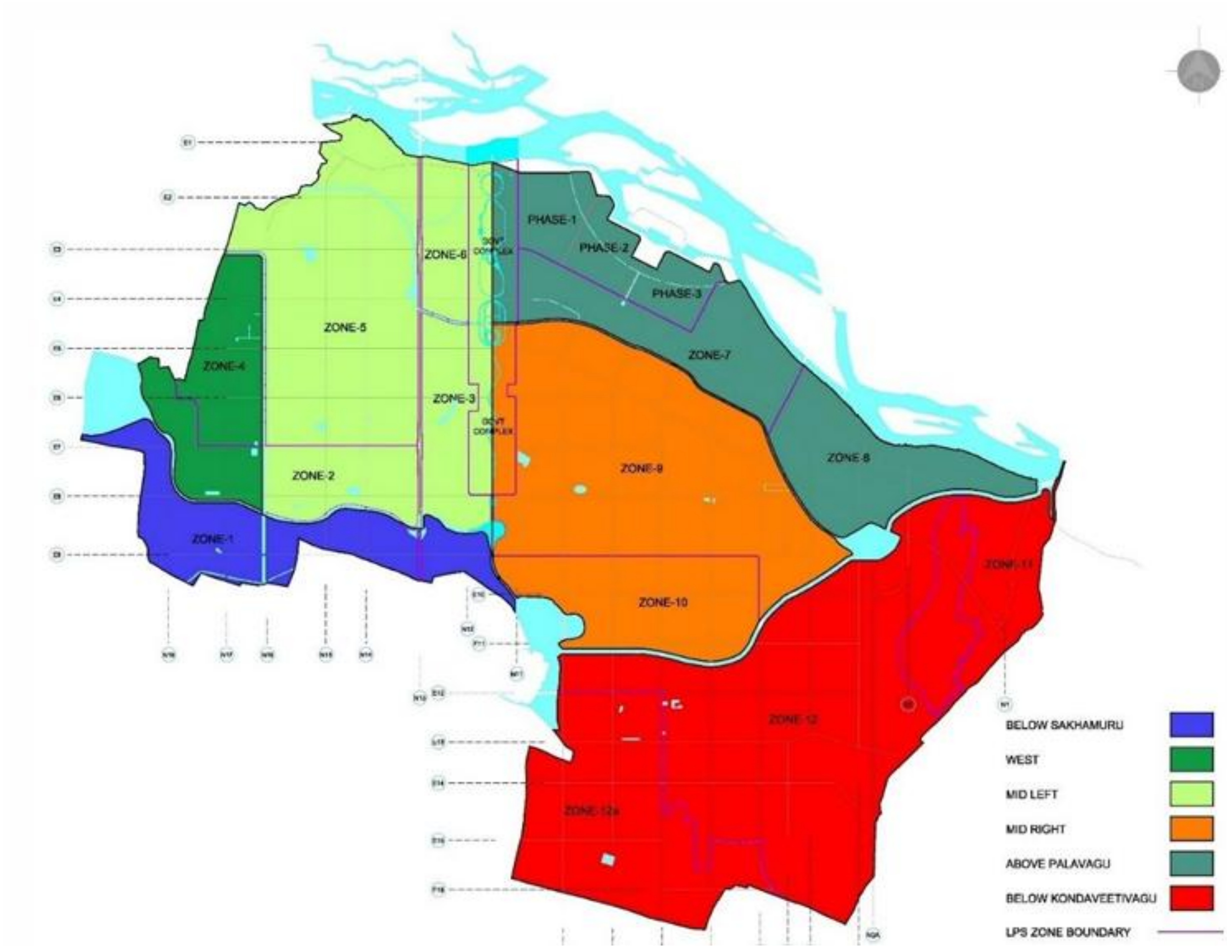

Figure 3-6 SWD zones

Source: Stormwater Management Final Detailed Project Report, ADCL, February 2025

3.4 Solid Waste Management

Existing Situation

Existing settlements in the capital city area are estimated to generate about 70 tonnes per day (TPD)[31] of solid waste as of 2024. 100% of the generated municipal solid waste in villages is collected and transported by APCRDA[32] to the waste-to-energy (WtE) plant for treatment located at Guntur. Solid waste generated within the MTMC area is also transported every day to the Guntur WtE plant for treatment by MTMC itself. At present, the capital city area does not have any waste treatment facilities . Before the establishment of WtE facility, MTMC and nearby settlements disposed of solid waste at the Kolanukonda disposal site, leading to accumulation of approximately 2.25 lakh metric tonnes of legacy waste. As of early 2024, 100% of the legacy waste has been remediated.

Proposed Solid Waste Management

[31] Per capita waste generation is estimated at approximately 0.38 kg per person per day based on the total waste generation and population figures sourced from APCRDA and MTMC. The per-capita figure is applied to existing population of 1,84,898 to estimate the total MSW generation of approximately 70 TPD

[32] APCRDA has engaged a contractor on buy/hire, own & operate (BOO) basis to collect mixed waste and transport it to Jindal waste-to-energy plant

Amaravati is estimated to generate 3,956 tonnes per day (TPD) of municipal solid waste (MSW) by 2058[33]. This includes about 2,028 tonnes will be wet waste (51%) and another 1,927 tonnes (49%) of dry waste including recyclables, combustibles and inert waste[34], basis waste composition for Hyderabad as Amaravati is planned to be a smart and capital city.

Table 3-8 Projected Waste Generation in Amaravati, 2028-2058

Year	Projected Waste Generation (TPD)
2028	527
2043	1,678
2058	3,956

Source: ICLEI South Asia Analysis

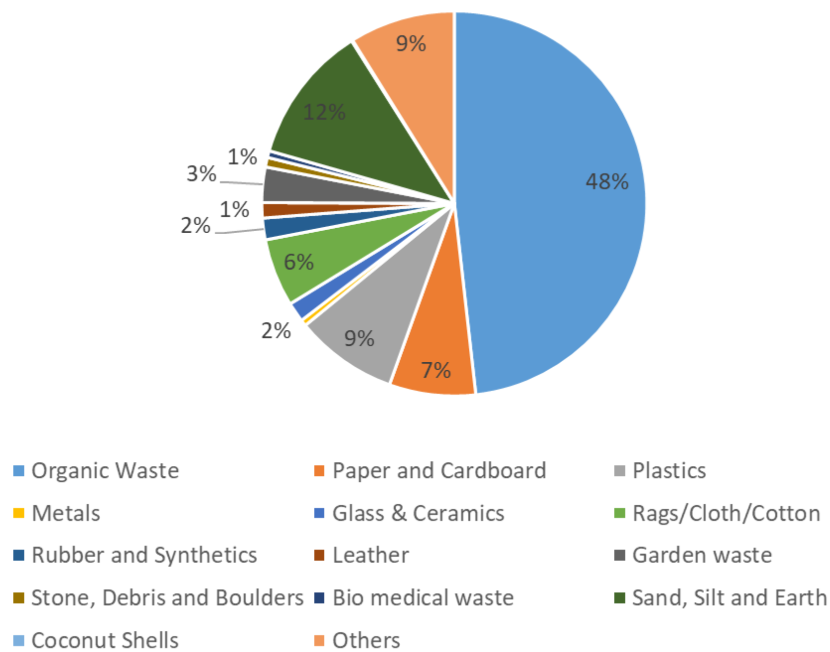

Figure 3-7 Expected waste composition in Amaravati

Source: Prepared by ICLEI South Asia based on data sourced from Solid Waste Master Plan, 2016

3.4.1 Waste Collection and Transport

Amaravati's integrated solid waste management is planned as a two-tier system for effectively collecting and transporting waste from every household in the city. The system is designed for its estimated population size until 2058, while reducing the impact on the environment. It proposes source segregation of waste, utilizing standardized, color-coded HDPE bins in accordance with EN 840 specifications. Residential areas will utilize a three-bin system—one for biodegradable (wet) waste, one for non-biodegradable (dry) waste, and one for domestic hazardous waste—while commercial, institutional, and passive areas (such as parks, gardens, and green spaces) are planned with a two-bin system. The segregated waste will be collected through a door-to-door collection service as well as automated systems for high-priority zones such as

[33] Total waste generation in the city for 2058 is estimated based on population projections for 2058 and per capita waste generation considered in the SWM Master Plan, 2016.

[34] Amaravati Solid Waste Master Plan, 2016

government complexes and the seed capital area. Primary collection vehicles—refuse compactors that have hydraulic bin lifts—are to be deployed along pre-determined routes.

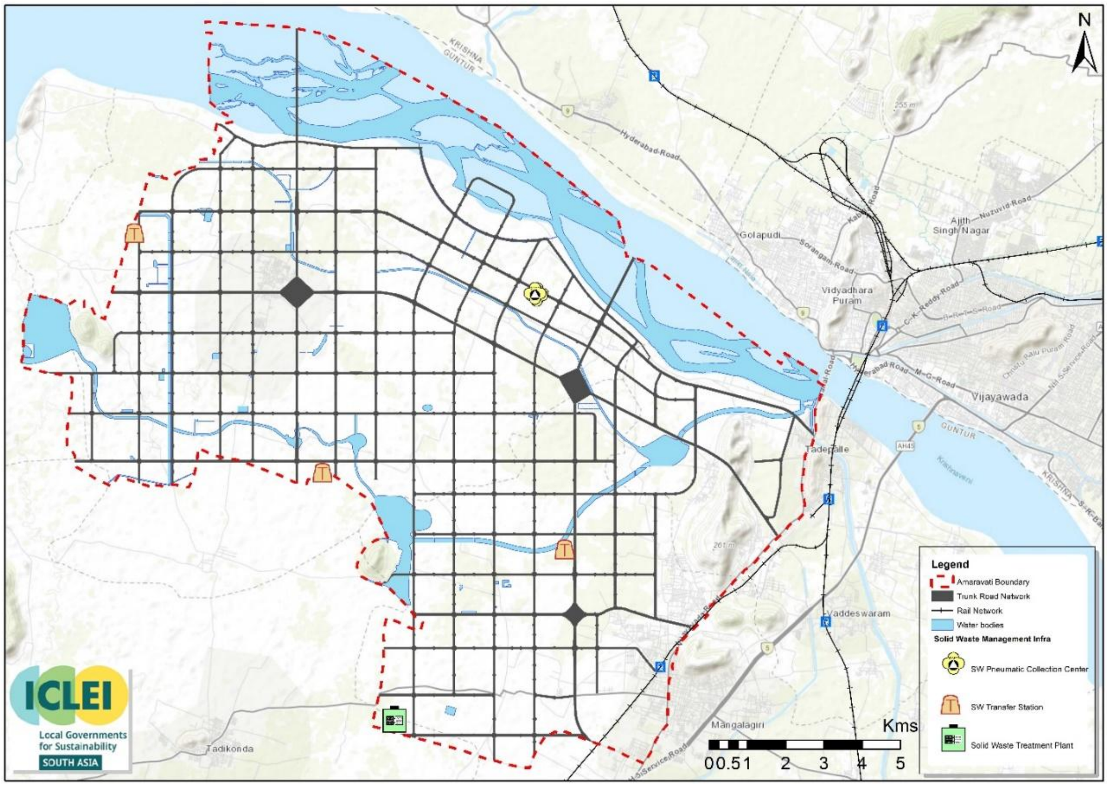

Figure 3-8 Proposed Solid Waste Management Infrastructure in Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA.

Waste transfer stations will act as intermediate nodes/secondary collection points. Waste collected through compactors will be mechanically compressed (i.e. compacted) and transferred to roll-on/roll-off containers for secondary collection at the transfer stations. Segregated waste will be compacted using stationary compactors with a processing capacity of 50 tonnes per hour. In addition, mechanical road sweepers will be deployed to clean the streets every day.

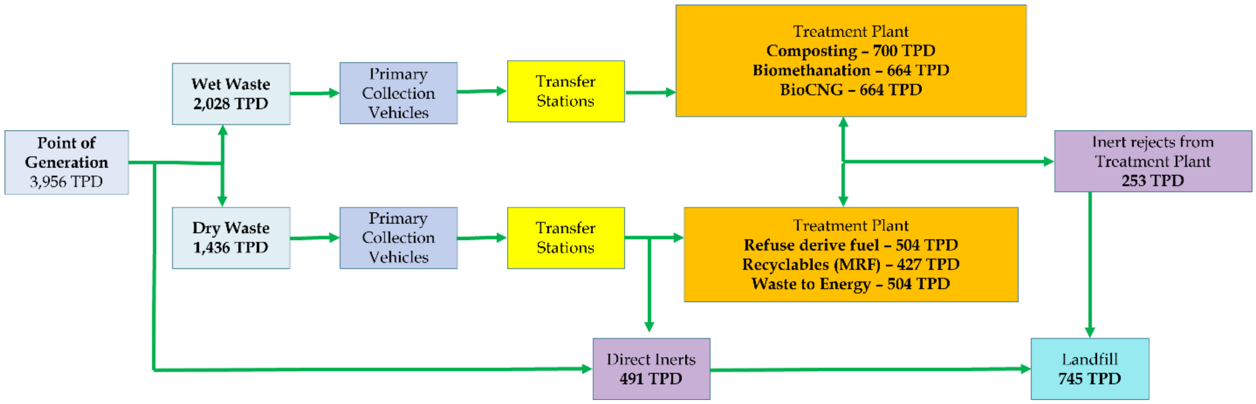

Figure 3-9 Proposed MSW Collection and Processing by 2058

Source: Chart prepared by ICLEI South Asia, data estimated by ICLEI South Asia in consultation with APCRDA[35]

3.4.2 Treatment, Processing and Disposal

When waste arrives at the transfer stations, it will be processed and treated before disposal, thus ensuring maximum recovery and reuse.

3.4.2.1 Wet Waste

Wet waste in Amaravati will be treated through a combination of biomethanation, composting, and waste-to-energy (WTE) technologies. Organic waste with high moisture content will be directed to bio-methanation plants, where it will undergo anaerobic digestion to produce biogas, which can subsequently be used for electricity generation. Yard waste or wet wood, unsuitable for bio-methanation facilities, will be diverted to windrow composting facilities, while the remaining wet waste will be sent to mass incineration type WTE plants.

As per the estimates by ICLEI South Asia, the treatment capacities include 1,328 TPD of bio-methanation and bio-CNG technology and 700 TPD will be treated through composting processes.

3.4.2.2 Dry Waste

Dry waste will be recycled at material recovery facilities (MRFs) located at bulk transfer stations, where recyclables such as plastics, metals, paper, and glass will be sorted and recovered. The recyclables will then be baled and stored after being recovered, before being transported to an authorised recycling facility. Non-recyclable dry waste will be compacted and transported to refuse derived fuel (RDF) plants. The RDF plants will take advantage of the remaining waste with high calorific values to produce alternative fuel which can be supplied to local industrial units such as cement manufacturing plants.

Of the total dry waste, 504 TPD[36] is planned to be converted into RDF, which then will be supplied further as an alternative fuel to industries. Additionally, 427 TPD of recyclables, including plastics, metals, paper, and glass are planned to be recovered through the MRF facility. Any excess dry waste that cannot be processed through RDF or recovered as recyclables is proposed to be diverted to the WTE plants.

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[35] ICLEI SA estimated treatment facilities quantities based on the values from Solid waste Master Plan, 2016 in consultation with APCRDA.

[36] Estimated by ICLEI South Asia based on the assumption that 50% of the non-recyclable RDF fluff is sent to WtE and 50% to cement kilns

3.4.2.3 Inert Waste and Rejects from Treatment Facilities

The residual inert and reject material from treatment plants will be disposed of at a sanitary landfill. The sanitary landfill will employ a composite liner system (clay liners and dense polyethylene geomembrane), leachate collection and drainage systems, as well as gas collection systems, which when used appropriately, can ensure safe disposal and minimal environmental impact.

Table 3-9 Projected Waste Generation by Waste Type, 2058[37]

S.No	Type of Waste	Generation Rate	Quantity for 2058
1.	Solid Waste (Municipal)		
a.	Residential	0.8kg/capita/day	3,196 TPD
b.	Commercial/Institutional	0.3kg/capita/day	481 TPD
c.	Passive areas	0.03kg/sq. m	278 TPD
2.	C&D waste (all through the construction phase)	50kg/sq. m	105.7 lakh tonnes
3.	Biomedical Waste	2kg/bed/day	5.33 TPD
4.	Hazardous Waste (Domestic)	1.2% of total residential waste	38 TPD
5.	Electronic waste	5% of total MSW	198 TPD

Source: Solid Waste Master Plan, 2016

3.4.2.4 Construction and Demolition (C&D) Waste

C&D waste is generated at every stage of a construction project including raw material extraction, building the structure, and finally, demolition or renovation. Based on a typical waste generation rate of 50 kg generated for every square meter of built-up area, Amaravati city is expected to generate roughly 105.7 lakh tonnes of C&D waste by 2058. Given the scale, recycling and reuse strategies for C&D waste will be essential to minimise environmental impacts.

3.4.2.5 Hazardous Waste

Hazardous wastes are toxic, reactive, flammable, or corrosive, and pose substantial risks to human health and the environment. Amaravati is projected to generate 38 TPD of hazardous waste by 2058, highlighting need for robust handling and disposal strategies.

3.4.2.6 Electronic Waste (E-Waste)

E-waste is one of the fastest growing waste streams and typically includes discarded electrical and electronic equipment that has become obsolete. In India, e-waste consists generally of iron and steel - 51% of the mass, non-ferrous metals - 13%, plastics - 21%, and miscellaneous materials. Amaravati is projected to generate around 198 tonnes of E-waste per day by the year 2058, which demonstrates the need for effective recycling and environmentally sound methods of disposal to meet the city's sustainable urban development goals.

3.5 Transport

Existing Situation

[37] Calculated based on the population projections and generation rate standards mentioned in the solid waste management master plan 2016

Amaravati city is located centrally in the APCRDA region, characterized by well-connected major railway stations in Vijayawada and Guntur, by two main national highways, and nearby international airport in Vijayawada city. Currently, private vehicles and intermediate public transport serve as the primary modes of transportation both within and beyond the Amaravati city, with public transport absent.

Residents primarily depend on two-wheelers and autos for travelling within and outside the area to neighbouring cities such as Vijayawada and Guntur especially for work and education trips.[38] During the COVID-19, the public transport services operated by Andhra Pradesh State Road Transport Corporation (APSRTC) were stopped. As of 2024, APSRTC has not resumed the bus services in some of the villages.

Proposed Transport System

The 2016 Draft Master Plan for Traffic and Transportation lays out a comprehensive mobility framework for Amaravati. The Transport Master Plan is in sync with city's Master Plan and aims to support the development of integrated multi-modal transport infrastructure for alternative travel options as well as smart and accessible transport infrastructure for non-motorized transport (NMT) modes. The master plan also focuses on real-time intelligent system integration.

The plan's fundamental targets include:

- Modal share of more than 70% for public transport and NMT in internal trips within the city
- Full integration across MRT, BRT, local bus services, intermediate public transport (IPT), and feeder modes
- Mass transit systems to contribute to 70% of modal share of public transport by 2050, with the same being 80% within the Central Business District (CBD)
- Intelligent transport systems (ITS) and SCADA for dynamic traffic management and system-level integration

The phased development plan for Amaravati aims to ensure that infrastructure development aligns with projected population growth and future travel demand.

3.5.1 Modal Share Strategy and Mode-Wise Distribution Targets

Amaravati's transportation strategy is focused on shifting commuter behaviour towards using public and NMT modes of mobility. The modal split targets are to be achieved through a combination of actions including deployment of mass transit system, NMT infrastructure, and regulating high private vehicle dependency (refer Table 3-10).

As per modelled projections for internal trips:

- By 2035, public and semi-public transport will account for 38% of internal trips, while non-motorized modes (walking and slow modes such as bicycling) are expected to account for 42% (30% walk + 12% slow modes) of internal trips. Private vehicle share is projected to be 20% of the internal trips.
- By 2050, public and semi-public transport will account for 35%, non-motorized around 40% (25% walk + 15% slow modes), and private vehicles account for about 25% of the internal trips.

[38] This information is captured during the FGD discussions held with village settlements on June 2nd and 3rd 2025.

Table 3-10 Modal Share Targets for Internal Trips in Amaravati

Mode Type	2035	2050
Public + Semi-Public Transport	38%	35%
Private Vehicles (2-wheelers + Cars)	20%	25%
Slow Modes (Cycle, Rickshaw)	12%	15%
Walking	30%	25%

Source: Draft Master Plan for Traffic & Transportation

Amaravati's transportation strategy seeks to reinforce sustainable commuting behaviour by prioritizing public transit infrastructure and last-mile connectivity.

3.5.2 Road Network

The proposed transport system for Amaravati is based on a fully planned road network designed to support the future mobility requirements, including public transport and freight movement, and remain adaptable as the city grows. The city master plan includes 1,693 km of road network with 593 km dedicated to major roads and 1,100 km for internal roads. The road design for Amaravati includes dedicated areas for public transport, walking and cycling pathways, utility and drainage systems, and public facilities that will be integrated into the right of way.

Table 3-11 Planned Road Hierarchy in Amaravati

Road Type	ROW (m)	Total Length (km)	Primary Function
Major Arterial Road	60	52	Linking capital city with the inter-city and sub regional roads of the surrounding network. 8 lane configurations.
Seed Access Road	60	19	4 lane configurations and 18m Mass transport corridor in median
Arterial Road	50	94	Serve both the inter-city and intra city traffic in equal measure
Sub-Arterial	50	151	Distributors connecting sectors and major destinations
Collector Roads	25	277	Local bus access and neighbourhood connectivity
Local Roads	–	1,100	Plot-level access, NMT corridors, pedestrian-priority segments
Total	–	1,693	

Source: Draft Master Plan for Traffic & Transportation

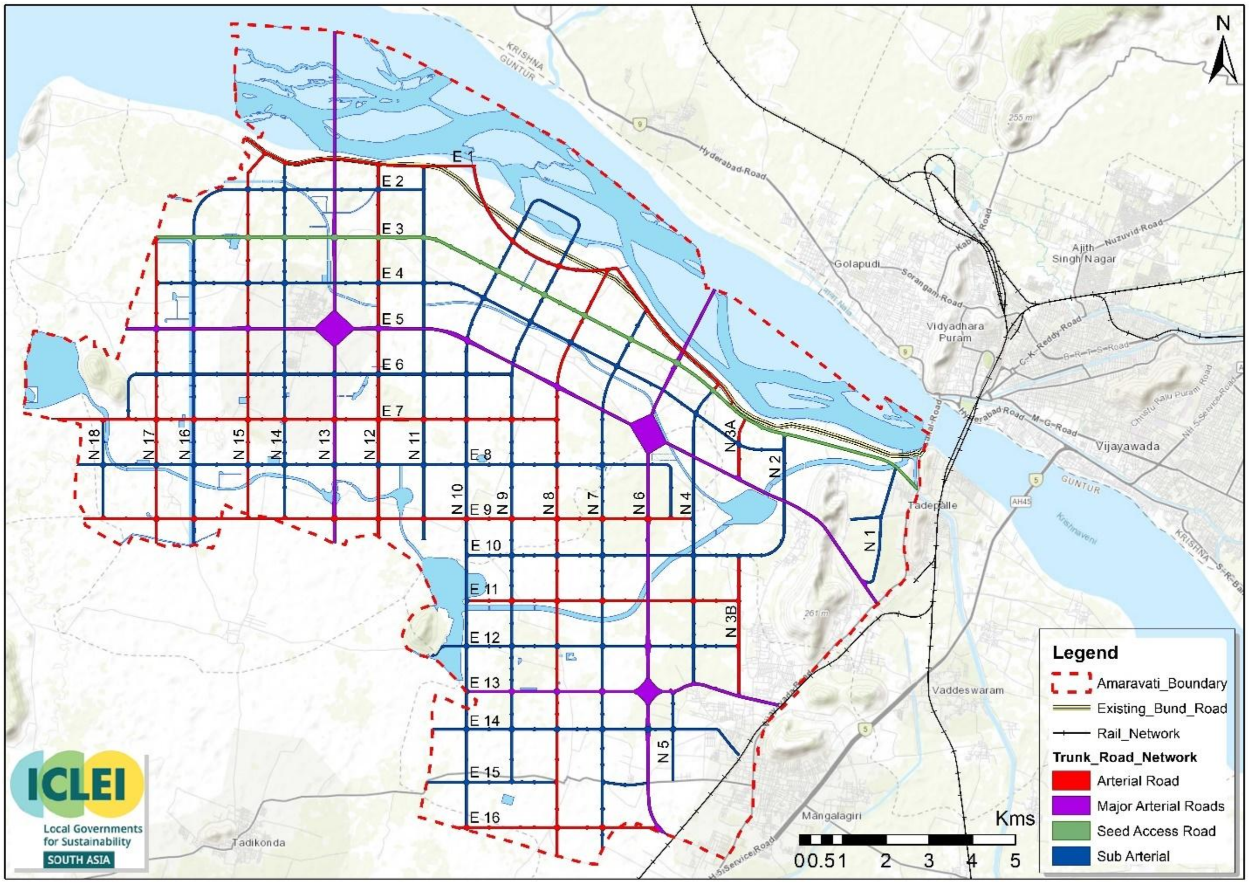

Figure 3-10 Hierarchical Road Network for Amaravati City
Source: Prepared by ICLEI South Asia based on data received from APCRDA.

Design priorities in Amaravati's road hierarchy include:

- Separation of local and through-traffic
- Bus lanes and MRT corridors within medians
- TOD-supportive alignment with mixed-use zoning and high FAR sectors
- Provision for cycle tracks, pedestrian walkways, and utility corridors

3.5.3 Public Transit

Amaravati's public transport system is centred around a high-capacity transit network combining BRT and MRT corridors. The BRT is proposed as the core transit system, with a subsequent upgradation to MRT depending on the growth in travel demand levels. By 2050, the total length of proposed mass transit corridors within the city is approximately 168 km, with an additional 57 km connecting Amaravati to Vijayawada and Guntur[39]. The corridors have been aligned with land use and projected demand.

The proposed corridors include:

- North–South Spine (Seed zone to Guntur)
- East–West Transit Spine (Government Core to Vijayawada edge)

[39] Draft Master Plan for Traffic & Transportation

- CBD Circular Loop
- Peripheral BRT Loops along Inner and Outer Ring Roads

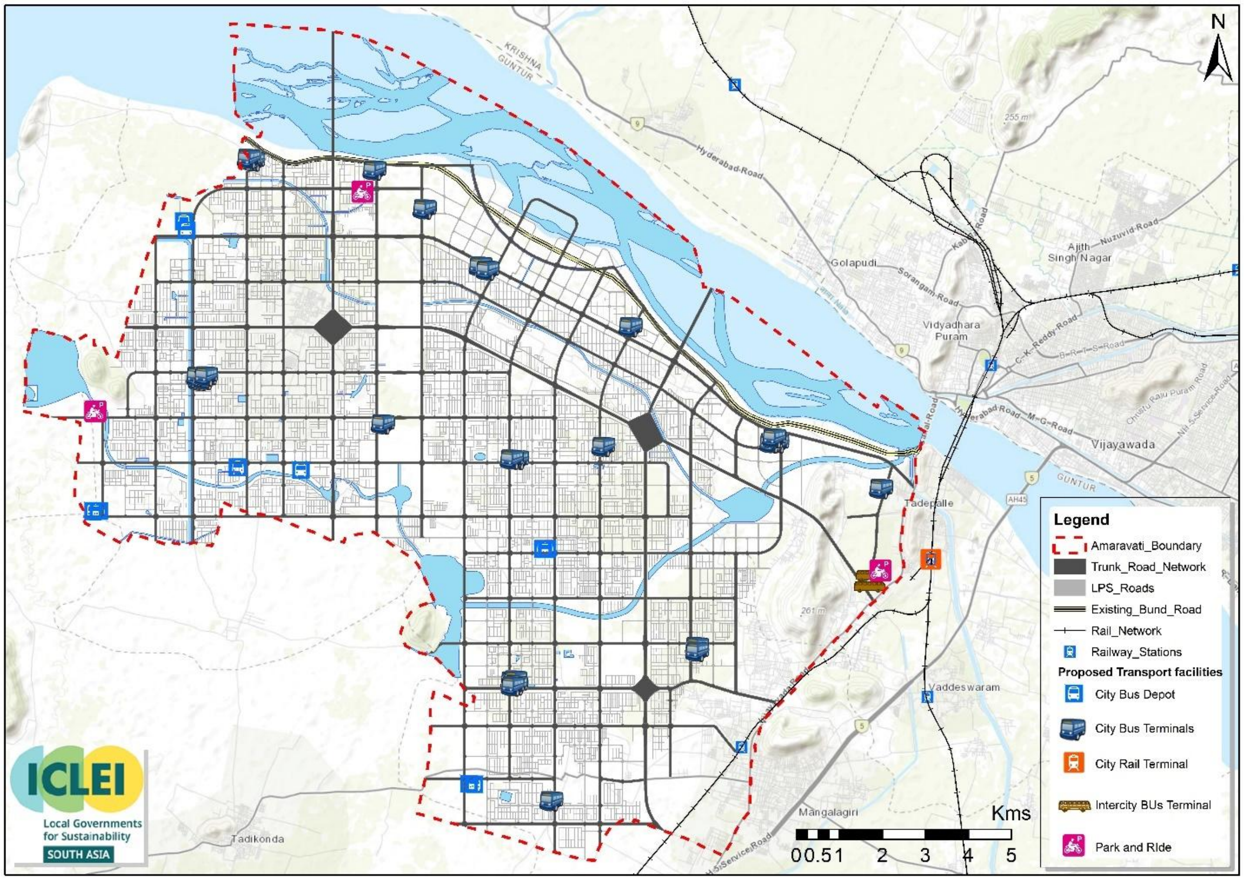

Figure 3-11 Proposed Public Transport Infrastructure in Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA

The plan also includes feeder bus networks, multimodal terminals, and dedicated interchange facilities to support system integration.

3.5.4 City Bus, Feeder, and Intermediate Public Transport (IPT) Services

The public transport system of Amaravati will also include a bus network which would function as a feeder system to high-capacity MRT and BRT corridors. The Master Plan establishes a grid-based city bus network with 22 intra-city terminals and 15 depots[40] to achieve extensive coverage and direct access to mass transit corridors. The feeder routes will operate at short intervals to provide dependable first and last-mile connectivity across the city's residential and institutional areas.

The IPT modes will serve to bridge accessibility gaps in lower-density and transition-phase areas. The plan establishes IPT terminals at multimodal hubs and MRT/BRT stations and major city nodes to enhance

[40] Section 9.1.4.5 City Bus Terminals and Depots, Draft Master Plan for Traffic & Transportation

transfer efficiency and minimize road congestion. The integration of IPT with cycling and pedestrian infrastructure and electric mobility corridors works to create uninterrupted multimodal travel options.

3.5.5 Electric Mobility and Charging Infrastructure

The Draft Master Plan for Traffic and Transportation for Amaravati presents a strategic vision which integrates electric mobility solutions into the city's overall transport framework. The plan establishes a goal to achieve 80% passenger trips through non-motorized, mass transport and electrically powered vehicles by 2050. The plan also recommends using battery-operated IPT modes including electric rickshaws and vans which will have designated parking areas throughout the Multi-Utility Zones (MUZ) of the city. The planning documents of Amaravati demonstrate its commitment to electric mobility, EV-ready building regulations or phased implementation plans. Additional detailing and implementation frameworks for EV infrastructure are essential to realize the city's clean mobility objectives.

3.5.6 Non-Motorized Transport (NMT) Infrastructure

NMT has high significance in the mobility framework of Amaravati. The transport plan establishes a policy structure to integrate NMT into street design and infrastructure. The NMT policy framework includes four main features which are:

- Dedicated pedestrian and cycling space across the entire road network
- Design guidance aligned with safety, universal accessibility, and climate resilience
- Promotion of walkable zones in public institutional areas and multimodal hubs
- Integration of green buffers and stormwater-friendly materials in street corridors

3.5.7 Street Design Guidelines

Amaravati's street network is envisioned not only as a transport corridor but as a shared public space that supports everyday life, social interaction, and neighbourhood vitality. Streets are meant to serve pedestrians, cyclists, public transport users, and vehicles, but also act as spaces for commerce, recreation, and environmental function. The street design guidelines aim to ensure that roads support the surrounding land uses, provide universal accessibility and prioritize safety for all users, especially pedestrians and non-motorized transport.

These guidelines define street hierarchy, cross-sectional standards, and usage functions, incorporating architectural, landscape, traffic engineering, and urban design elements. Pedestrian-first design has been incorporated to guide all typologies, followed by public and shared transport, and then private vehicles. Universal design for children, elderly, and differently abled users will be mandatory across all street elements.

3.5.8 Parking Policy

The parking policy for Amaravati is structured to support a compact, transit-oriented city. The policy discourages long-term on-street parking in high-mobility corridors and promotes the development of multi-level or underground parking in commercial zones. The residential areas are required to include shared and EV-ready parking spaces and building bylaws specify the minimum number of EV slots. The high-demand areas will use dynamic pricing and digital reservation systems to control parking space and decrease roadside congestion.

The integrated parking management system will support public transport access through facilities near transit hubs and discourage private vehicle use in dense walkable districts. The development control regulations will define parking requirements based on land use intensity and public transport accessibility and location-specific demand assessments.

3.5.9 Intelligent Transport Systems (ITS) and Traffic Management Systems

Amaravati envisions ITS as its core component to establish safe and efficient transportation. The master plan establishes ITS as an essential base that connects infrastructure development with operational management of every transport system. The ITS system functions as an essential element that supports Amaravati's mission to create a world-class sustainable capital with enhanced citizen benefits.

The ITS planning system of Amaravati exists through separate components for each transportation mode and functional application:

3.5.9.1 ITS for Non-Motorized Transport (NMT)

- Deployment of surveillance and safety systems to protect pedestrians and cyclists at both crossing points and intersections along with mid-block areas
- Cycle tracking systems for bike-sharing schemes, designed based on estimated demand
- The design of crossing types along with safety features depends on both pedestrian demand and network configuration
- The deployment of ITS components will match NMT corridor implementation phases to determine bike station positions while determining the timing for safety infrastructure construction.

3.5.9.2 ITS for Public Transport (PT)

- Installation of priority signals for transit vehicles at essential intersections according to demand patterns and public transport routes
- On-board ITS systems such as Automated Vehicle Location (AVL), Passenger Information Systems (PIS), and surveillance systems
- Installation of passenger Information Displays and journey planning systems for passenger use at bus stops and terminals
- ITS design for multi-modal hubs includes device counts, station-level equipment, and coordination points based on transfer volumes

3.5.9.3 ITS for Road Networks and Private Vehicle Users

- SCADA-based traffic signal control at all arterial and sub-arterial junctions
- Variable Message Signs (VMS) and Public Address systems to disseminate real-time traffic and emergency information
- Integration of Area Traffic Control (ATC) systems at high-demand intersections
- Enforcement systems for traffic rule compliance, including access-controlled expressways and key commercial routes

- Parking management systems for proposed lots, with dynamic parking guidance in high-density areas like the CBD
- ITS deployment around logistics hubs to optimize freight movement and enforcement

All ITS systems will be developed according to the infrastructure expansion schedule and projected land use development and transportation demand forecasts.

3.6 Built Environment and Energy

Existing Situation

A population of about 1.84 lakh is estimated to reside in the capital city area as of 2025, which encompasses 25 villages, two hamlets and portions of the Mangalagiri-Tadepalli municipal corporation area. The existing buildings primarily include low-rise residential houses, village panchayat buildings, institutional buildings of the Mangalagiri-Tadepalli corporation, small commercial shops, and community facilities such as schools and health centres. The area currently reflects emerging urban and rural development patterns, with limited infrastructure.

The power supply to the Amaravati city is generated from the Vijayawada Thermal Power Plant (VTPP) and distributed by Andhra Pradesh Central Power Distribution Corporation Limited (APCPDCL). Power lines presently link the VTPP to a primary electrical substation which distributes power to the existing village settlements within the city. The total electricity consumption of the capital city area in the year 2024-25 was 220.5 million kWh[41], with the Residential sector having the highest share of electricity consumption (~48%) followed by the Commercial and institutional consumers (~45%). (see Table 3-12)

Table 3-12 Electricity Consumption for Amaravati city by Sector in 2024-25

Sector/Consumer type	Total Annual Electricity Consumption in 2024-25 (million kWh)	Percentage share of electricity consumption
Residential	104.85	47.5%
Commercial and Institutional	99.81	45.2%
Industrial	12.04	5.5%
Agriculture	3.78	1.8%
Total	220.48	100%

Source: APCPDCL, 2025

Proposed Energy Systems and Built Environment

The urban development strategy of Amaravati emphasizes the integration of energy-efficient buildings and decentralized renewable energy sources. The 2015 Capital City Master Plan includes zoning codes, prescribes plot-level Energy Conservation Building Code (ECBC) norms compliance and promotes green buildings to reduce energy consumption in Amaravati.

[41] The electricity consumption dataset received from the APCPDCL covers both the MTMC area and the villages under the Amaravati city area. However, since only one-third of the current MTMC population falls within the Amaravati city boundary, the dataset has been scaled down and apportioned using per capita consumption to estimate electricity use specific to Amaravati city.

The Draft Power Master Plan supports this goal by establishing an electricity distribution system, smart metering provisions and rooftop solar integration potential. The city plans to provide uninterrupted round the clock power supply through a smart distribution network which combines Gas Insulated Substations (GIS) with SCADA systems and underground cabling. Solar photovoltaic (PV) system has been identified as the major contributor to the city's energy mix, accounting for at least 60% of total power demand.

The Amaravati building energy performance standards demands that all buildings fulfil the requirements of the ECBC specifications. The implemented measures work to reduce grid dependence while improving operational performance and supporting the city's clean energy transition goals.

3.6.1 Power Demand Forecast and Sector-Wise Load Distribution

Amaravati's power demand has been estimated based on detailed assessments of built-up areas, population growth, and sectoral energy intensities.

Table 3-13 Estimated Power Demand for Amaravati City

Classification	Estimated Power Demand (MW)
Residential	1,076.59
Commercial	521.43
Institutions	21.25
Industrial	498.85
AGC (Excluding DC)	169.25
Startup Area	202.35
Residential area in commercial & Industrial Zones	36.49
Utilities (Including District Cooling Systems)	123.21
Line losses (@2.84%)	77.47
Total Demand	**2,726.89**

Source: Design Basis Report, Zone 7, Power & ICT

By 2050, the city's total power demand is projected to reach 2,726.89 MW, with a power density of 12.56 MW per sq. km, comparable to global cities like New York or Tokyo. The sector-wise power demand forecast is summarized in Table 3-13 above.

3.6.2 Power Source

As per the power policy of Andhra Pradesh, Andhra Pradesh Power Generation Corporation Limited (APGENCO) is responsible for power generation, Transmission Corporation of Andhra Pradesh (APTRANSCO) for power transmission and Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL) for power distribution. The power supply for Amaravati will depend on APGENCO's thermal and hydel stations which have a total installed capacity of 6,080 MW and will be transmitted through EHV lines, managed by APTRASNCO, through the capital area. The power transmission lines operate within the Andhra Pradesh and Southern Regional Grid network with reliable power feed points located within 5 km of the capital area that originate from the Vijayawada Thermal Power Station (VTPS). APTRANSCO has approved two substations, a 220/33KV substation (380 MVA) at Lingayapalem and a 400/220KV substation (1,500 MVA) at Tallayapalem and has proposed two more 400/220KV substations at Borupalem and Nidamarru, along with 400KV double circuit transmission lines, to cater to Amaravati's growing energy demand.

3.6.3 Renewable Energy & Rooftop Solar

The renewable energy strategy of Amaravati promotes decentralized power generation through rooftop solar PV systems. The technical evaluation shows that 18.16 million square meters of rooftop area is suitable for rooftop solar PV systems. The available rooftop space amounts to approximately 1,816 MW of solar energy potential based on estimated solar density of 1 kW per 10 sq. meters (refer Table 3-14). The planning guidelines of Amaravati specify mono-crystalline PV panels with 20% minimum efficiency while requiring suppliers to demonstrate R&D capabilities and achieve global reliability ratings.

Table 3-14 Rooftop Solar Power Potential for Amaravati

Category	Rooftop Area for PV (acres)	Estimated Potential (MW)
Residential	1,19,17,992	~1,190 MW
Commercial	39,78,060	~397 MW
Industrial	13,15,228	~131 MW
Government	3,60,170	~36 MW
Education	5,90,841	~59 MW
Total	**1,81,62,292**	**~1,816 MW**

Source: Draft Power Master Plan, 2017

The state net metering policy will enable rooftop solar installations to connect with Amaravati's grid as part of its distributed generation strategy. The policy mandates the use of bi-directional meters for all grid-connected rooftop photovoltaic systems. Consumers will be billed based on net energy usage, with provisions to carry forward surplus energy units for up to two billing cycles. Additionally, any remaining net exports are settled bi-annually by the DISCOMs at the pooled cost of power purchase.

Amaravati’s strategy also includes exploration of floating solar installations, solar farms, and canal-top PV systems to fully utilize the city’s renewable potential.

3.6.4 Transmission and Distribution Infrastructure

The transmission system of Amaravati follows a three-tier grid structure:

- 400KV/220KV GIS substations (city grid interface)
- 220KV/33KV GIS substations at regional load centres
- 33KV/415V Compact Substations for local distribution

The entire transmission system will use GIS at all voltage levels to achieve space efficiency and better reliability. The planned substation locations follow planned development phases with compact station installations in high density areas. The underground cabling system will minimize conflicts with rights-of-way while creating smart infrastructure corridors. The planning of substations includes power requirements from common utility infrastructure including WTPs, STPs and DCS.

Amaravati will also include an underground cabling network throughout the city which will link GIS-enabled substations with compact substation nodes and distribution automation systems (DAS) to enable integration of renewable energy into the grid. The 33 kV distribution centre level microgrid structure will integrate rooftop solar power through decentralized microgrids to enable real-time demand-response controls and bi-directional energy flow.

3.6.5 ECBC and Energy-Efficient Building Compliance

All major buildings in Amaravati must comply with the ECBC and green building certification systems such as GRIHA, IGBC, or LEED. Specific targets and design mandates are listed below[42]:

- U-value limits:
    - Roof: Max 0.261 W/m^2K (24-hour use); 0.409 W/m^2K (day use)
    - Wall: Max 0.44 W/m^2K
    - Windows: Max 3.30 W/m^2K
- Energy Performance Index: Less than 150 kWh/m^2/year for major complexes
- Solar water heating for buildings with more than 500 m^2 plots
- All commercial buildings with more than 100 kW connected load to comply with ECBC
- 15% of external lighting in residential complexes and 5% in commercial/institutional buildings must come from renewable sources

These requirements are to be incorporated into the city's building byelaws and monitored through planning permissions.

3.6.6 Street-Lighting

The street lighting network of Amaravati follows a strategic design to maintain uniform and dependable illumination throughout all road types. LED lamps will be used across all street-lights. The streetlight specifications follow a wattage range from 45W to 337W based on road width and usage between narrow 9-meter lanes and major 60-meter arterial corridors. Pole spacing and mounting arrangements have been tailored for each road type to ensure proper visibility and uniform lighting, while avoiding glare and excessive energy use. The system uses standardized pole types and layouts, including double-arm poles for wider medians and staggered placements for narrower roads, ensuring that the lighting design matches both safety requirements and urban form.

The lighting infrastructure will be supported with smart controls to support efficient operations and minimize long -term costs. The system will enable dimming functions based on traffic density, time of day and weather conditions, while also providing remote monitoring for fault detection and maintenance scheduling. Streetlights will be managed through a network of wirelessly connected Light Nodes, which communicate with Road-Side Units and a central control centre. This enables automated alerts when faults occur and supports real-time energy tracking. In areas where underground cabling is difficult, solar-powered LED streetlights with battery backup will be used to extend coverage.

3.6.7 Smart Grid, SCADA, and Distribution Architecture

Amaravati's power infrastructure is designed as a Smart Grid ecosystem integrated with SCADA, GIS substations, and smart meters. The Main Control Station (MCS) and Secondary Control Stations (SCS) and Micro Grid Stations (MGS) operate as a hierarchical system to monitor and control power flow and outages and maintain load balance.

Highlights include:

[42] EC Order, State Level Environment Impact Assessment Authority (SEIAA), Order No. SEIAA/AP/GTN-151/2015

- SCADA Integration: Real-time monitoring of power supply and distribution faults
- Smart Meters: Real-time energy consumption feedback
- Compact Substations: Load centres located strategically to minimize transmission losses
- Distributed Energy Systems: Rooftop solar and localized battery systems integrated into the grid

3.6.8 District Cooling System (DCS)

DCS in Amaravati has been planned as a centralized energy network for space cooling across buildings. Designed to improve energy efficiency and reduce greenhouse gas emissions, the system replaces individual cooling units with a shared infrastructure, significantly lowering power consumption and improving air quality.

For Amaravati's 900-acre Government Complex (S1 Zone), two DCS plant with a total estimated cooling capacity of 50,000 TR has been proposed. The system will be powered by a hybrid model, combining grid electricity with renewable solar thermal energy. The system has been designed to prioritize the use of clean, renewable energy to meet the city's cooling needs, and will only switch to grid-based electricity during shortfalls. Additionally, recycled wastewater from the STP (21 MLD) is planned to be used as the plant's water source.

3.7 Health

Existing Situation

There are only primary health centers in Amaravati, and residents need to travel to nearby hospitals in Mangalagiri, Guntur, and Vijayawada for any other medical needs. During the monsoon season cases of vector-borne and waterborne diseases are monitored by the district health department through fever surveys and the provision of required healthcare services.

Proposed Healthcare System

Amaravati is planned as a "people's city," promoting economic growth and liveability, with a strong emphasis on quality health care. The health sector plan for Amaravati incorporates modern clinical facilities, innovative technology platforms (telemedicine), and a combination of conventional care and traditional care such as Ayurveda, Yoga, and Naturopathy, Unani, Siddha, and Homeopathy (AYUSH) to meet the needs of both the local population and regional clientele. This broad plan will be supported by quantitative benchmarks for social infrastructure and aims to position Amaravati as a national centre for quality health care delivery and medical manufacturing.[43]

3.7.1 Proposed Health Infrastructure and Service Delivery

The health sector plan anticipates innovative health services as part of wider smart city initiatives, including new facilities. Amaravati's vision outlines the provision of more than 40 hospital beds per 10,000 population and an emergency care response time of 5-10 minutes in line with benchmarks proposed in the draft concept note on Smart City Scheme, Government of India[44]. Planned health-related development mandates a minimum of 300 acres of land earmarked for public health facilities, which will serve as critical nodes into

[43] Socio-economic Master Plan 2018

[44] Draft concepts note on Smart City Scheme, 3 December 2014 Available at: https://praja.in/files/Note_on_Smart_City_10914.pdf (accessed 15th May 2025)

primary and secondary care networks. A health centre with emergency services will be included in every township and 3 new multi-speciality hospitals are planned to assist with tertiary services.

The plan also identifies the importance of deploying digital technologies. The health plan outlines a health integrated command and control centre for 24x7 surveillance. The plan identifies the deployment of telemedicine as an integral tool to narrow the geographic gap to remote and regional populations. The city's plans to establish partnerships with leading service providers for conventional medical facilities, as well as traditional AYUSH services is an important way to develop a holistic, inclusive health care ecosystem.

Table 3-15 Proposed Healthcare Infrastructure Benchmarks for Amaravati

Component	Proposed Specification	Remarks
Hospital Beds	>40 beds per 10,000 population	Supported by three multi-specialty hospitals in first 10 years
Emergency Response	5–10 minutes response time	Health centres in every township ensure timely care
Public Health Facilities	300 acres reserved	Designed to support regional primary and secondary care
Telemedicine Services	Integrated network with 24×7 command centre and high-speed Wi-Fi	To extend care to remote areas and optimize resource use

Source: Socio-economic Master Plan 2018

3.7.2 Medical Devices Manufacturing: An Emerging Hub

Amaravati seek to establish itself as a national centre for medical devices manufacturing, which is an extremely significant component of modern health care delivery. The medical device industry made about INR 15 lakh crore globally in 2015. According to the latest figures (2014), domestic revenues in India have already crossed INR 33 thousand crore, with a projected growth rate of approximately 13% every year, resulting in a domestic market of more than INR 42,500 crore by 2018. This industry is comprised of four major segments: small and medium devices, large devices, consumables, and implants. Amaravati will focus on small and medium devices since these devices can utilize local raw materials and present skilled (semi-skilled) labour and are at a much better cost position.[45]

3.8 Urban Greening and Biodiversity

Existing Situation

The capital city area is characterised by riverine ecosystems, agricultural landscapes and vegetation. Its environmental features include forests, agricultural fields, hills of Kondaveedu, Mangalagiri, and Undavalli, and the Krishna River and other water bodies. The area supports biodiversity including native trees, wetlands and aquatic and semi-aquatic fauna, especially given the riverbanks and water bodies. It is a habitat for resident and includes ecologically sensitive zones near the floodplains of Krishna River.

Proposed Measures

[45] Socio-economic Master Plan 2018

The urban greening initiatives in Amaravati are interrelated actions structured to combine environmental sustainability with urban enhancement. Preserving and maintaining the area's critical habitats, biodiversity and ecological balance is important as it transforms is high on the agenda.

3.8.1 Urban Greening and Biodiversity Initiatives

APCRDA and ADCL have mandated that no trees are to be cut down in the city during the development of the capital. Instead, existing trees are being carefully relocated using modern techniques. ADCL maintains a comprehensive inventory of existing trees, cataloguing their species, age, and trunk diameter. The APCRDA has also prepared a list of native species that are well-suited to the local environment, ensuring that the majority of new plantings throughout the city will be indigenous.

The development of green areas in the first phase includes the enhancement of 35 priority roads, canal fronts, parks, and the restoration and development of water bodies, along with improved riverfront areas along the Krishna River. These activities will feature avenue and median plantations throughout the road network, as well as buffer zone development along watercourses. A buffer zone of 30 meters is planned along the Kondaveeti Vagu and a 20-meter buffer along the Pala Vagu to protect water bodies through the establishment of green areas.

One unique aspect of the implementation is the reuse of topsoil excavated during construction activities. This topsoil is mixed with organic manure obtained from local farming associations and then used in median plantations to promote plant growth. Plantation activities are supported by the Venkatapalem nursery, located within Amaravati, which supplies most of the landscaping plants. By utilizing native species for these plantings, we are also helping to conserve the natural ecology.

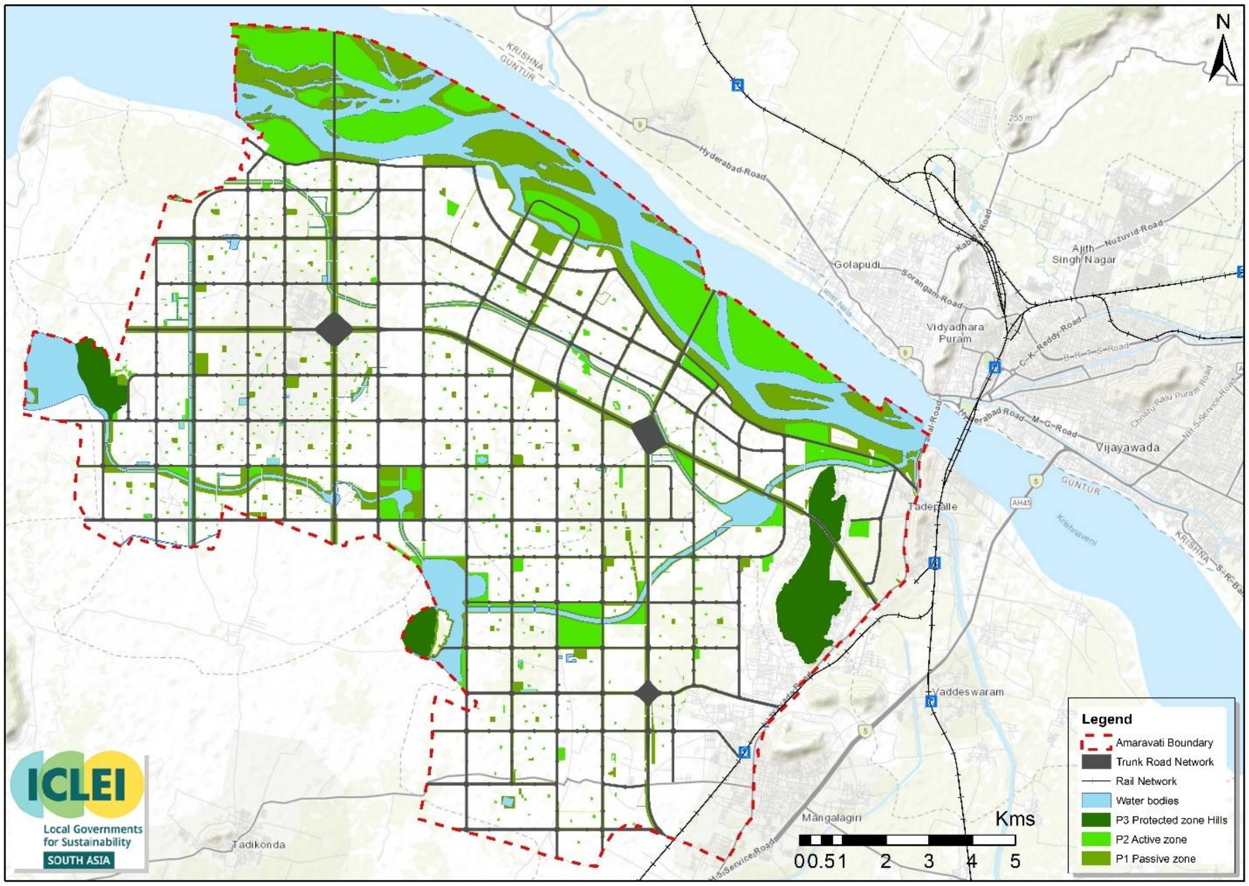

Figure 3-12 Green areas in Amaravati
Source: Prepared by ICLEI South Asia based on data received from APCRDA

Development initiatives involve the creation of approximately 500 parks in different areas throughout the city, which will feature amenities for both commercial and recreational use while enhancing the city's natural landscape. The green cover of Amaravati is expected to be between 15% and 17% of the total land area. The initiatives also include the adoption of Miyawaki plantations and nutrition gardens to enhance carbon sequestration rates, thereby accelerating the capture of carbon from the atmosphere while improving urban food security. According to the National Green Tribunal (NGT), the expected carbon sequestration target is 5 tonnes per hectare of land. These initiatives are designed to support achieving these targets.

The urban greening initiatives are primarily being carried out by the ADCL, with overarching guidance from the APCRDA. A Greening Policy is currently being developed, which will provide detailed guidelines, including technical specifications on the appropriate times for planting, maintenance, and monitoring. The approach focuses on sustainability in several key areas: (a) planting deep-rooted native species for resilience, (b) conserving and enhancing the existing natural vegetation and grass cover, and (c) employing advanced techniques for tree transplantation to reduce shock and increase survival rates.

4 Climate Risk and Vulnerability Assessment

4.1 Introduction and Methodology

This chapter presents the analysis of climate risks and vulnerability for Amaravati due to climate change induced hazards (urban flooding, heat stress). This assessment will help the city adopt climate sensitive urban planning, effectively manage climate change induced risks, and efficiently implement climate resilient policies and interventions. The assessment is carried out using the Net-zero ClimateResilientCities Methodology of ICLEI South Asia.[46]

4.1.1 Step-by-step approach based on ICLEI's ClimateResilientCITIES methodology

Step-1: Climate Trends Analysis

Historic climate and weather data from 1994 to 2024 was analysed to identify trends and patterns in temperature and rainfall. The analysis covers both annual and seasonal variations for 2024. In addition to trends, the study also analyses the increase in number of relatively hotter days and the frequency of high intensity rainfall events over the 30 year period.

Step-2: Analysis of Historical Extreme Events

Information on the past extreme weather events such as heatwaves, floods, droughts, cyclones was analysed from the Guntur District Disaster Management Plan and desktop research. This analysis helped to identify the types of extreme events that have occurred and their impacts on local settlements.

Step-3: Climate Projections

Further, climate projections for different scenarios were derived from the Bias-corrected climate projections for South Asia from Coupled Model Intercomparison Project-6 and State Action Plan on Climate Change for Andhra Pradesh, 2012. Based on the climate trend analysis and future projections, climate scenario statements were developed.

Step 4: Climate Risk and Vulnerability Assessment

Based on the assessments from the previous sections, this step involved identifying and assessing the risk posed by climate hazards such as urban floods, extreme heat and air quality to both people and infrastructure. The assessment considered three key components – hazard exposure, vulnerability to future climate projections and adaptive capacity. GIS tools were used to map high risk zone such as heat hotspots, flood prone areas and regions with poor air quality. Existing and planned critical infrastructure in these zones were analyzed.

To understand the vulnerability, focused group discussions (FGDs) were conducted in 7 settlements – six rural - Rayapudi, Borupalem, Neerukonda, Velagapudi, Krishnayapalem, Penumaka, and one urban - Tadepalli. The FGDs engaged with the community and local stakeholders to gather community-specific insights, identify existing challenges and explore feasible adaptation measures. More than 200 participants took part in the discussions, including farmers, daily wage labours, women, elderly, youth and

[46] CRC methodology is an action planning process tailor-made for local governments, providing step-by-step guidance for the development of a CRCAP that addresses both climate change adaptation and climate change mitigation

representatives from local institutions. These qualitative insights were a critical component of the risk and vulnerability assessment, ensuring that the Climate Change Action Plan reflects ground realities.

The adaptive capacity of the communities and stakeholders was analyzed based on their capacity to organise and respond to climate threats, access to technical and financial resources to respond to such threats, and ability to access information regarding such threats for timely response.

4.2 Climate Profile

Amaravati has a tropical climate characterised by hot summers and moderate winters. The climatic cycle is divided into four seasons: the cooler months of January and February, the hot months from March to May, the Southwest Monsoon from June to September, and the Northeast Monsoon from October to December.

The Gannavaram IMD station, located close to the jurisdiction of Amaravati, has historical weather records that are used for analyzing temperature and rainfall in the region. This analysis includes annual and seasonal data for the most recent year, 2024, as well as a historical trend analysis of both temperature and rainfall from 1994 to 2024. Analysis also includes the change in relatively hotter days and high-intensity rainfall events annually.

4.2.1 Climate Trend Analysis

The weather records for 2024 indicate that the maximum recorded temperature was 42.4°C in May, and the minimum recorded temperature was 18°C in December. The monthly average maximum temperature in 2024 ranges from 39.53°C in April to 29.99°C in December, while the 30-year trend shows maximum monthly averages are recorded high in May and low in December (Section 4.2.1.1). The monthly averages of minimum temperatures in 2024 range from 21.04°C in December to 28.13°C in May, recording higher averages than the 30-year trend.

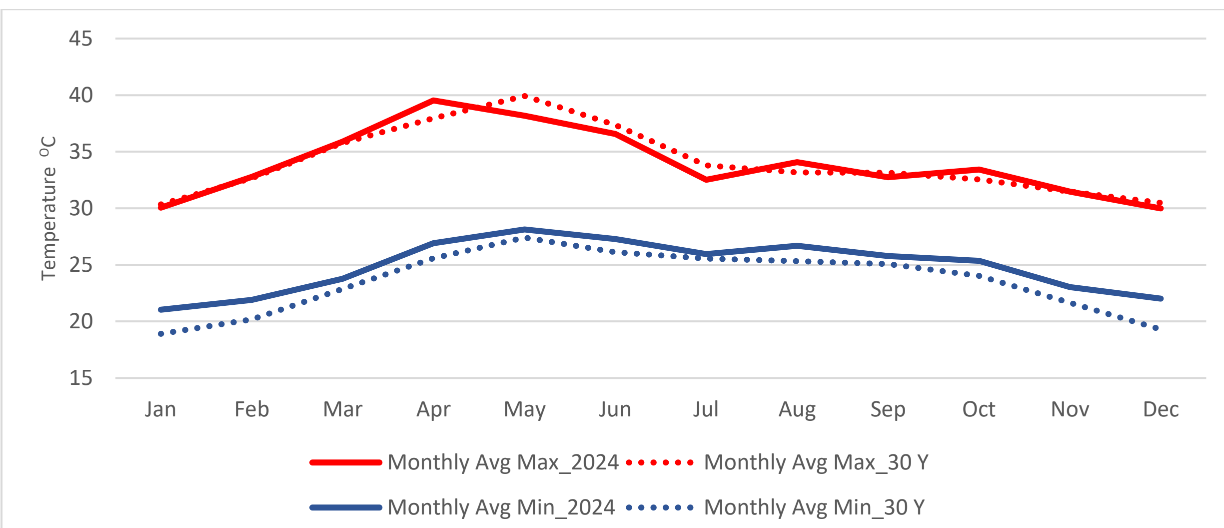

Figure 4-1 Comparison of Monthly Max. and Min. Temperatures in 2024 with 30-Year Monthly Average
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

Rainfall records for 2024 indicate that the city received an annual rainfall of 1160 mm, which is 64 mm higher than the annual average. The city recorded 937 mm of rainfall, exceeding the southwest monsoon average by 200 mm, and during the northeast monsoon, it received twice the 30-year average. The winter months (January and February), which typically receive an average rainfall of 25.47 mm over a 30-year trend, remained completely dry.

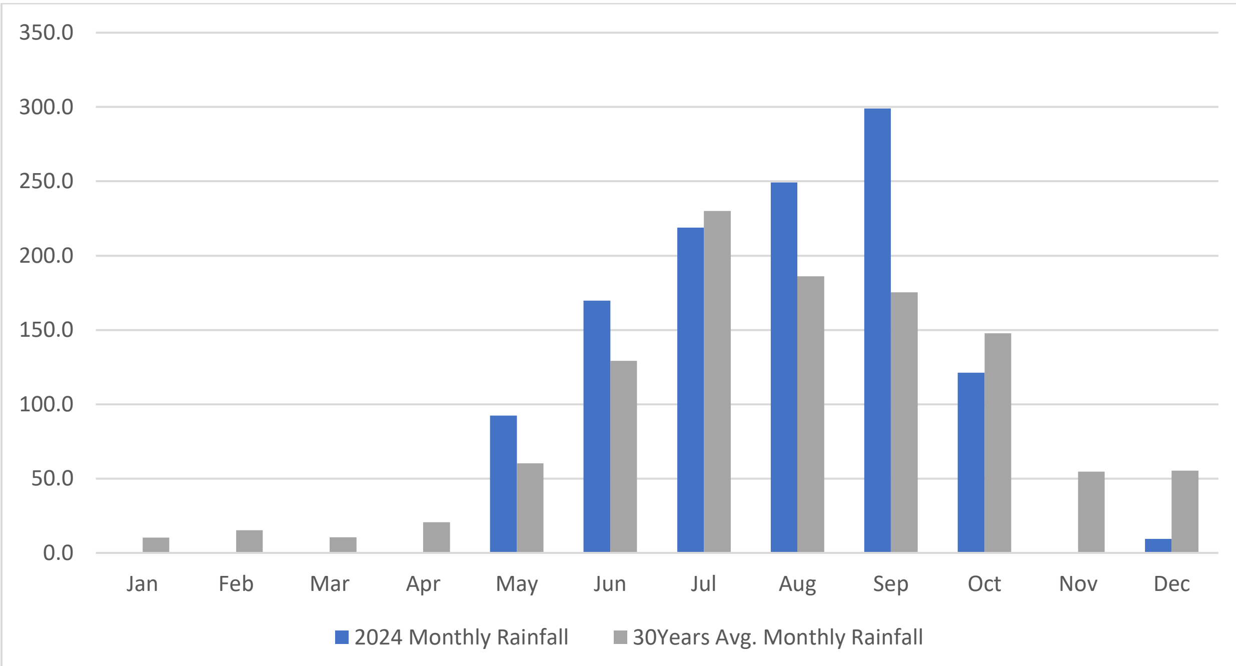

Figure 4-2 Comparison of monthly rainfall received in 2024 with 30 year monthly averages
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

4.2.1.1 Air Temperature Trend Analysis

From 1994 to 2024, IMD's air temperature records indicate that maximum daily temperature ranges from 16°C to 48.8°C, and minimum daily temperature ranges from 12.4°C to 33.9°C. May is the hottest month, and January is the coldest month of the year. Monthly averages of maximum temperature recorded vary from 30.34°C to 39.92°C, and the monthly averages of minimum temperatures vary from 18.91°C to 27.41°C.

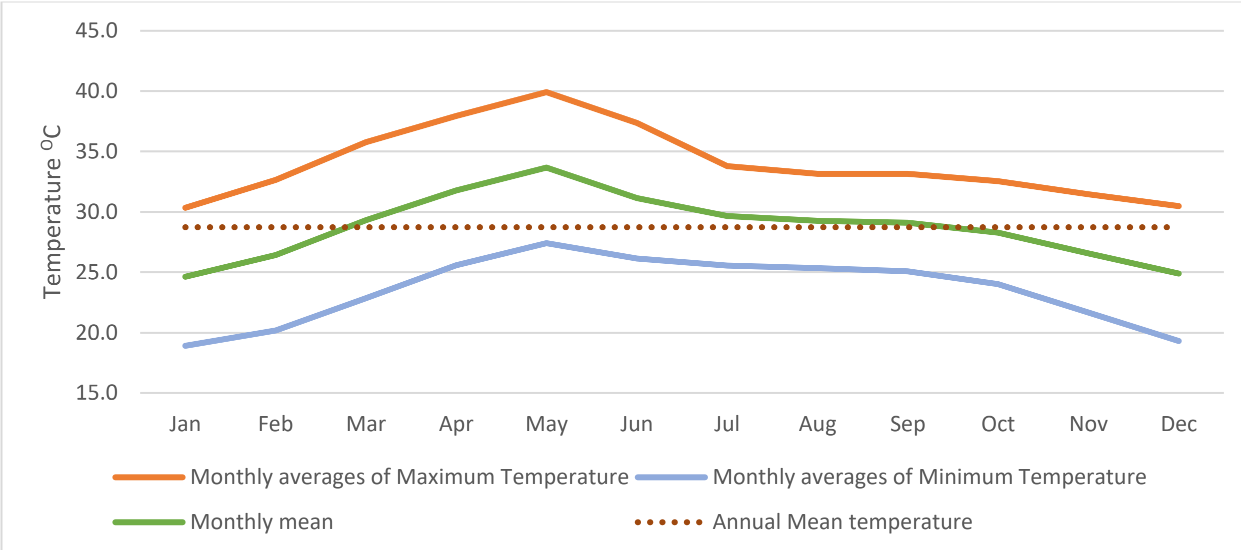

Figure 4-3 Month wise Temperature Variation with respect to Annual Mean Temperature for Amaravati
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

Analysing the annual mean temperatures from 1994 to 2024 indicates a decadal increase of 0.36°C. The maximum temperatures are increasing at a rate of 0.2°C per decade, while the minimum temperatures are increasing at a rate of 0.32°C per decade, indicating a reduction in the difference between maximum and minimum temperatures over the years and an overall warming of the city.

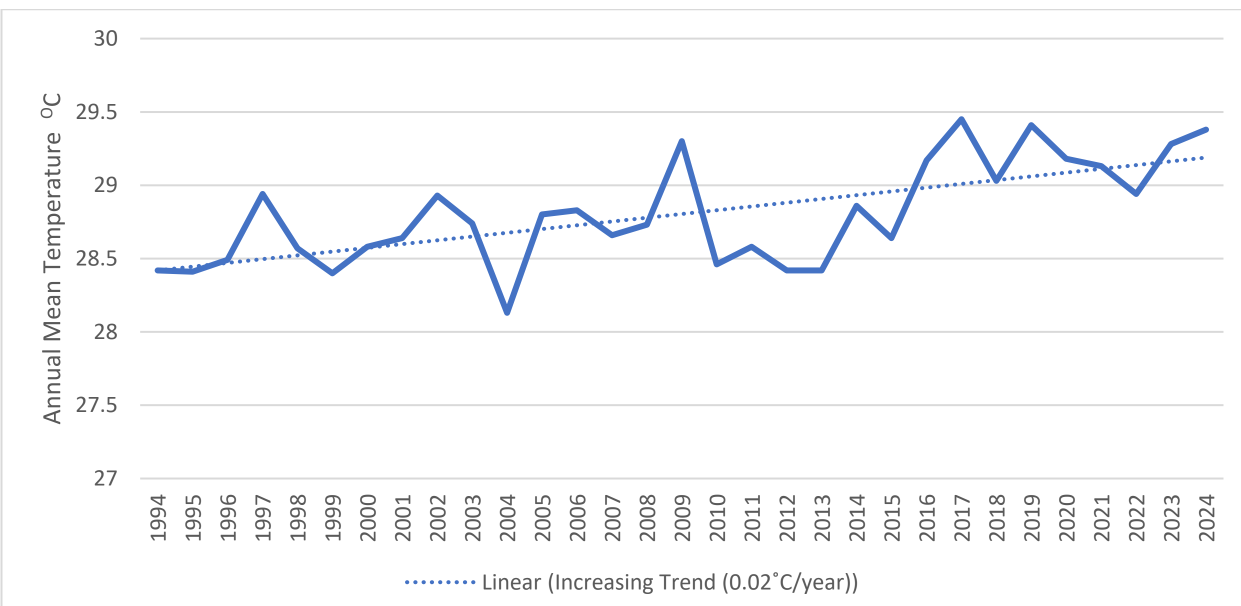

Figure 4-4 Annual Mean temperature trend for Amaravati
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

A significant increase in the hotter years[47] was observed from 1994 to 2024. Between 1994 and 2000, there was only one hotter year. The hotter years from 2001 to 2010 and 2011 to 2020 were 3 and 6, respectively. From 2021 to 2024, all of them are hotter years. In total, there are 14 years where the annual mean temperatures crossed the mean average temperatures from 1994 to 2024. Over the last ten years, 9 years recorded higher temperatures, exceeding the annual mean temperatures by 0.14°C to 0.61°C.

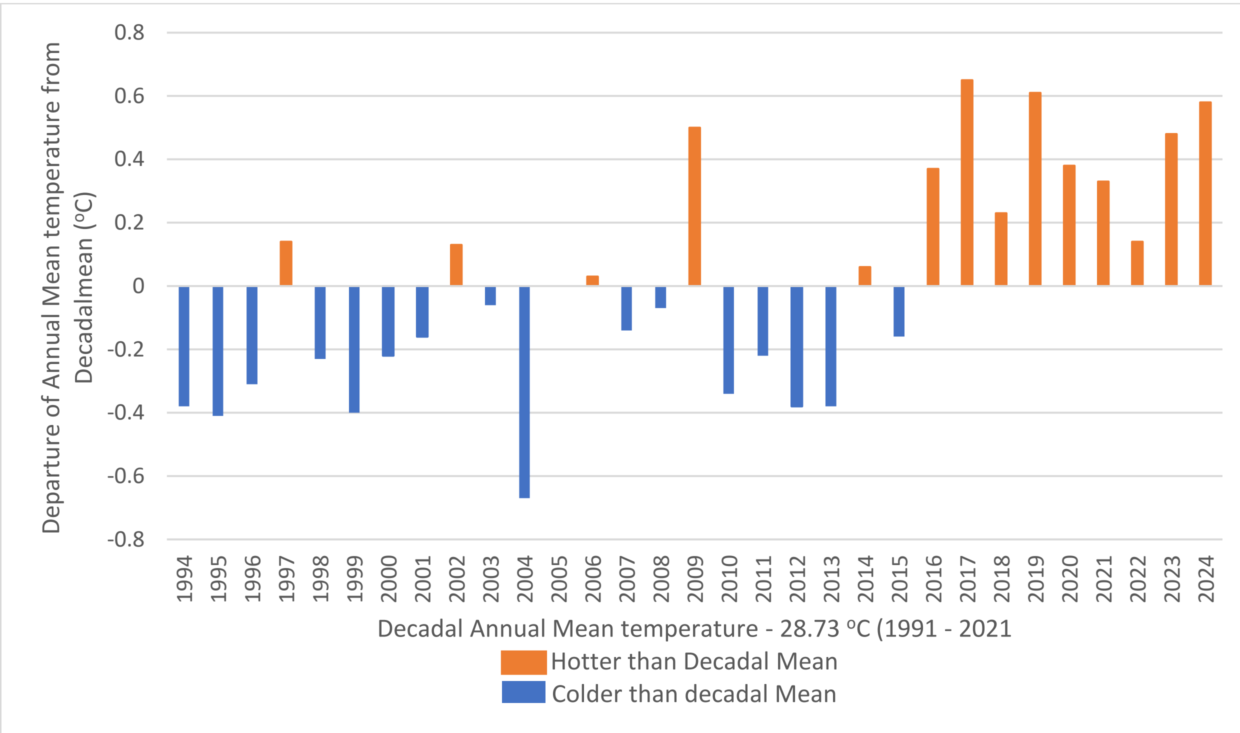

Figure 4-5 Anomalies in Annual Mean Temperature (1991 to 2021)
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

4.2.1.2 Relative Humidity Trend Analysis

The annual average relative humidity in Amaravati is 70.41%. Humidity levels exceed this annual average in January and from July to November, while the summer months experience relatively lower humidity.

[47] A hot year is defined as a year in which the annual average temperature exceeds the mean annual temperature over the studied time frame, which is 30 years in this case

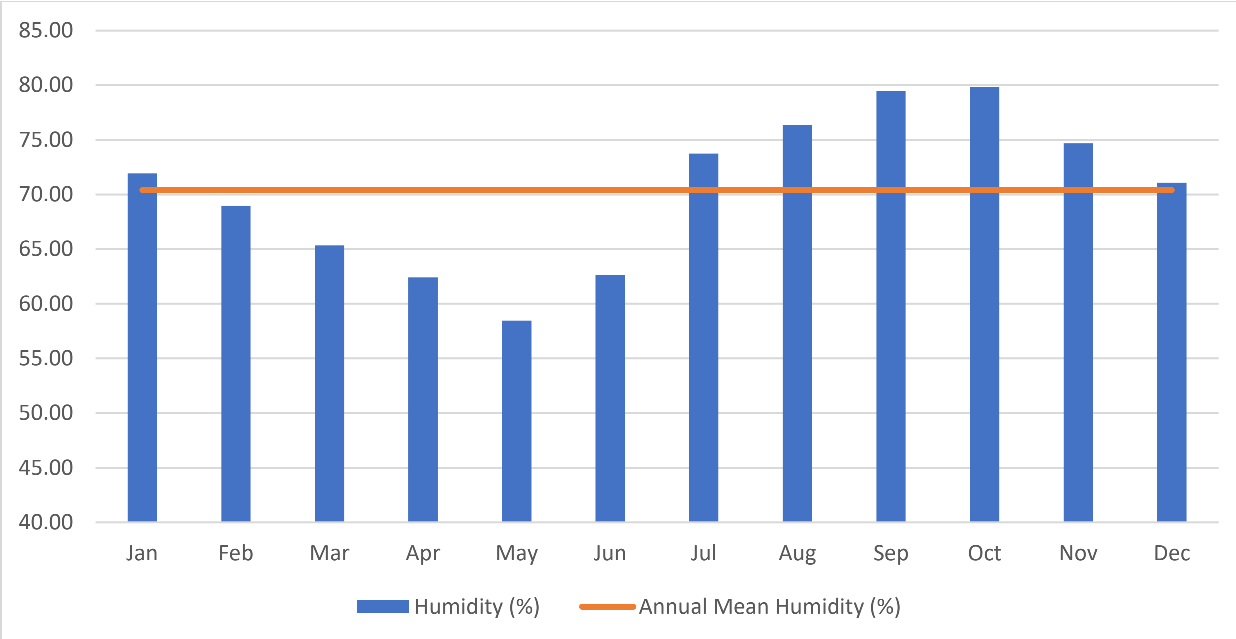

Figure 4-6 30-year Monthly Average Relative Humidity compared with Annual mean humidity for Amaravati

Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

4.2.1.3 Rainfall Trend Analysis

Amaravati receives rainfall primarily during the South-West and North-East monsoons. The annual average rainfall recorded in Amaravati from 1994 to 2024 is 1061 mm. Analysing the historical rainfall data indicates an increase in rainfall at a rate of 45 mm per decade.

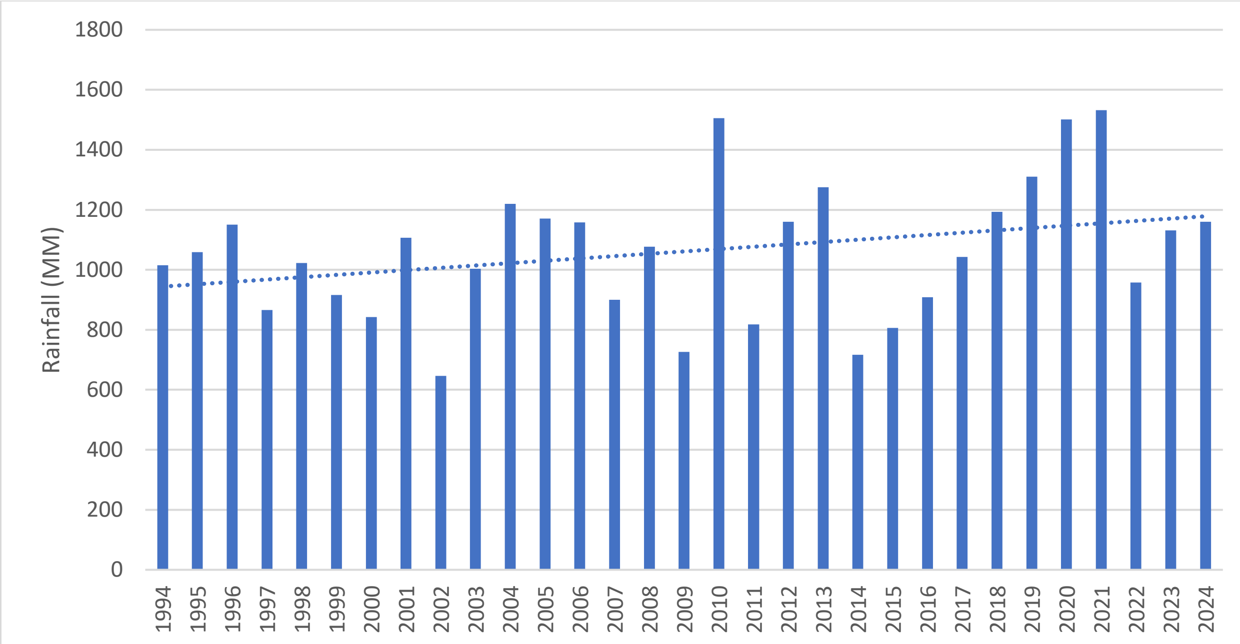

Figure 4-7 Annual rainfall trend for Amaravati for past 30 years (1994-2024)
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

The wettest month is July, which has an average rainfall of 230 mm, while the driest month is January, with an average of only 10.24 mm.

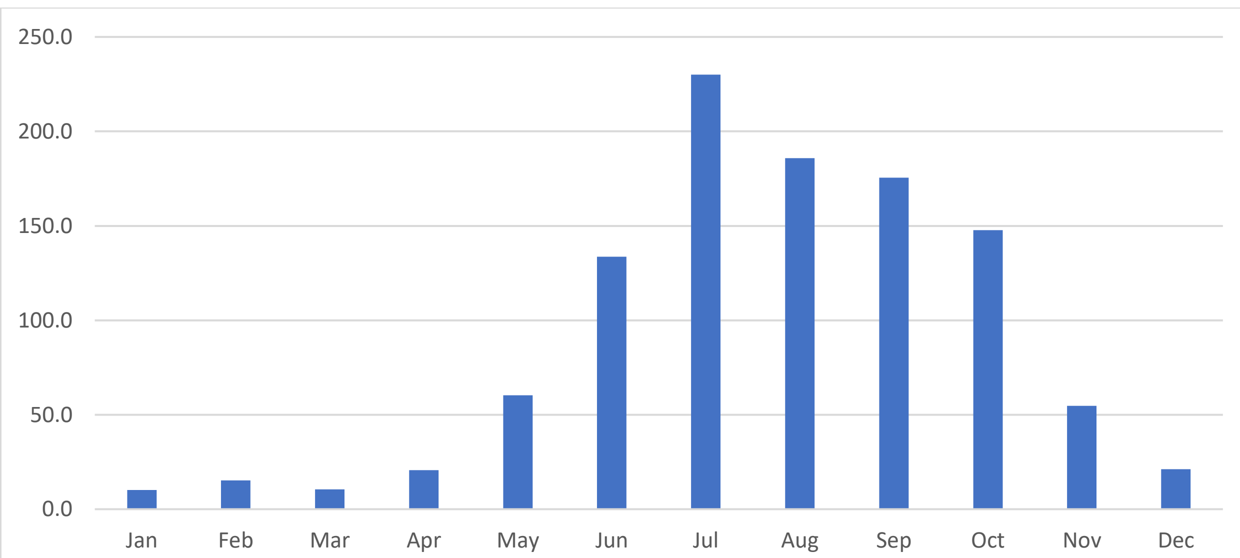

Figure 4-8 30 Year monthly average rainfall recorded
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

As discussed earlier, it is clear that Amaravati receives the majority of its rainfall during the monsoon season, which lasts from July to December. Additionally, there is an increasing annual trend in rainfall, primarily evident during the Southwest monsoon, with a minor increase during the hot and cooler months. This growing trend in rainfall during the southwest monsoon underscores the need for planning infrastructure to manage higher volumes of runoff and enhance the holding capacity of retention ponds.

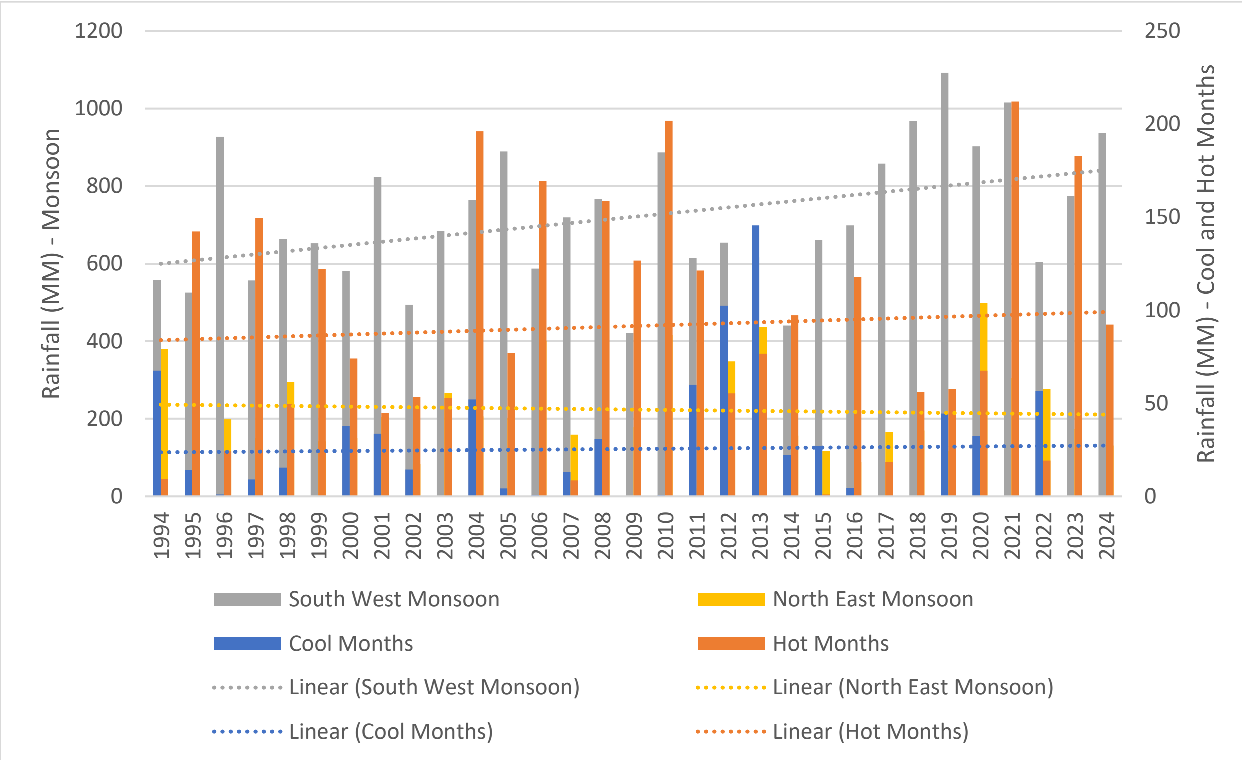

Figure 4-9 Seasonal rainfall trend of Amaravati for 30 years (1994-2024)
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

The number of years recording higher rainfall than the annual mean has increased over the decades. From 1994 to 2000, only one year had rainfall higher than the annual average, while from 2001 to 2010, there were six years, and from 2011 to 2020, there were five years. From 2021 to 2024, three years have already recorded rainfall higher than the annual mean rainfall. At the same time, a decreasing trend in the number of rainy days at a rate of 2.6 days per decade is observed. Even though there is a positive record of more rainy days than the 30-year average of 54 rainy days from 2019, except in 2023, the number of rainy days meeting half of the annual average rainfall is decreasing, which is further exacerbated by the increase in the number of heavy rainfall days[48]. All of these trends indicate the rising frequency of high intensity rainfall events, which could lead to flooding events when the infrastructure gets surcharged due to the discrepancy between designed rainfall and actual rainfall.

[48] Heavy rainfall days are days which receive rainfall in the range of 64.5-115.5 mm/24 hour

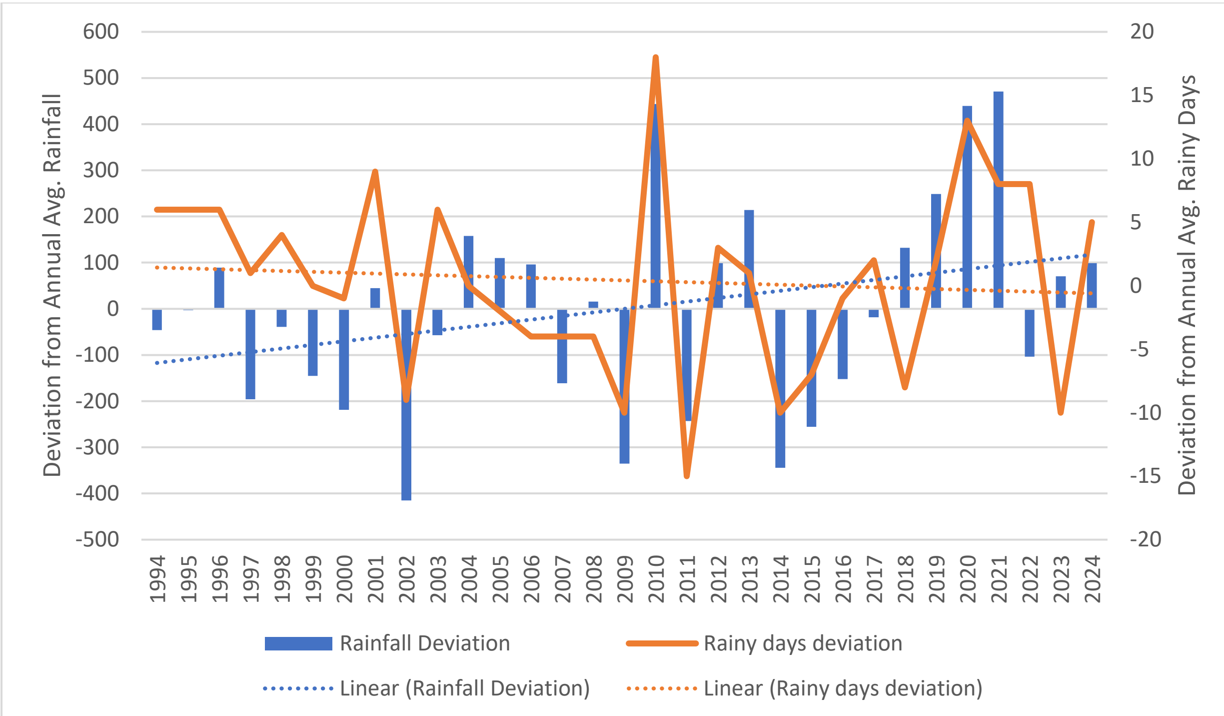

Figure 4-10 Anomalies in annual rainfall and number of rainy days (1994 to 2024)
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

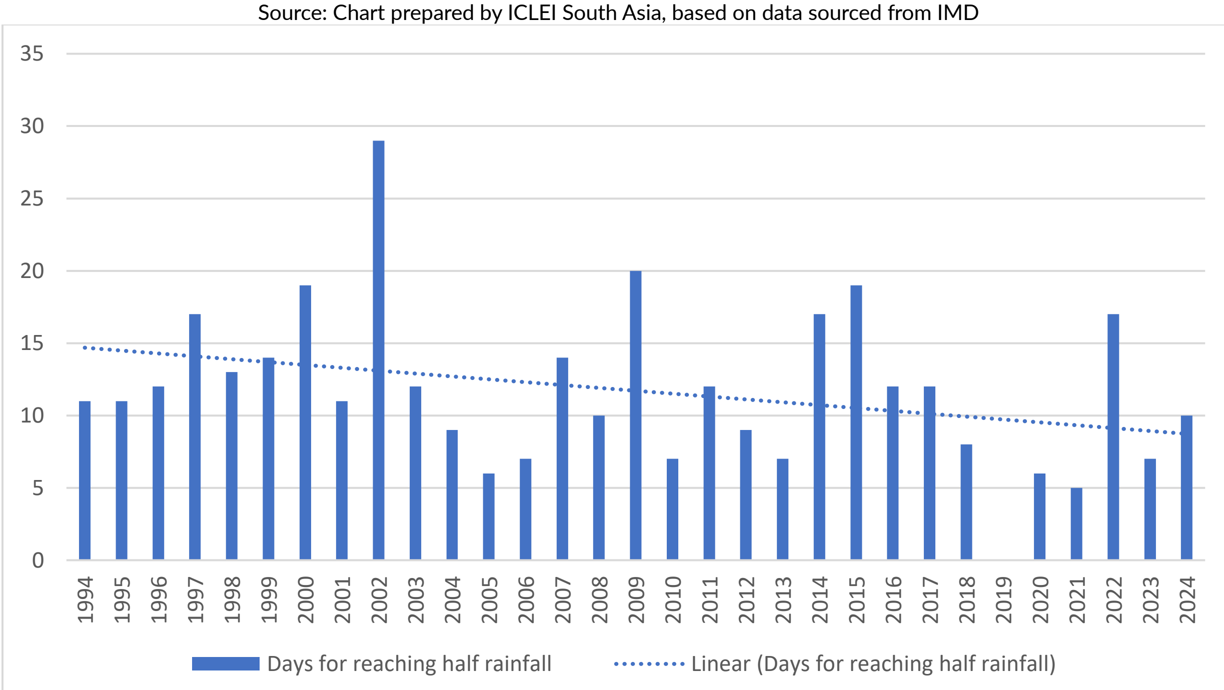

Figure 4-11 Number of days taken to receive half of total annual avg. rainfall (530.6 mm), 1994-2024
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

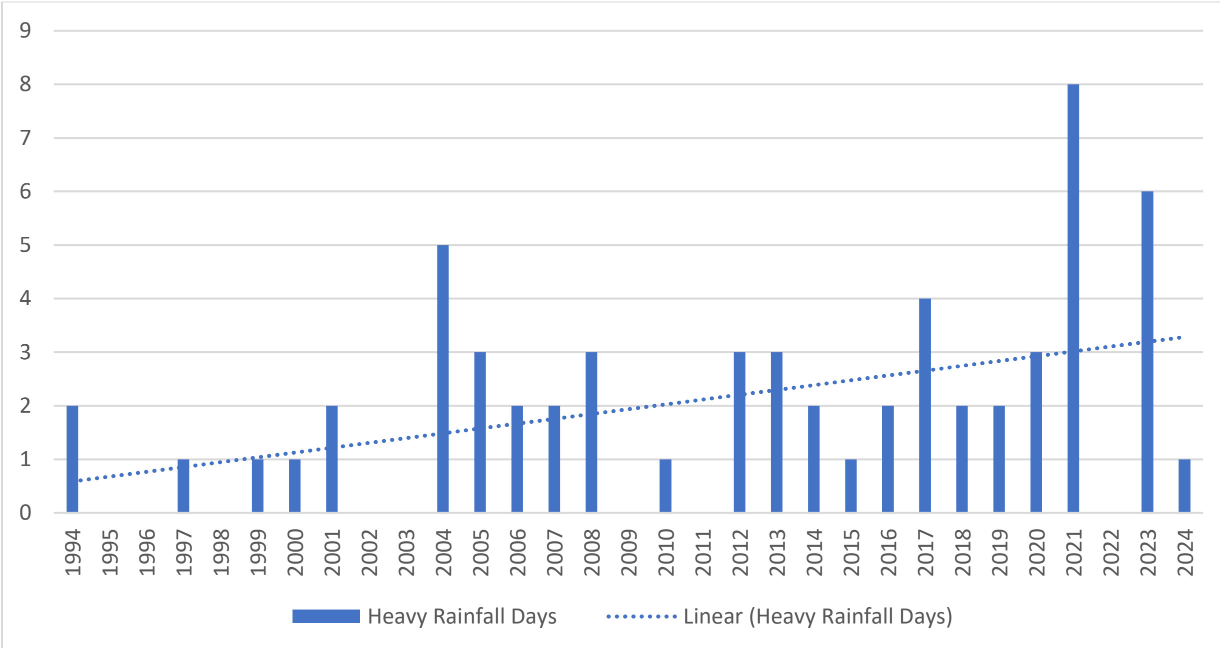

Figure 4-12 Number of Heavy rainfall days (1994-2024)
Source: Chart prepared by ICLEI South Asia, based on data sourced from IMD

4.2.2 Analysis of Historical Climate Events

Amaravati is experiencing the impacts of climate change, marked by noticeable shifts in temperature and rainfall patterns. The rising average temperatures and increasing erratic rainfall are the primary observed climate risks, contributing to growing instances of heat stress and urban flooding. Data sourced from Guntur District Disaster Management Plan (DDMP) and other secondary sources indicate that the city is vulnerable to climate induced hazards, including urban flooding caused by riverine flooding and intense rainfall, heat stress, cyclones and droughts. Since disaggregated data specific to Amaravati is limited, mandal level information has been used where necessary. The available data is sufficient to understand the climate risks and their impacts on existing settlements within the city jurisdiction.

Table 4-1: Mandal-wise Hazard Risk Mapping

Mandal[49]	Urban Flooding	Cyclone	Drought	Heatwave
Mangalagiri	High	Medium	Low	Medium
Tadepalli	High	Medium	Low	Medium
Thulluru	High	Medium	Low	Medium

Source: Guntur DDMP, Volume-1

4.2.2.1 Urban Flooding

Flooding is a major concern in Amaravati due to runoff from the up streams of Kondaveeti vagu catchment and flat terrain, proximity to the Krishna River. The Kondaveeti *vagu* (water channel) often overflows during

[49] Amaravati city spans across Managalagiri, Tadepalli and Thulluru mandals, due to lack of city level data availability, mandal level information is considered to understand the hazards risk. The Hazard risk mapping has been carried based on Hazard exposure, frequency and intensity, coping capacity as outlined in the Guntur DDMP, volume-1.

heavy monsoon rains causing localized flooding, and flood risk is exacerbated when the Krishna River is at high flood levels, restricting the outflows from Kondaveeti *vagu*.

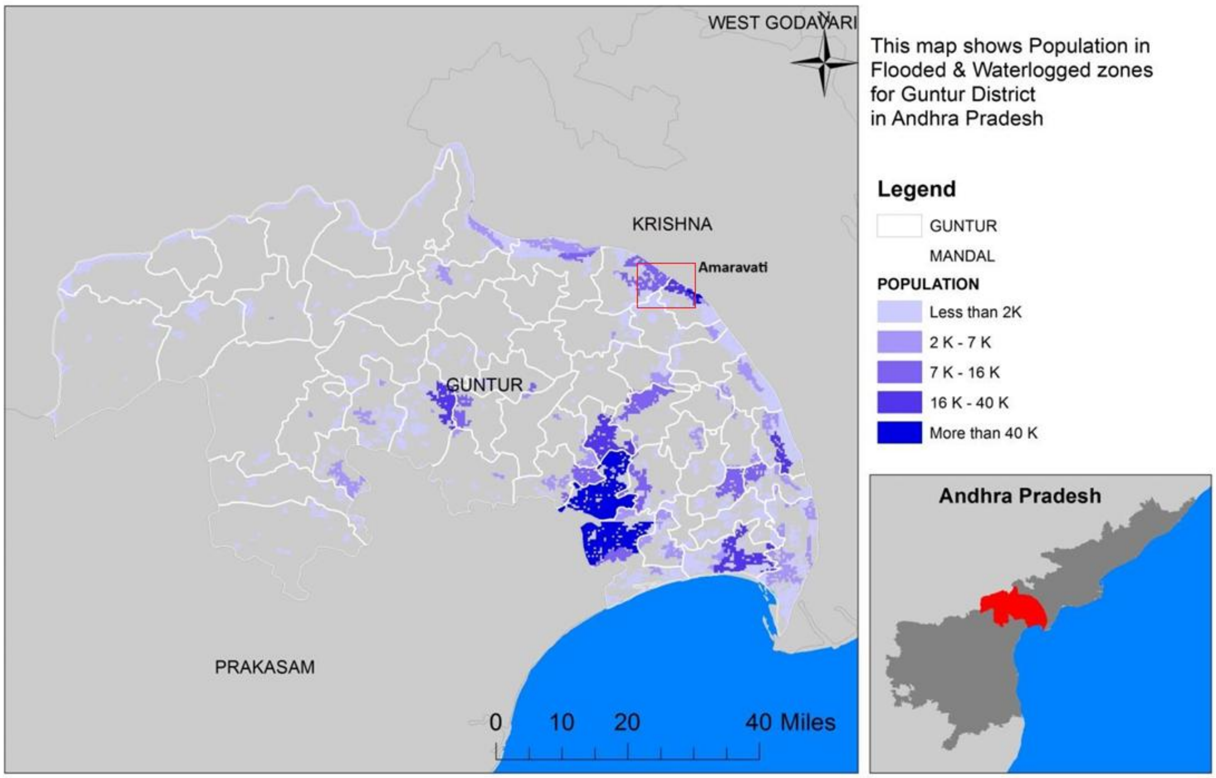

Figure 4-13: Flood and Waterlogged zones in Guntur District
Source: Guntur DDMP, Volume-1

The flooding of Krishna River and excessive rainfall in the Kondaveeti vagu catchment has very rare occurrence at same time. A notable exception occurred on 20th September 2005, a major flood event was recorded with the Krishna River reaching a peak discharge of 20,545 m^3/sec, accompanied by an average of 162 mm rainfall in the Tadikonda and Thulluru areas. [50]

On 31st August 2024, Amaravati experienced about 280 mm of rainfall in one day and 150 mm of rainfall in 3 hours.[51] While there was no reported loss of human life, the flooding caused widespread disruption to connectivity and livelihoods. Several villages were affected, including Penumaka, Undavalli, Nowluru, Nidamarru, Kuragallu, Krishnayapalem, Velagapudi, Venkatapalem, Borupalem, Abbarajupalem, Dondapadu and Sakamuru, with roads submerged, and access to livelihood and public services impacted. The inundation areas and impacts are detailed in section 4.4.2.1.

4.2.2.2 Cyclone

As per the Wind and Cyclone Hazard Map of India, Amaravti city falls within a moderate risk zone for cyclones, with a wind speed of 44m/sec. Although Amaravati has not experienced direct landfall of major

[50] Source: DPR for flood management for Amaravti capital city, Volume-1, June 2017.
[51] Hindustan times new article published on September 10, 2024.

cyclones in recent decades, it has been affected by the peripheral impacts of cyclonic storms such as Cyclone Phethai (2018), Cyclone Gulab(2021), etc., which brought heavy rainfall and waterlogging in low-lying areas.

4.2.2.3 Heatwave

According to Guntur DDMP, Amaravati has witnessed more frequent heat conditions over the past years and the whole city falls in extreme heatwave conditions with a temperature range of 43-49˚C.

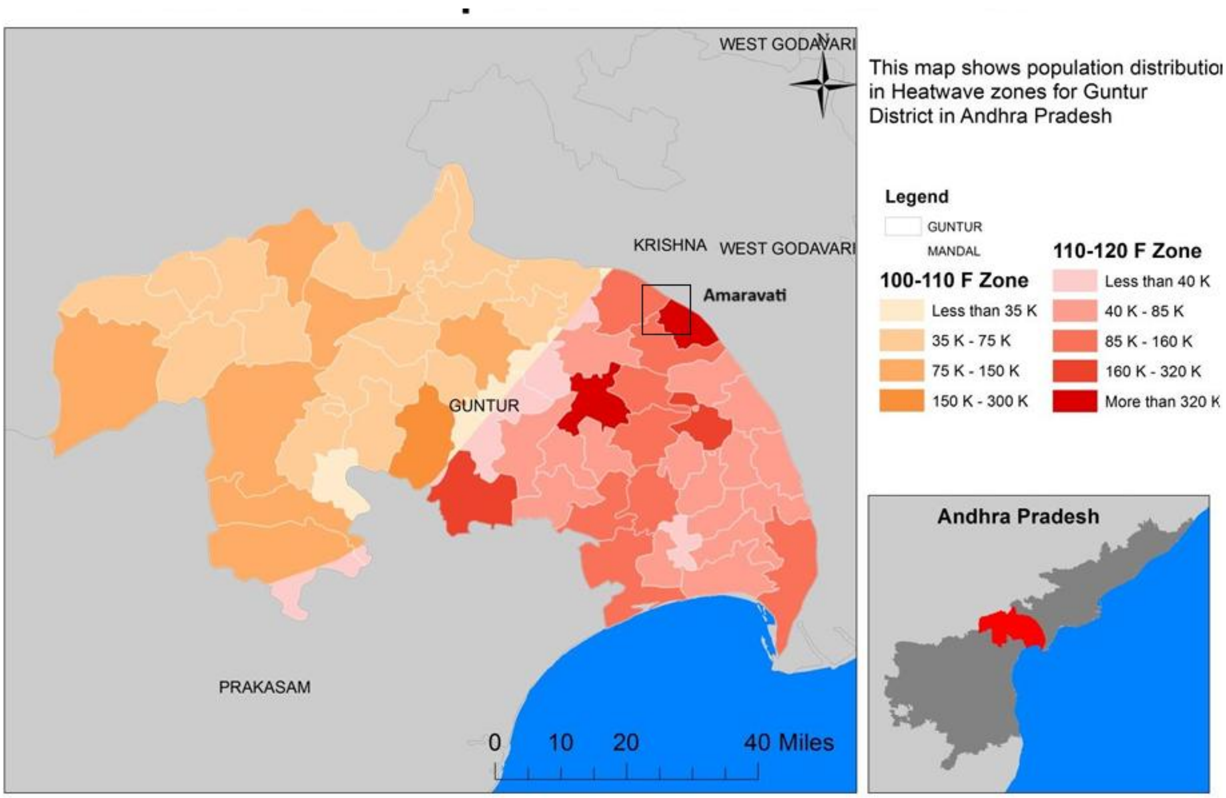

Figure 4-14: Heatwave zones in Guntur District
Source: Guntur DDMP, Volume-1

As per the Andhra Pradesh State Heatwave Action Plan, the Thulluru, Tadepalli and Mangalagiri mandals are vulnerable to rising temperature and heat stress. The maximum temperature of 48°C was recorded in this region on 11th May 2002 and 31st May 2003.

Although the region is heat-prone, the local community is habituated to it and does not consider it as a major concern. However, physical vulnerability remains high due to outdoor occupations, elderly populations and a lack of cooling infrastructure particularly in rural settlements.

4.2.2.4 Drought

As per the Memorandum on Drought in Andhra Pradesh 2014, all three mandals that comprises the Amaravati region – Thulluru, Tadepalli and Mangalagiri were classified under the moderate drought category. However, the overall drought risk for the region is considered low as per the DDMP.

4.2.3 Air Quality

The Amaravati capital region is experiencing increased construction activities aimed at urban infrastructure development, resulting in a higher concentration of particulate matter leading to deteriorated air quality. The CPCB has been monitoring air quality through the installed AAQMS at the secretariat building in Amaravati since 2018. Analysing the information from 2018 to 2024 for this AAQMS indicates that the annual average concentrations of NO2 and SO2 have not surpassed the National Ambient Air Quality Standards (NAAQS), with only the concentration of NO2 exceeded the NAAQS of 80 µg/m^3 in 2018 and 2019 for 13 and 14 days, respectively. The annual average concentration of PM 2.5 remained at 32.15µg/m^3, below the NAAQS of 40 µg/m^3 from 2018 to 2024. In contrast, the annual average concentration of PM10 exceeded the NAAQS of 60µg/m^3 in 2018, 2019, and 2023, with an annual average of 65.22 µg/m^3. Analysing the daily records of particulate matter concentrations indicates that the concentration of PM2.5 is higher during the months of January, February, November, and December and the concentration of PM10 is higher in January, February, and from October to December.

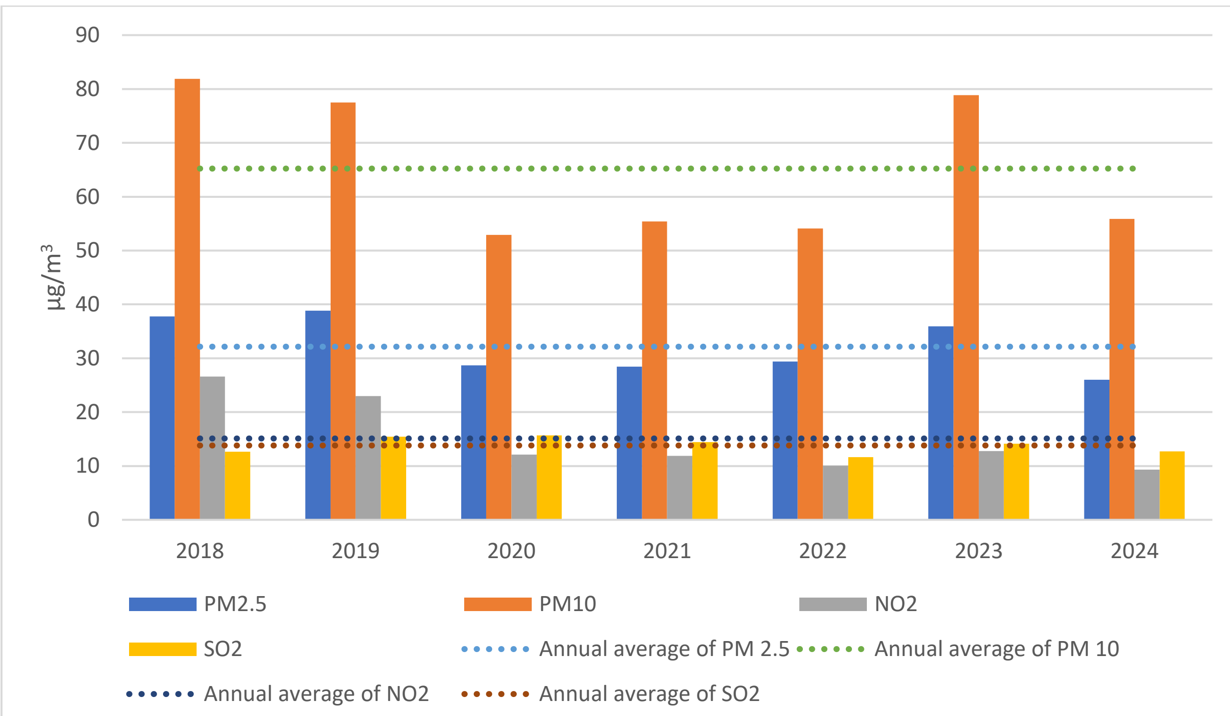

Figure 4-15 Trend of concentration of Air Pollutants (2018 to 2024)
Source: Chart prepared by ICLEI South Asia, based on data sourced from CPCB

4.2.3.1 Spatial analysis

Spatial analysis is performed to identify areas with high concentrations of PM2.5 and PM10 using MODIS AOD spatial data in Google Earth Engine. The study was conducted using the data captured in March 2024 and January 2025, with a primary focus on comparing the period of a few construction activities to the period with higher construction activities.

PM2.5 concentrations in March 2024 range from 23 µg/m^3 to 24 µg/m^3, which is higher than the WHO permissible limits, although it is within the Indian NAAQS standards. By January 2025, the concentration has risen to between 29.8 μg/m³ to 49.4 μg/m³. The PM2.5 levels are higher in existing villages, namely Nidamarru, Kuragallu, Nowluru, Ainavolu, Rayapudi and Borupalem.

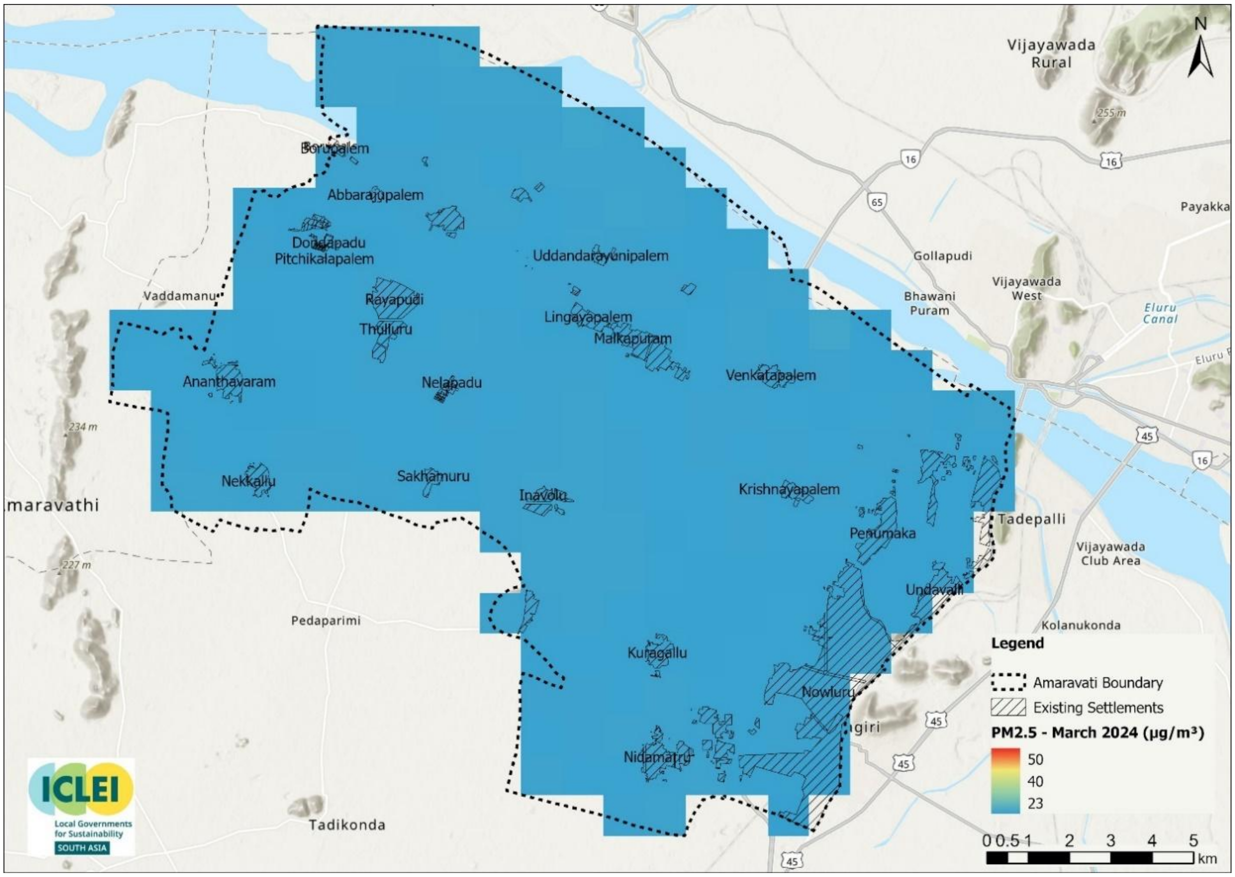

Figure 4-16 PM 2.5 Concentration in Amaravati for March 2024
Source: Map prepared by ICLEI South Asia, based on MODIS satellite imagery

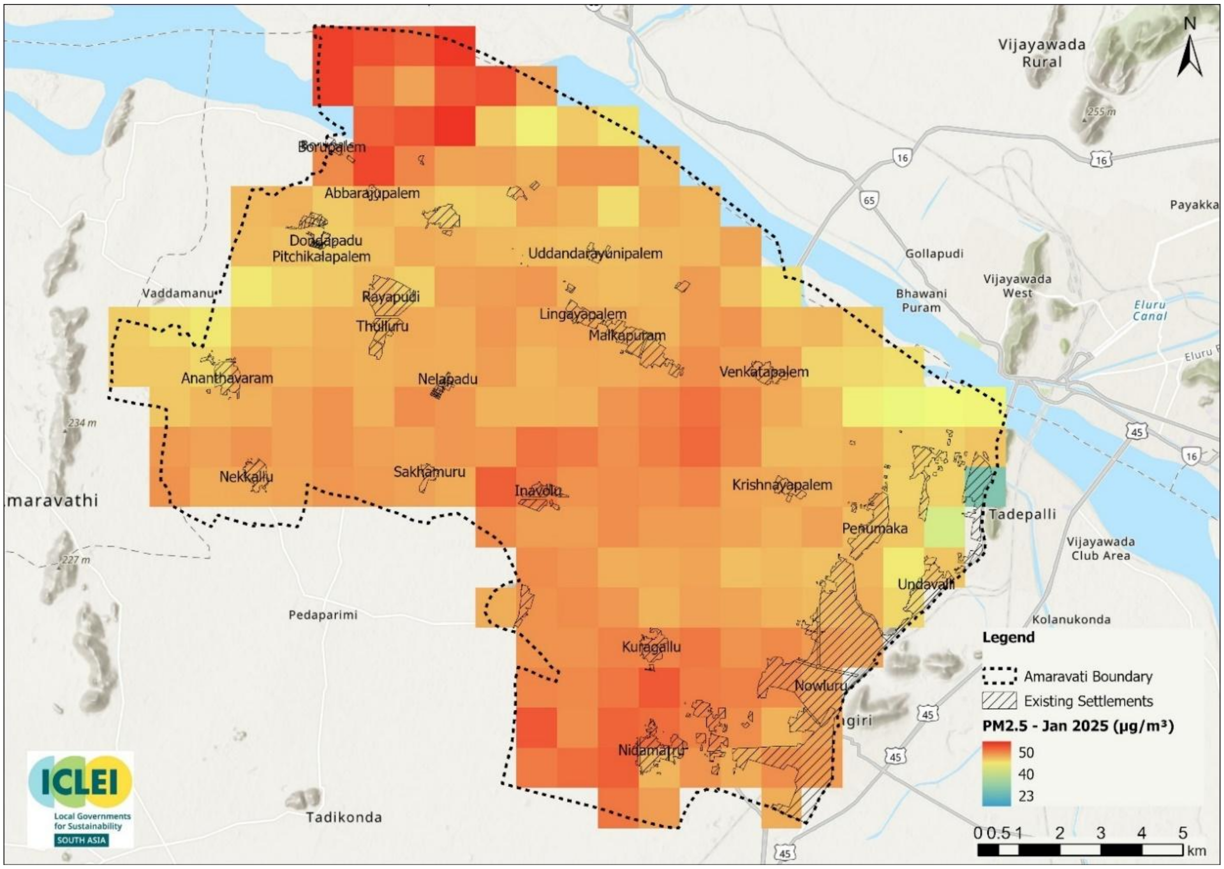

Figure 4-17 PM 2.5 Concentration in Amaravati for January 2025
Source: Map prepared by ICLEI South Asia, based on MODIS satellite imagery

Although the PM10 concentration was within permissible limits, ranging from 52.5 µg/m^3 to 55 µg/m^3 in March 2024, the concentrations increased significantly in January 2025, exceeding the permissible limit of 60 µg/m^3 throughout the city and reaching as high as 105.5 µg/m^3. Areas such as Nidamarru, Kuragallu, Ainavolu, Nelapadu, Mandadam, and Borupalem exhibited very high concentrations of PM10.

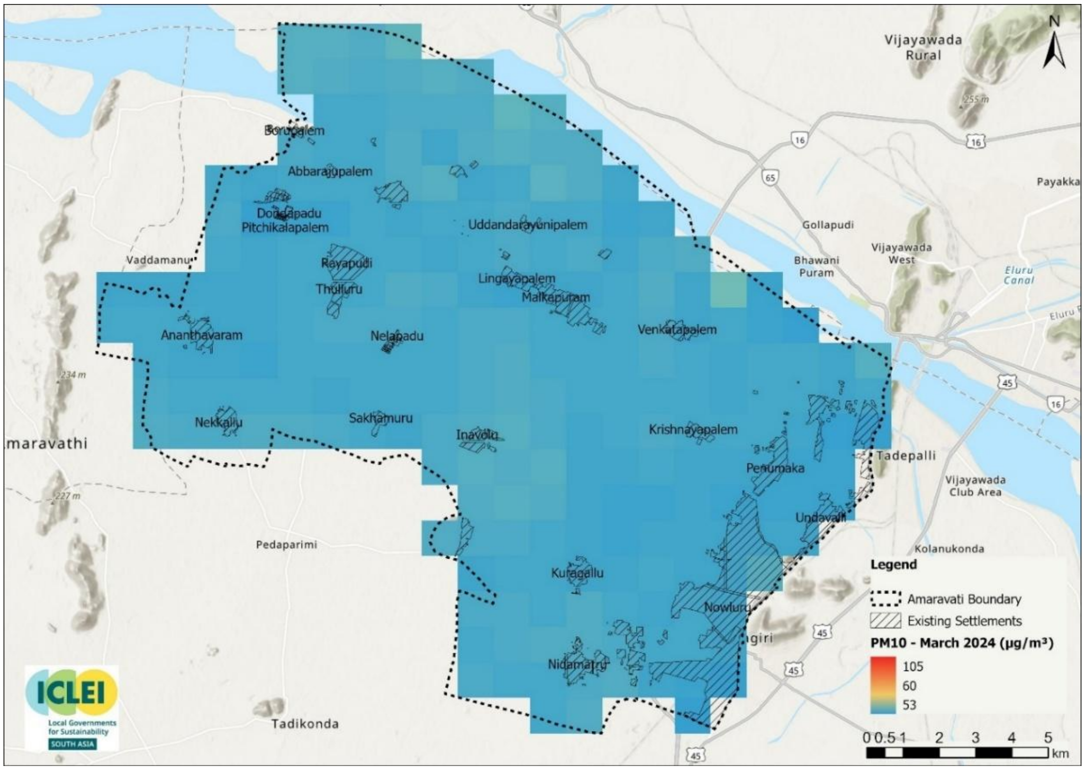

Figure 4-18 PM 10 Concentration in Amaravati for March 2024
Source: Map prepared by ICLEI South Asia, based on MODIS satellite imagery

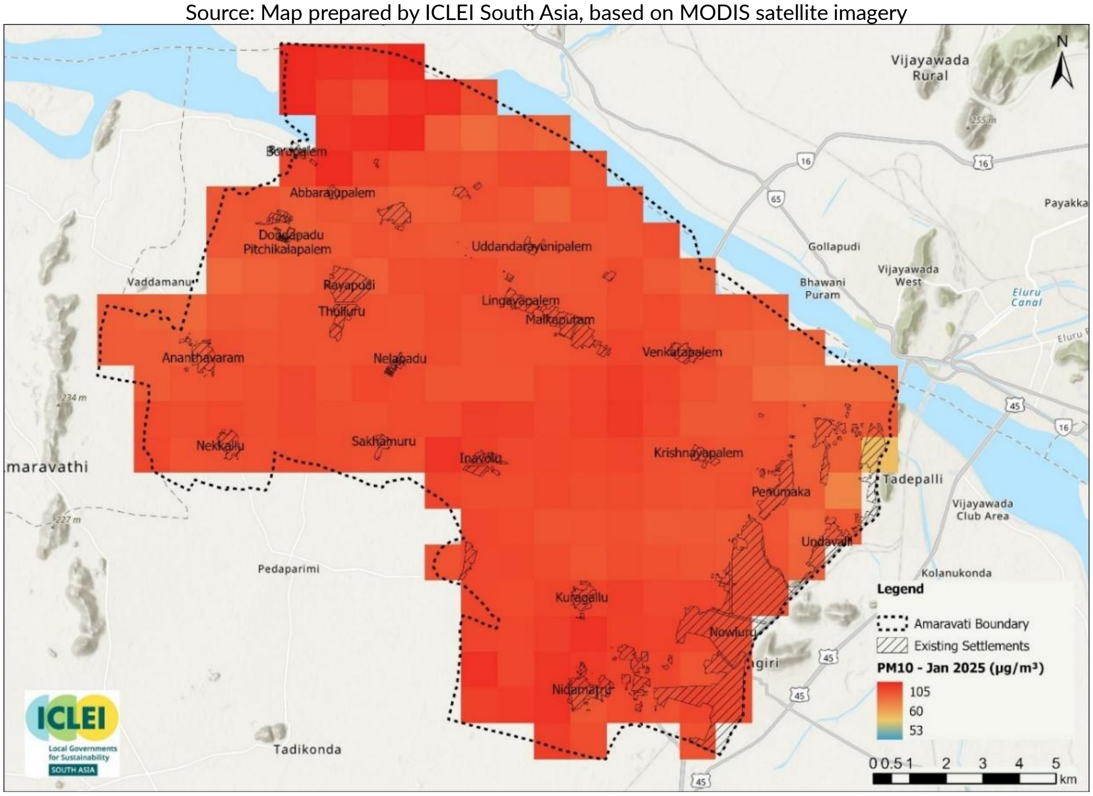

Figure 4-19 PM 10 Concentration in Amaravati for January 2025
Source: Map prepared by ICLEI South Asia, based on MODIS satellite imagery

4.2.3.2 Air Quality Index

Data from the CPCB monitoring centre shows that the AQI in Amaravati was mostly satisfactory and good for about 82% of the days from 2020 to 2024. Approximately 14% of days had moderate AQI levels, and 3% experienced poor air quality. There was only one instance in 2020 when the AQI was categorized as very poor. AQI tends to decline to poor levels in January and December, while it remains moderate or better in the other months. Days with poor air quality have been recorded across all five years.[52]

Table 4-2 Month-wise no. of days recorded AQIs from 2020 to 2024

AQI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good	10	25	54	73	56	101	140	125	114	51	34	16
Satisfactory	66	93	89	68	88	36	3	22	18	66	48	49
Moderate	52	21	10	5	8	7	0	2	1	35	58	52
Poor	16	0	0	0	0	0	0	0	0	0	4	28
Very poor	0	0	0	0	0	0	0	0	0	0	0	1
Severe	0	0	0	0	0	0	0	0	0	0	0	0

Source: AQI Data repository, NAQI, CPCB

4.3 Climate Projections and Scenario Statements

To assess Amaravati's future vulnerabilities, it is necessary to understand the projected climate trends in its region. Since city-level projections are not available, regional-level projections have been considered from two key sources. The first is the "Hydrological and Climate Modelling of Solapur and Vijayawada cities" by IIT Madras, wherein the Vijayawada projections have been considered due to its proximity and comparable climatic conditions with Amaravati. The second reference is the "Draft Andhra Pradesh State Action Plan on Climate Change (SAPCC)", which provides climate projections for Guntur district, where Amaravati is located. These references provide a relevant contextual basis for deriving precipitation and temperature projections for Amaravati.

The climate scenarios are based on Representative Concentration Pathways (RCPs)[53] – RCP 2.6, 4.5, 6.0 and 8.5,[54] representing varying levels of GHG emissions and mitigation efforts. These scenarios help understand potential climate futures under different socio-economic and policy trajectories. The precipitation and temperature projections for Vijayawada and Guntur district, have been used to derive the climate scenarios for Amaravati.

Table 4-3: Temperature and Precipitation projections for RCP 2.6,4.5,6 and 8.5 scenarios

Parameter	RCP 2.6		RCP 4.5		RCP 6.0		RCP 8.5	
	2020-2048	2050-2078	2020-2048	2049-2078	2020-2048	2049-2078	2020-2048	2049-2078

[52] Ranges of AQI categories are Good 0 to 50, Satisfactory 51 to 100, Moderate 101 to 200, Poor 201 to 300, Very poor 301 to 400, Severe 401 to 500 as per the National Air Quality Index.

[53] Representative Concentration Pathway (RCP) scenario describes different trajectories for greenhouse gas concentrations and the resulting radiative forcing (energy added to the climate system) by 2100

[54] RCP 2.6 scenario, GHG emissions and air pollutants are reduced substantially over time.
RCP 4.5 is a stabilization scenario in which a range of technologies and strategies are employed to reduce emissions before 2100.
RCP 6 is a stabilization scenario in which stabilization is achieved after 2100 using a range of technologies and scenarios.
RCP 8.5 is a high-emission scenario leading to high greenhouse gas concentrations

Average maximum temperature	Increase by 1.1°C	Increase by 1.2°C	Increase by 1°C	Increase by 1.5°C	Increase by 1°C	Increase by 1.5 - 1.7 °C	Increase by 1.2-1.3°C	Increase by 2.2-2.4°C
Average minimum temperature	Increase by 1.1°C	Increase by 1.2°C	Increase by 1°C	Increase by 1.5°C	Increase by 1°C	Increase by 1.5 - 1.6°C	Increase by 1-1.2°C	Increase by 2-2.3°C
Average precipitation	Decrease in monsoon rainfall, increase in non-monsoon		Decrease by 50mm from historic mean		No change in mean annual rainfall		Decrease by 70mm from historic mean	
Extreme precipitation/ wet events	Overall decline in annual rainfall, with peak years up to 1650mm and dry years less than 550mm. Non-monsoon rainfall increases by 10%		8-10 years of high rainfall expected with annual rainfall >1500mm		7-8 extremely wet years expected with annual rainfall >1700mm		Peak rainfall during wet years reach 1500mm	
Drought occurrence	25-30 moderate to severe drought years		20-25 moderate to severe drought years with annual rainfall below 450mm		10-15 severe droughts		25-30 moderate to severe drought years	

Source: Hydrological and Climate Modelling of Solapur and Vijayawada cities by IIT Madras,2019

According to Hydrological and Climate Modelling of Solapur and Vijayawada cities study by IIT Madras (2019), Amaravati is projected to increase in both mean annual minimum and maximum temperatures across all future scenarios. The mean annual maximum temperature is expected to rise by 1- 1.3°C in the near term (2020-2048) and by 1.2-2.4°C during the mid to late century period (2049-2078). Under RCP 8.5 scenario, the increase could reach 2.2- 2.4°C by 2049-2078 period. Similarly, the mean annual minimum temperature is projected to rise by 2 to 2.3°C under the RCP 8.5, while other scenarios indicate a rise of atleast 1 to 1.5°C in the far period.

The study indicates a shift in rainfall patterns with an increase in the frequency of floods and droughts in the region. The mean annual rainfall is projected to decrease by 40mm under RCP 2.6 and by up to 70mm under RCP 8.5. However, all the scenarios project extreme rainfall events are expected to increase, indicating the heightened potential for flooding. The combination of reduced total rainfall and more intense rainfall events heightens the risk of both urban flooding and drought conditions.

According to the draft SAPCC, similar patterns are projected for the Guntur district, where Amaravati is located. The SAPCC highlights a temperature rise of around 0.9°C across Andhra Pradesh. The maximum temperatures are projected to increase by 1.35 to 1.8°C across the scenarios, leading to a notable increase in the occurrence of extreme heat events. The annual average number of rainy days in Guntur district is projected to be 91-100 days under RCP4.5 and 81-90 days under RCP 8.5 scenario until year 2100, indicating the rainfall variability and concentration over shorter duration.

Table 4-4 Climate scenarios

Climate parameter	Climate Scenario Statement

Change in Rainfall	• Annual average rainfall is expected to decrease by 40-70mm, depending on the scenario • Rainfall variability is projected to increase, ranging as high as 1650mm during peak rainfall years to less than 450mm in dry years. • Frequency and intensity of extreme rainfall events are likely to rise, leading to an increased risk of urban flooding. • Monsoon rainfall is projected to decline by up to 10%, while an increase in non-monsoon rainfall is anticipated • Annual average number of rainy days in Guntur district is projected to be 91-100 days under RCP4.5 and 81-90 days under RCP 8.5 scenario (until year 2100).
Change in temperature	• Rising trends in both mean maximum and minimum temperatures, ranging from 1 to 2.4°C • Increase in heatwave frequency and intensity
Drought events	• At least 10-15 Moderate to severe drought events are projected across all scenarios. • Up to 25-30 droughts are expected under high-emission scenarios.

4.4 Climate Risk and Vulnerability Mapping

4.4.1 Assessment of Heat Hotspots

The objective of this analysis is to identify potential heat stress zones based on the surface temperature trends, land use transformation, and the role of natural and built environment features. The result is critical to inform planning interventions such as green infrastructure, heat resilient design and zoning regulations. Temperature in a region is influenced by various parameters, including natural features such as soil cover and solar radiation, as well as manmade interventions that alter surface albedo. Identifying heat hotspots in Amaravati, which spans 217 sq. km, is essential for understanding how the upcoming development might result in temperature changes compared to baseline year temperatures and relatively hotter areas once the city is fully developed according to the Master Plan. The conventional heat mapping techniques that rely on historical surface temperature data from built-up areas is not relevant in this case. A forward-looking approach has been adopted to assess the potential future heat risks in line with the city's projected land use as per the Amaravati Master Plan. Indicators and methodology used for assessment are described in Table 4-5.

Table 4-5 Indicators and Methodology Used for Heat Hotspots Assessment

Heat Hotspots Assessment	
Indicator	**Methodology**
Air Temperature Trend and Future Scenario (Section 4.2.1.1)	**Methodology**: Historic trend analysis of annual air temperature (including minimum, mean, and maximum temperature). **Data Used**: Daily air temperature data from 1994 to 2024. **Data Source**: IMD Station at Gannavaram.
Land Surface Temperature (LST) Baseline Analysis	**Methodology**: Pixel-based statistical analysis of satellite imagery for daytime over the years 2023, 2024, and 2025 was conducted to understand the spatial distribution of LST. A mean LST was developed using the results from these three years, which gives an average value for each pixel to neutralise variations in temperature at the time of capturing the satellite information. A gradual increase in expansion in hotter land surface temperatures, especially over those hotter surfaces, was used as an indication of a temperature hotspot. **Data Used**: 30m x 30m resolution Landsat 8 & 9 imagery from May 2023, May 2024, and April 2025 for Daytime Surface Temperature **Data Source**: Earthexplorer.USGS
Land Surface Temperature (LST) projected for 2058	**Methodology**: **Step-1: Land Surface Temperature (LST) for the current scenario** A mean LST has been generated considering the Landsat 8 & 9 satellite imageries for May 2023, 2024 and 2025 using the raster calculator in ArcGIS. The LST for the existing settlements, protected and natural features is considered from the mean LST. **Step-2: Calibration from reference cities**

Heat Hotspots Assessment	
Indicator	**Methodology**
	To develop an estimated temperature model for future built-up areas in Amaravti, LST data from cities with similar urban features – Vijayawada, Hyderabad, and Chandigarh were referred to. Rationale for considering the cities is as follows **Vijayawada** – Selected for its similar climatic conditions and being adjacent to Amaravati, provides a reliable thermal baseline for the built-up areas under similar geographic conditions. **Hyderabad** – Considered for its established urban heat island studies and mixed peri-urban development. As it is a capital city with similar density and the types of activities would be similar to those in Amaravati. **Chandigarh** – A planned city comparable to Amaravati in spatial layout and zoning, provides insights on how the planned urban design and blue-green infrastructure has its impact on the surface temperature of the surrounding areas and mitigate heat stress. Surface temperatures from these cities is utilised for establishing the impact of blue-green infrastructure in the proposed land use, allowing us to project likely heat conditions under the fully developed scenario. **Step-3: Assigning the differentials values for the future land use** Land use categories from the Amaravati Master Plan were used as the base layer. For each of the land use categories, temperatures from the reference cities were applied, FSI and the type of development that would come in the areas. The impact of the blue-green infrastructure is incorporated into the assigned land use temperatures by assigning differential/ delta values based on the expected heat modulating characteristics.

Land use Type	Delta Value (˚C)[55]
Large Green Spaces	1.3
Small Green Spaces	1.5
Avenue plantation	1.5
Water bodies	2
Canals	1.3
Roads with avenue plantation compared to roads without plantation	1.7

These delta values were used to adjust the surface temperatures relative to one another among different land use categories and simulate the spatial temperature variation aligned with future urban forms.

[55] Delta value is the estimated difference in temperature for every 100m meters away from the natural features like green spaces, water bodies etc.

Heat Hotspots Assessment	
Indicator	**Methodology**
	GIS tools like Euclidean distance, raster calculator, statistical tools and other tools were used to generate the map. **Data Used**: 30m x 30m resolution Landsat 8 & 9 imagery for 2025 Daytime Surface Temperature. Amaravati's Master plan to identify land surface patterns that correlate with land use patterns. **Data Source**: Earthexplorer.USGS, APCRDA

4.4.1.1 Baseline Land Surface Temperature

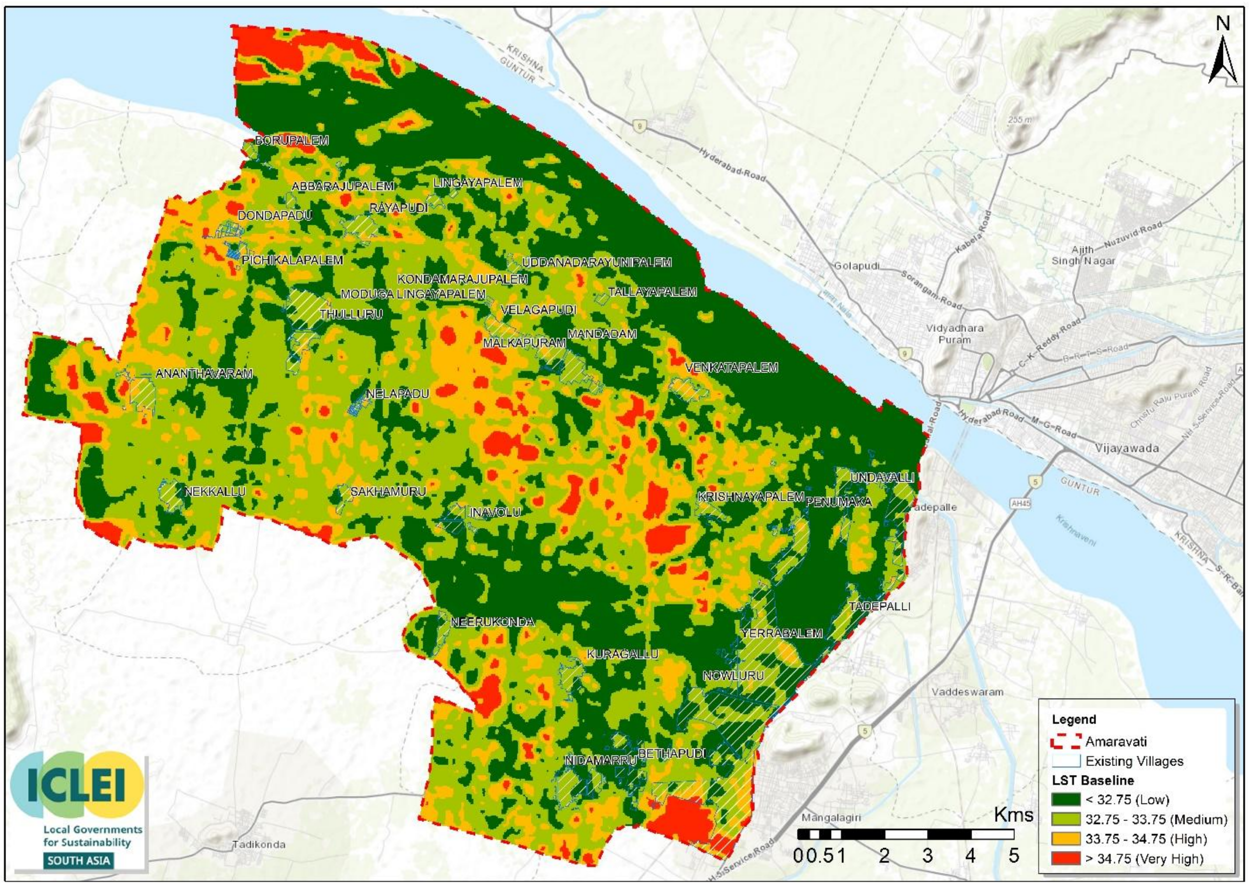

Figure 4-20 Land Surface Temperature Baseline
Source: Prepared by ICLEI South Asia based on Landsat 8 & 9 imagery

In the baseline scenario, LST for Amaravati varies between 27.69°C and 37.03°C. The cooler temperatures are observed in the deep backwaters of Prakasam barrage, while the highest surface temperatures occur in the Lanka villages, primarily due to the exposure of sand beds. Areas currently with no agricultural activity, particularly the region surrounded by the villages of Krishnayapalem, Ainavolu, Nelapadu, Velagapudi, and Lingayapalem, feature Black cotton soil, which is predominant in Amaravati and the Krishna basin has high thermal conductivity[56], allowing barren land to absorb heat more rapidly during the day and cool down faster at night, resulting in very high LSTs exceeding 34.75°C. Notably, 16.44% of the Amaravati falls within the high LST range, largely due to the low albedo of barren land, which impedes its ability to reflect sunlight. Areas with vegetation and waterbodies reflect the lower LST.

4.4.1.2 Projected Land Surface Temperature for 2058

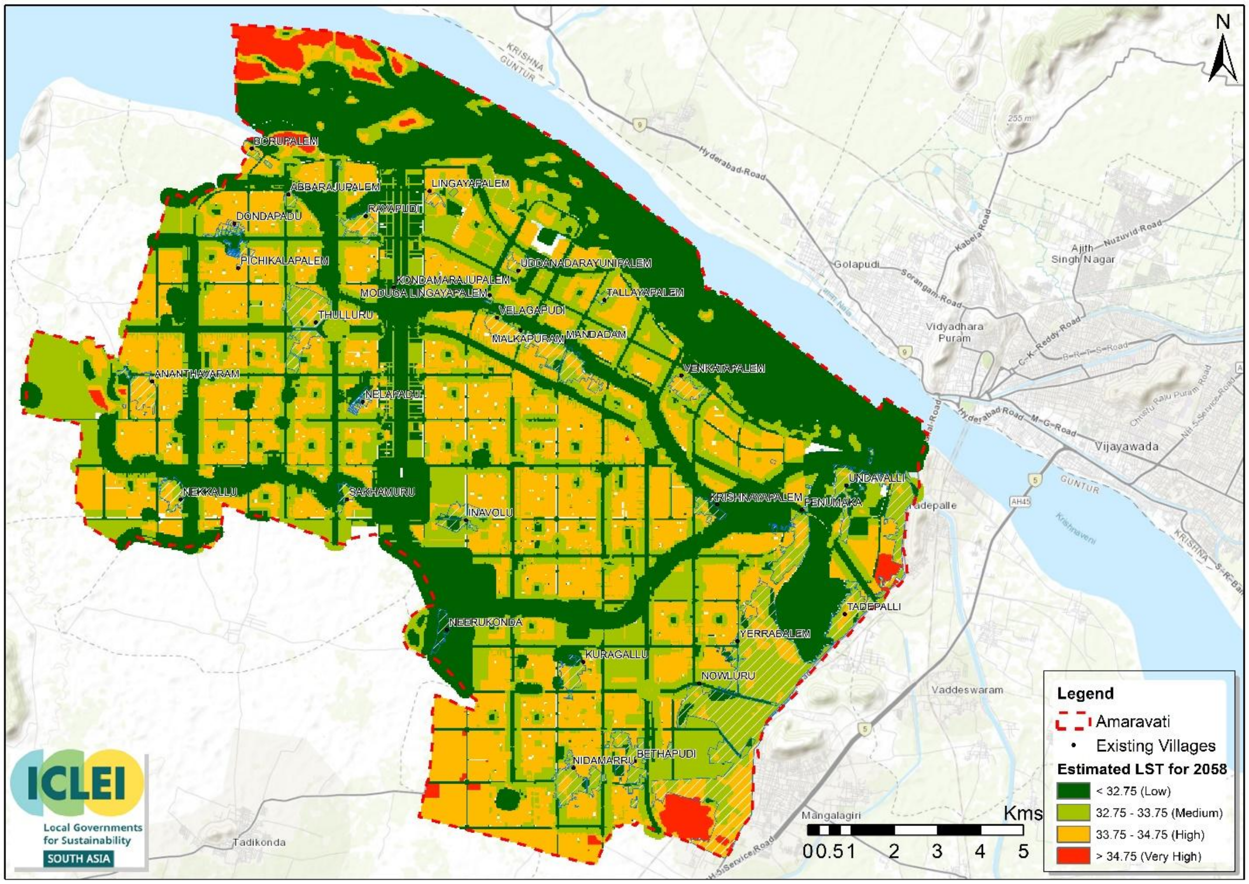

Figure 4-21 Land Surface Temperature projected for 2058

The estimated LST for 2058 was calculated to assess the effects of the proposed Master Plan on the temperature levels. The projected LST for 2058 ranges from 27.65°C to 36.93°C. Areas with very high LST are expected to decrease, as there will be no barren lands left without any activity. This is primarily limited to the villages of Lanka, which are situated in the backwaters of the River Krishna, and city level transport facilities. With the anticipated full development of Amaravati, the area is expected to be dominated by buildings that will produce higher LST values. However, the impact of proposed avenue plantations along the entire road network, as well as both passive and active green buffer areas along water bodies, is expected to play a vital role in lowering LST values. Once fully implemented, these initiatives are expected to significantly influence the microclimate of the Amaravati at the neighborhood level as well.

[56] Thermal conductivity of black soil 2 Days after Saturation (DAS) is 8.61 W m−1K−1 (1.4 Mgm-3 Compaction level) and 14.02 W m−1K−1 (1.2 Mgm-3 Compaction level) and 6 DAS is 3.88 (1.2 Mgm-3 Compaction level) and 5.73 (1.4 Mgm-3 Compaction level) (Pramanik & Aggarwal, 2013).

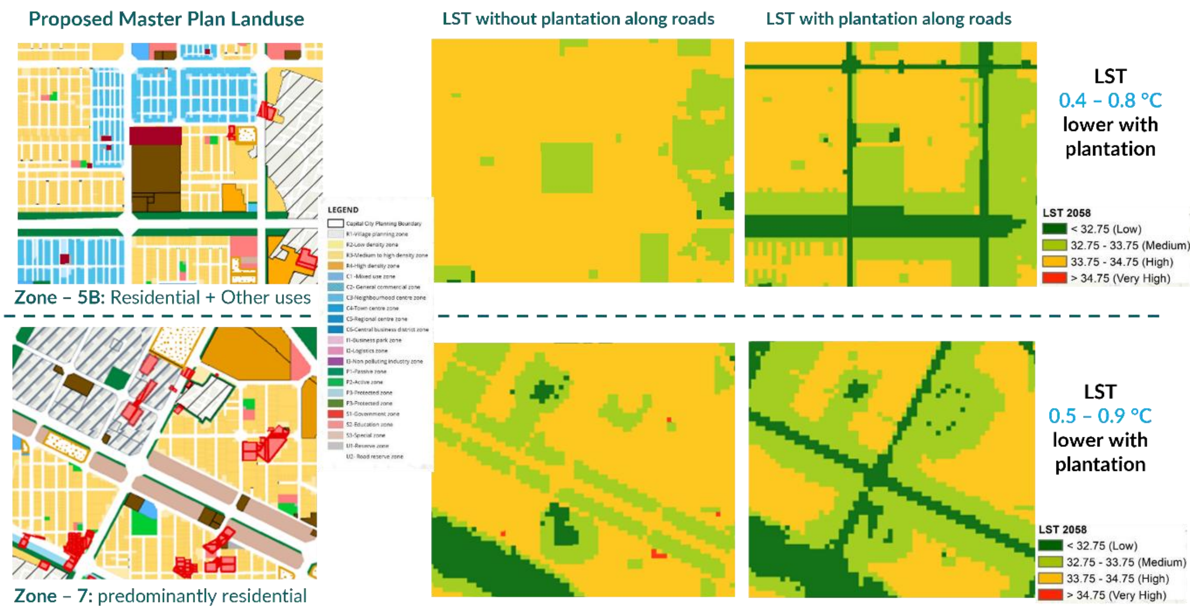

Figure 4-22: Illustration of expected reduction in LST from planned greening measures

The above illustrations demonstrate the modelled impact of the proposed plantation interventions on surface temperature reduction across selected land parcels in zone 5B (residential and mixed-use) and zone 7 (predominantly residential). The analysis compares the projected LST values for 2058 under two scenarios – without and with plantation along roads.

The results indicate that introducing roadside plantations and vegetative buffers could lead to a localized temperature reduction of approximately 0.4 to 0.9°C, depending on the landuse, surface characteristics and green cover. This highlights the importance of integrating nature-based solutions such as avenue plantations, green buffers, and parks into Amaravati's road and open space design. Such measures can mitigate the urban heat island effect, improve pedestrian comfort, and enhance micro-climate resilience as the city develops.

4.4.1.3 Spatial distribution of relatively hotter areas:

The hotspots are identified as areas within the city that exhibit relatively higher LST. Identifying these hotspots is crucial for implementing necessary precautionary measures and for recognizing vulnerable individuals who live or work in these areas for their livelihoods.

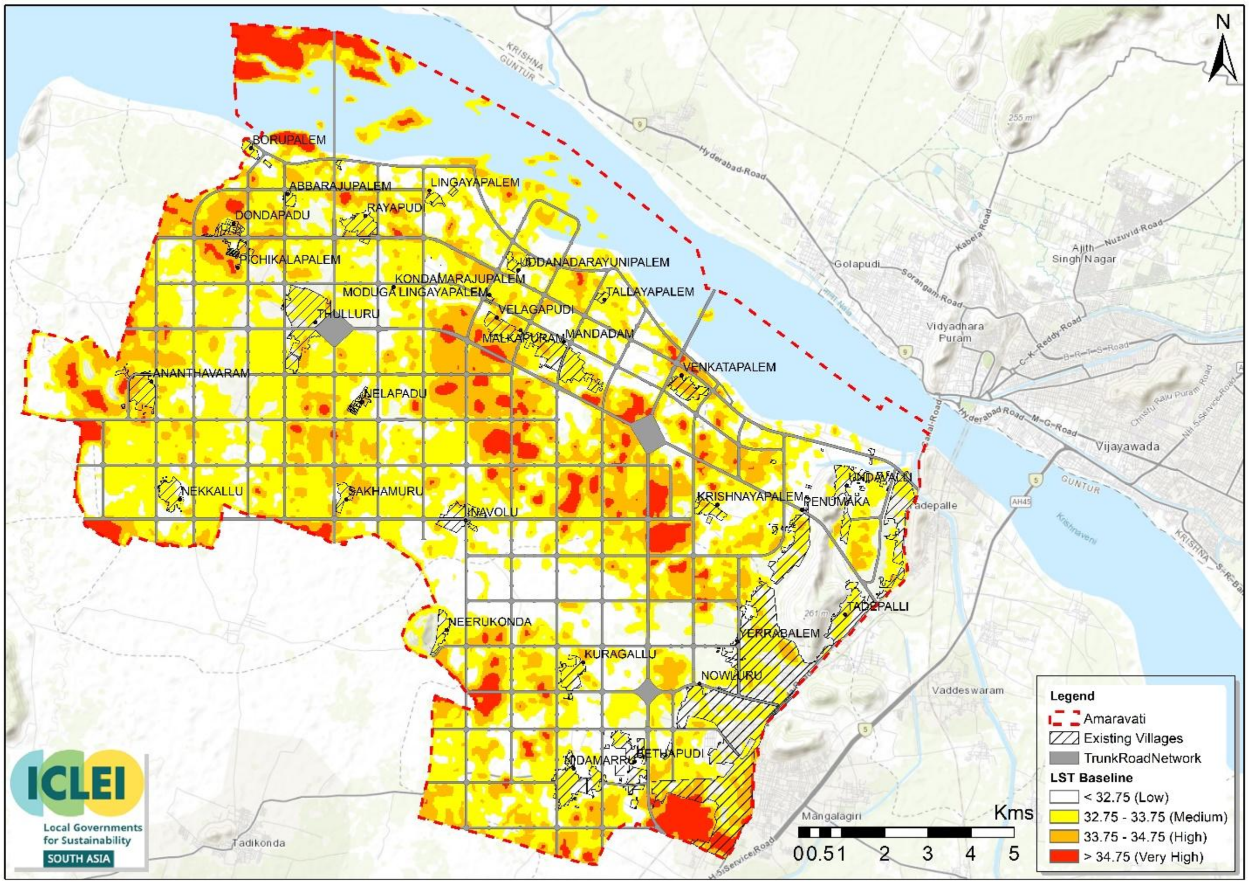

Figure 4-23 Hotspots in the baseline LST

As discussed in section 4.4.1.1, the baseline scenario indicates that the hotspot areas with very high and high LST are primarily open agricultural fields, where activities are currently limited. The existing village settlements display a mean of 33 °C, with values ranging from 28.9 °C in Nidamarru to 36.1 °C in Mangalagiri due to its urban context. With the anticipated construction of infrastructure and buildings, the number of vulnerable individuals is expected to increase. This could lead to negative health impacts such as fatigue, thermal discomfort, and heat strokes, as well as reduced productivity. In the baseline scenario, construction workers, along with village residents, are particularly susceptible to extreme heat. Although converting open lands to buildings may reduce LST to some extent, it is important to address the potential exposure risks during the construction phase as well as try to reduce the heat island effects by using green roofs or cool roofs and increasing green belt cover around built up areas.

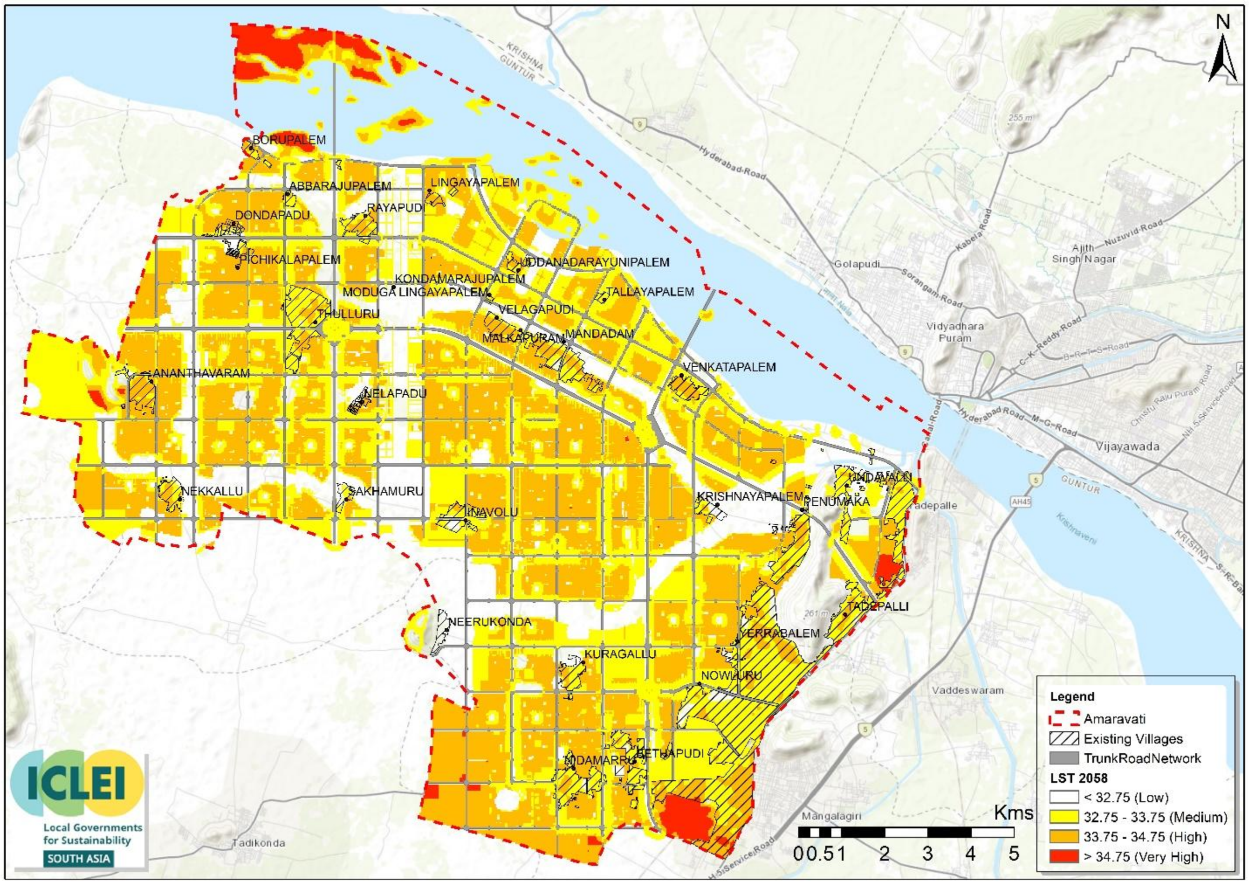

Figure 4-24 Estimated LST hotspots for 2058

Table 4-6 Comparison of areas under baseline and 2058 projected LST ranges

Range	LST Baseline		2058 LST	
	Area (sq. km)	Percentage	Area (sq.km)	Percentage
< 32.75 (Low)	81.99	37.74%	82.5	37.98%
32.75 to 33.75 (Medium)	89.25	41.09%	63.96	29.44%
33.75 to 34.75 (High)	35.72	16.44%	66.68	30.70%
> 34.75 (Very High)	10.27	4.73%	4.09	1.88%

In 2058, LST estimate indicates that the percentage of land area classified as very high heat zones (temperatures exceeding 34.75 °C) decreases from 4.73% in 2025 to 1.88% in 2058. In contrast, the percentage of land falling under high heat zones is projected to increase from 16.44% to 30.7%. This change suggests that a significantly larger portion of the city will experience temperatures in the range of 33.75 °C to 34.75 °C. Consequently, a greater number of residents will be subjected to considerable heat stress, potentially affecting their health and productivity. As the population grows, it is particularly concerning for vulnerable groups, such as the elderly and children, who may be at greater risk from exposure to extreme heat.

Analyzing the relationship between heat hotspots and the master plan reveals that these high heat areas correspond to medium and high-density zones, as well as locations designated for residential and commercial land use. This underscores the importance of implementing policies such as zoning regulations in accordance with Energy Conservation and Building Code (ECBC), which incorporate heat resilience measures. These measures encompass both passive and active thermal comfort strategies aimed at mitigating the effects of extreme heat as well as maintaining green belts and sufficient green cover to regulate the micro climate.

4.4.2 Assessment of Flood

Flooding in the greenfield city of Amaravati primarily occurs due to the low-lying topography and overflow of backwaters to the *vagus* from Krishna River. The flood is further exacerbated by the backflow of water from *vagus* when the Prakasam Barrage gates are closed, impacting the residents in the existing village settlements. As the village settlements get flooded, residents divert the water to nearby agricultural fields using pumping motors. The fields are inundated for a prolonged period, disrupting agricultural work. When construction activities in Amaravati city began in 2024, there was a temporary blockage and diversion of the natural drainage channel of the *vagus*. Rapid urbanization and encroachments on natural flood paths have hindered the natural drainage of floodwaters, resulting in the recent flooding event in September 2024[57][58].

The following analysis aims to identify areas that have experienced persistent waterlogging over the past 30 years and compare these waterlogged areas with the September 2024 flood event[59] to analyse the changes in recurring inundation patterns and assess waterlogging occurrences during ongoing construction in Amaravati.

Methodology for occurrence and recurrence flood analysis

Step 1: Data Acquisition and Preprocessing

An extensive archive of Landsat satellite imagery from 1984 to 2021 has been gathered. The collected satellite imagery, in spite of the presence of extensive cloud cover and atmospheric interference, was processed using radiometric calibration, atmospheric correction, and quality filtering to remove cloud cover.

Step 2: Water Classification via an Expert System

Each pre-processed Landsat imagery is then analysed pixel by pixel using an expert system specifically designed to detect water. The system uses spectral properties and signatures of water, incorporating indices such as Normalized Difference Water Index (NDWI), to classify each pixel as water or non-water.

Step 3: Temporal Aggregation to Generate Water Occurrence and Recurrence Datasets

After water has been detected in individual images, the results are aggregated over time.

[57] Rainfall inundating 25 out of its 29 villages in Amaravati city, Hindustan Times, September 2024, Accessed June 2025
[58] Budameru causes flooding in Vijayawada again after 20 years, The Times of India, September 2024, Accessed June 2025
[59] The most recent flood event is selected for the study as it recorded 28 cm of rainfall at the Amaravati weather station on 31 August, with 15 cm falling in just three hours due to cumulonimbus clouds and a Bay of Bengal depression. Torrential rain in the Krishna River's upper catchment submerged land in 25 of 29 villages, with floodwaters taking over a week to recede

• **Water Occurrence Dataset[60]:** At every pixel, the water occurrence value is determined as the ratio between the number of times water was detected and the total number of clear-sky, valid observations. This ratio is then expressed as a percentage, providing a long-term statistic of the presence of water at that location during the entire period of observation.

• **Water Recurrence Dataset:[61]** To capture seasonal dynamics, the water occurrence data are further organized by month. Specifically, the system calculates the percentage of years in which water was observed in each of the 12 calendar months of the year. The monthly recurrence metric is used to understand the regular seasonal patterns and variability of water presence.

Step 4: Risk assessment and adaptive capacity

The water occurrence and recurrence maps are overlaid with existing village settlements to assess exposure and adaptive capacity of the vulnerable sections.

Limitations to this process followed are noted below:

- A 30-meter pixel resolution cannot capture ponds, narrow streams or small irrigation channels
- Landsat captures images every 16 days, so waterlogging events lasting less than two weeks may be missed entirely
- Cloud cover reduces the number of clear-sky observations, causing waterlogging occurrences to be lower

4.4.2.1 Occurrence and Recurrence of Flooding

Amaravati city experienced a high-intensity rainfall event in September 2024, the highest in the last decade. Waterlogged areas from the September 2024 event are mapped using Landsat imagery processed in Google Earth Engine and ArcGIS. The September 2024 floods have affected approximately 8% (17.5 square kilometer) of the total Amaravati city area (Figure 4-25). During the focus group discussion,[62] village residents of Rayapudi and Velagapudi reported that the embankments and other construction activities along the two *vagus* are hindering natural water flow, causing waterlogging in the settlement area.

The village residents pump and divert the water from the settlements to the nearby agricultural fields, causing waterlogging for 3–5 days. Primarily, the north central part of the city is observed to be severely inundated due to the overflow of the *vagus*.

[60] The Water Occurrence shows where surface water occurred between 1984 and 2021 and provides information concerning overall water dynamics. This dataset captures both the intra and inter-annual variability and changes.
[61] The Water Recurrence provides the inter-annual behavior of water surfaces between 1984 and 2021 and captures the frequency with which water returns from year to year.
[62] Focus Group Discussions were held with key stakeholders to gather valuable insights, local knowledge, and sector-specific perspectives that will inform the existing Climate Risks and Vulnerabilities Annexure M.

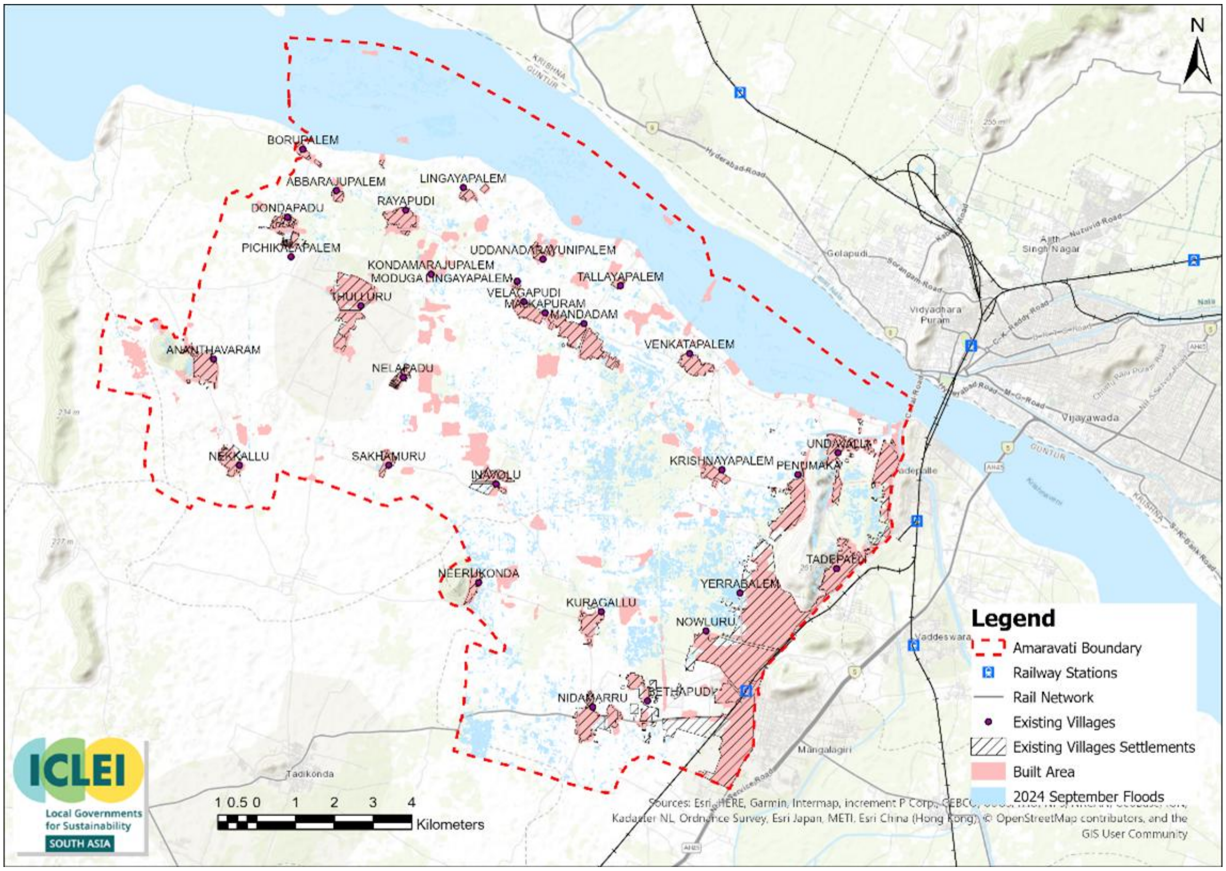

Figure 4-25 Waterlogging in September 2024

Source: Map prepared by ICLEI South Asia, based on data sourced from APCRDA and Sentinel-1 imagery processed using Google Earth Engine

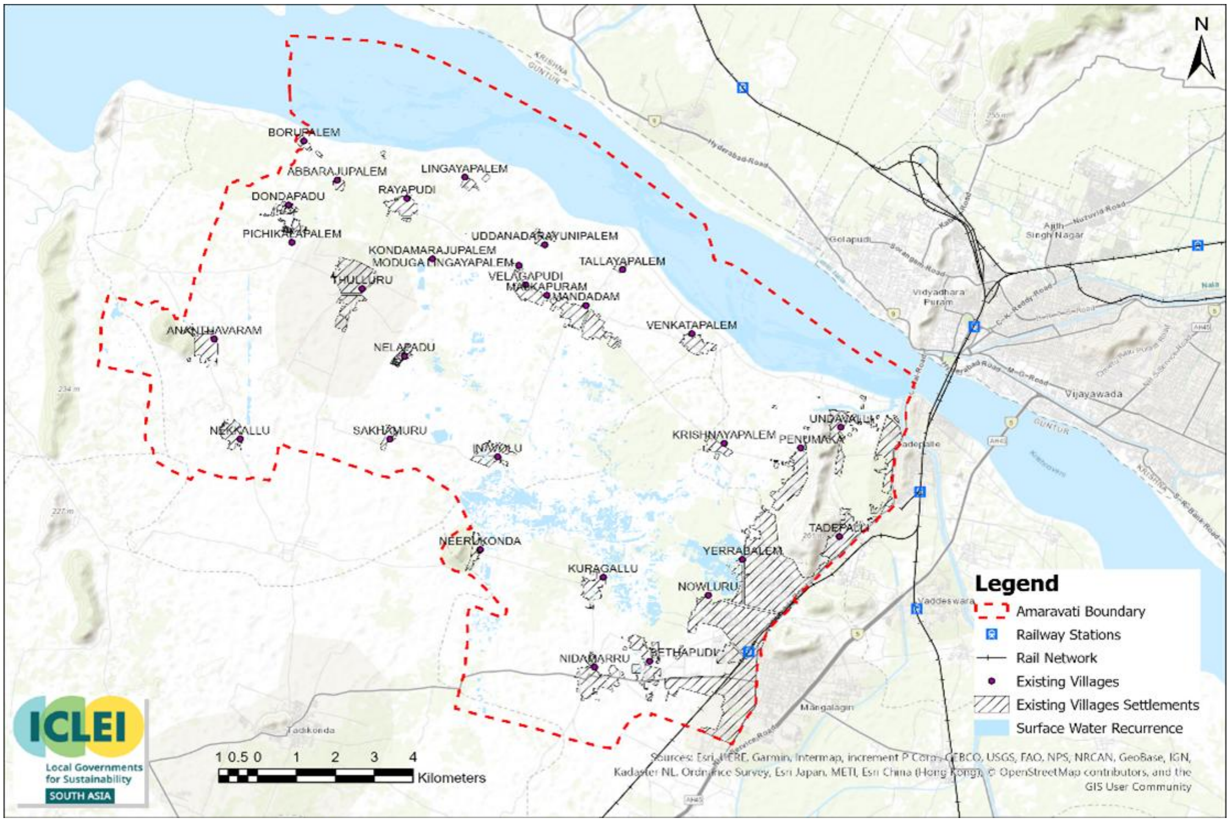

Figure 4-26 Recurrence of Waterlogging (1984-2021)

Source: Map prepared by ICLEI South Asia, based on data sourced from APCRDA and raster data sourced from Global Surface Water Explorer.

The recurrence of waterlogged areas from 1984 to 2021 is mapped using Landsat imagery and processed in Google Earth Engine and ArcGIS. Landsat imagery is used to generate the 100% waterlogging recurrence[63] map. In Figure 4-26, it is seen that the south and central part of the city is severely waterlogged, particularly impacting village settlements such as Neerukonda, Kuragallu, Yerrabalem, and Nowluru that are adjacent to the vagus. Approximately 6% (14.2 square kilometers) of the total Amaravati city area is seen waterlogged in the recurrence scenario.

[63] Water recurrence measures how often a body of water appears in the same location over many years, expressed as a percentage. 100% water recurrence means that water is observed every year during the water season. It is calculated by dividing the number of water years by the total number of observation years; if these numbers match, water recurrence is 100%.

Figure 4-27 Weeds obstruct the natural flow of water in Kondaveeti Vagu during heavy rainfall events, as dated 02nd June 2025

Figure 4-28 Weeds obstruct the natural flow of water in Pala Vagu during heavy rainfall events, as dated 02nd June 2025

The analysis presented in Figure 4-5 and Figure 4-6 shows that the pattern of flooding has changed, with a shift evident in inundated areas from the southern part of the city towards areas in the north central part. Infrastructure development for the capital city has altered *vagus* pathways and flow patterns, diverting rainwater away from retention ponds. The obstruction of water flow caused by excessive weed growth in the *vagus* is impeding water flow and increasing retention time and inundation, leading to severe waterlogging. Effective planning is crucial to prevent waterlogging in existing settlements until a integrated stormwater system is established. (Figure 4-27 and Figure 4-28).

4.4.2.2 Spatial analysis of flood risk

As Amaravati develops, it is crucial to assess flood extent to determine which parts of the city and settlements might be at risk, and to plan measures that reduce vulnerability and enhance the city's resilience to flooding. The analysis in this section is based on the inferences from the spatial flood analysis in the Kondaveeti Vagu flood management report.[64]

Baseline flood analysis:

Amaravati baseline analysis examines the entire Kondaveeti Vagu catchment area, with 2% imperviousness. Existing natural drainage network of Kondaveeti vagu and Pala vagu with planned outflow through the

[64] KONDAVEETI VAGU FLOOD MANAGEMENT, UPDATING OF THE BLUE MASTER PLAN, Final Report on Phase-1 & Phase-2, Flood Management Works within ACC, ADCL, APCRDA

Krishna West Distribution Canal and Undavalli pumping station, which is equipped with 15 pumps with a total discharge capacity of 150 cumec is major infrastructure in place considered for analysis. A design rainfall of 277 mm over 24 hours in the Kondaveeti vagu catchment, based on a 100-year return period, has been identified. These parameters serve as the foundation for the HECRAS analysis to determine the extent of flooding, with the results presented below (Figure 4-29 and Figure 4-30).[65]

The analysis indicates that flooding severity is concentrated along the Kondaveeti Vagu and Pala Vagu channels, primarily due to inadequate cross-sectional capacity to accommodate the generated runoff. Additionally, adjacent settlements in Neerukonda, Kuragallu, Bethapudi, Nowluru, and Yerrabalem are at risk of flooding and inundation due to overflow from existing water bodies. The backwater flow observed at Undavalli results from peak runoff volumes exceeding the designed hydraulic capacity of the installed pumping infrastructure.

[65] Draft Report on Phase-1 & Phase-2 Works of Kondaveeti Vagu Flood Management, ADCL, APCRDA.

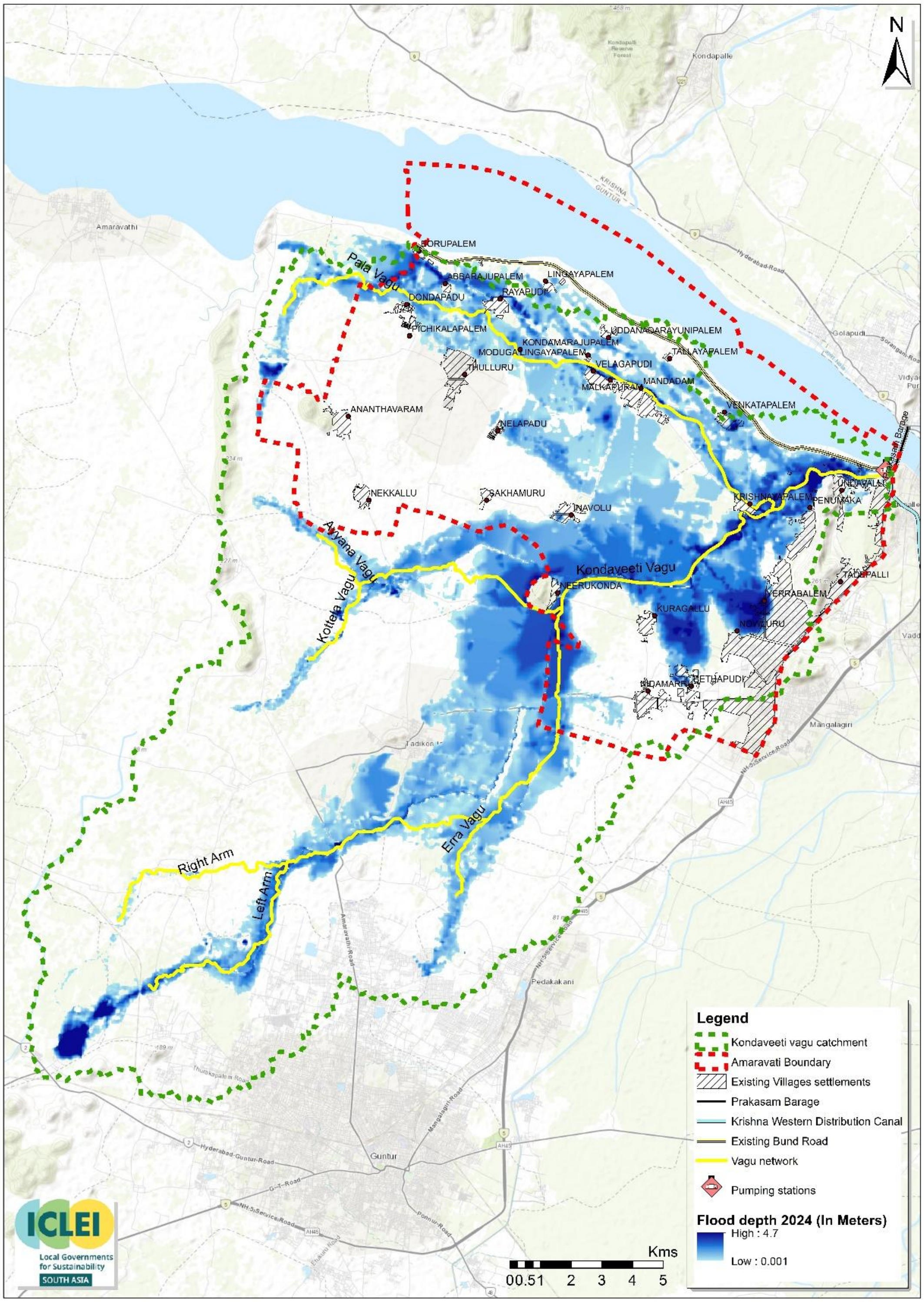

Figure 4-29 Flood analysis of Kondaveeti vagu catchment for baseline scenario 2024 for a 100-year return period rainfall

Source: Map prepared by ICLEI South Asia, based on 2024 scenario from Report on Phase-1 & Phase-2 Works of Kondaveeti vagu flood management, ADCL, APCRDA.

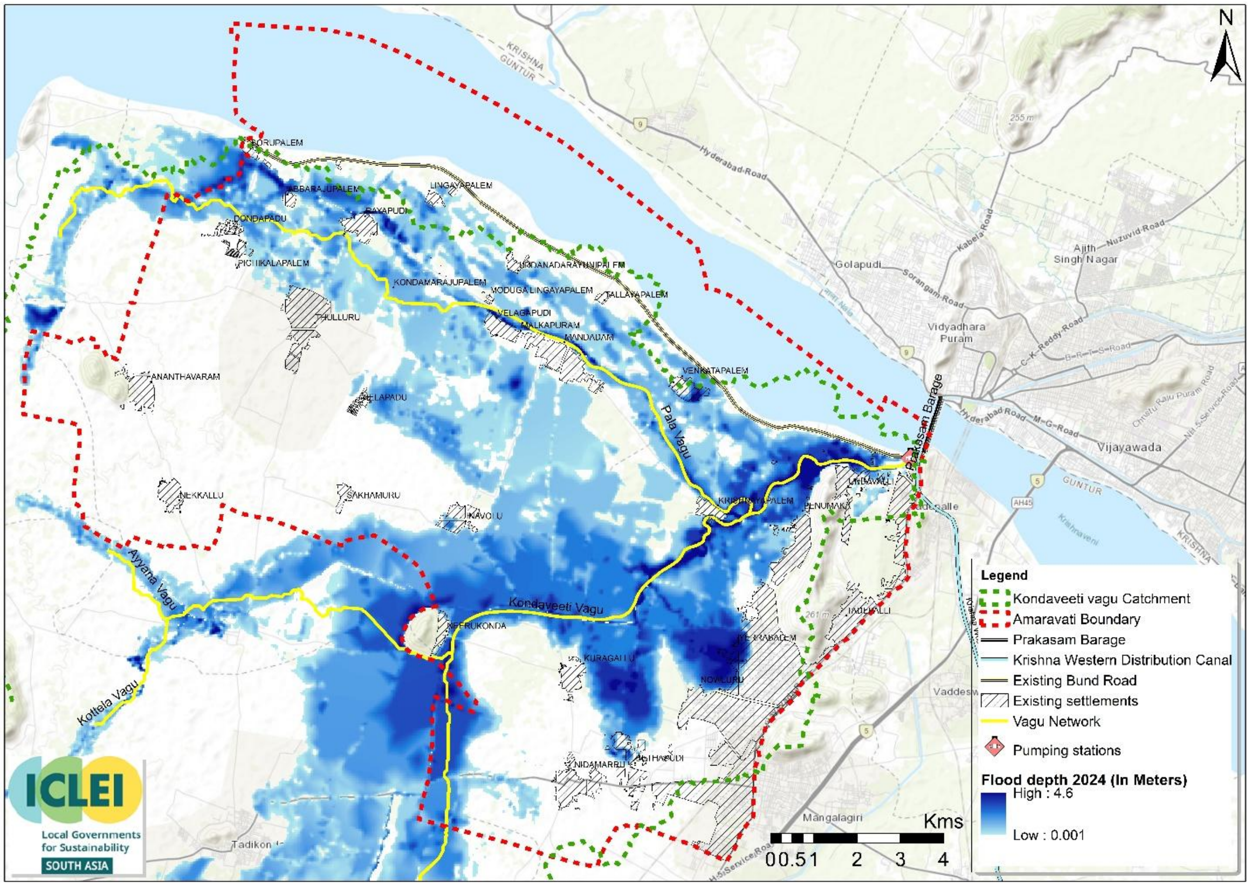

Figure 4-30 Flood analysis of Amaravati for baseline scenario 2024 for a 100-year return period rainfall
Source: Map prepared by ICLEI South Asia, based on 2024 scenario from Report on Phase-1 & Phase-2 Works of Kondaveeti vagu flood management, ADCL, APCRDA.

Near future scenario:

Analysis for the near future scenario is for the period of ongoing first phase of network construction, such as widening of Kondaveetivagu and Pala vagu, and enhancement of pumping capacity at Undavalli to 360 cumec from the existing 150 cumec, along with reservoirs at Krishnayapalem, Sakamuru, Nowluru, Yerrabalem, and Neerukonda. Also, the construction of the gravity channel is part of the first phase works.

In this scenario, it is observed that road junctions of E10, E11, E12 with N4, N6, N7, N8, N9 are prone to waterlogging. Additionally, the existing settlements in Ainavolu, Krishnayapalem, Nowluru, and Yerrabalem are prone to flooding, making them vulnerable to this hazard.

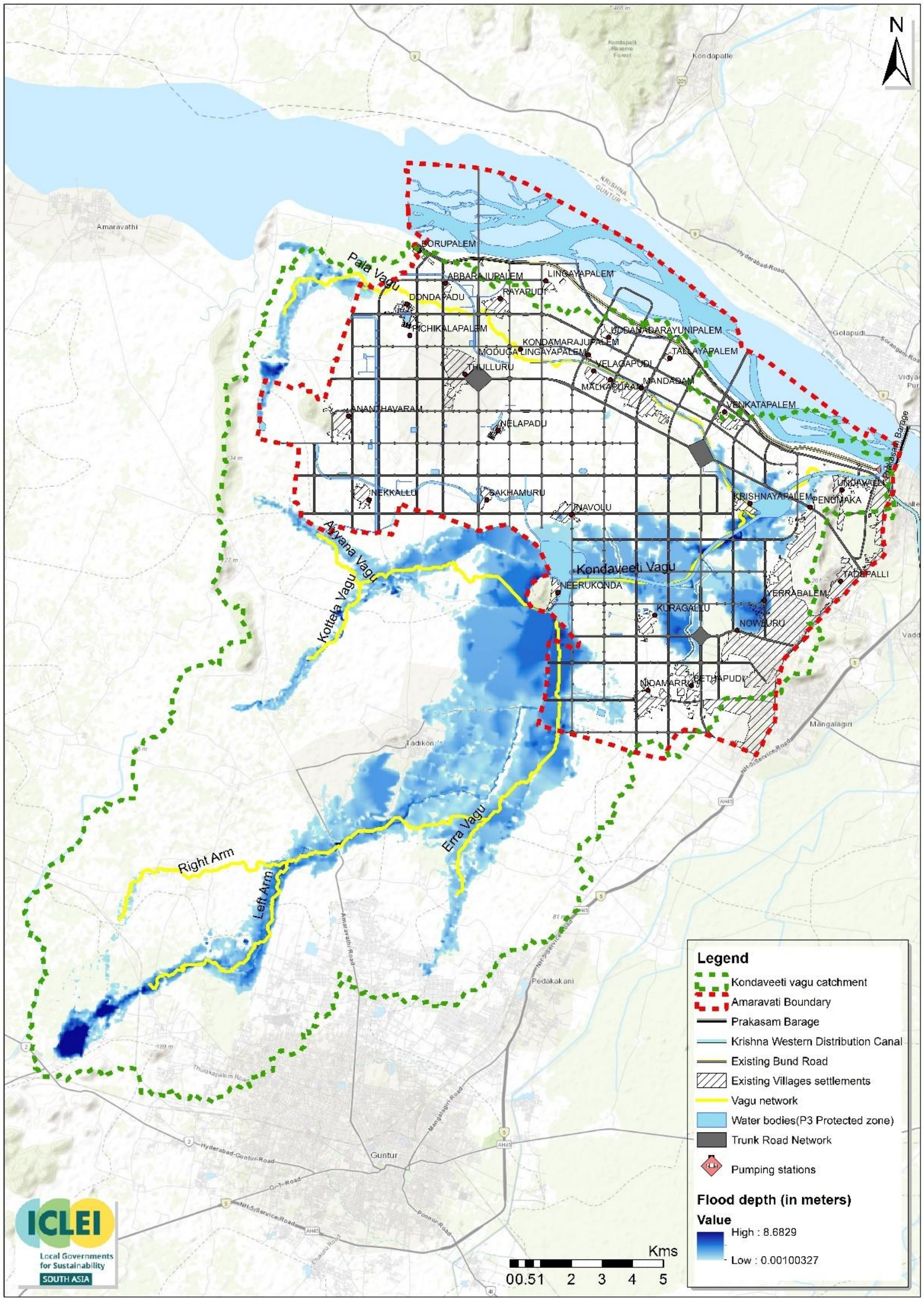

Figure 4-31 Flood analysis of Kondaveeti vagu catchment for near future scenario for a 100-year return period rainfall

Source: Map prepared by ICLEI South Asia, based on 2025 scenario from Report on Phase-1 & Phase-2 Works of Kondaveeti vagu flood management, ADCL, APCRDA.

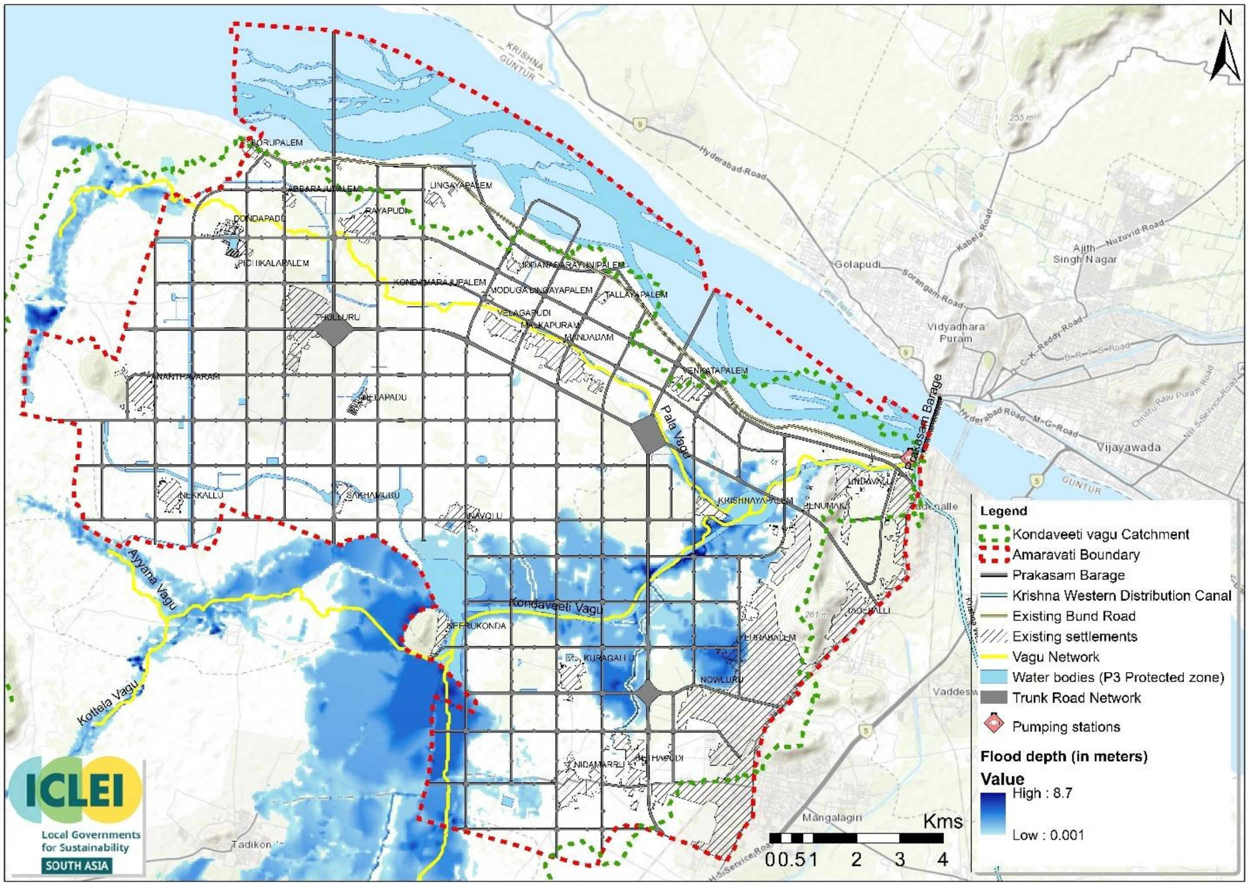

Figure 4-32 Flood analysis of Amaravati for near future scenario for a 100-year return period rainfall
Source: Map prepared by ICLEI South Asia, based on 2025 scenario from Report on Phase-1 & Phase-2 Works of Kondaveeti vagu flood management, ADCL, APCRDA.

The vulnerability of the areas on the upstream of the Amaravati has seen no change, as there are no infrastructure upgradation plans in the first phase. Areas continue to have the same risk as before in the baseline scenario.

4.4.3 Existing villages' vulnerability to climate risks

The vulnerability of existing villages to higher temperatures and flood risk requires different interventions to mitigate these risks. With the anticipated urbanisation, the relative risk level compared to the Amaravati jurisdiction might change over time with infrastructure and interventions in place. Still, in the near future, these vulnerable villages can be targeted for immediate interventions and data collection to identify changes that can be studied and analyzed, which will help in developing new policies and interventions.

Table 4-7 Existing villages' vulnerability to climate risks

Vulnerability to high temperature	**Vulnerability to flood risk**
Pichukalapalem, Dondapadu, Ananthavaram, Velagapudi, Venkatapalem.	Krishnayapalem, Sakamuru, Nowluru, Yerrabalem and Neerukonda

4.5 Consequences of Projected Climate Change on urban services infrastructure

4.5.1 Projected Climate Change

Projected climate scenarios indicate a trend of rising maximum and minimum temperatures over time, which may lead to the emergence of more hotspots. By overlaying identified hotspots with planned infrastructure, we can analyze the potential impacts on various urban service infrastructures, which could affect service levels.

According to the rainfall projection studies detailed in Section 4.3, there is an overall change in rainfall patterns due to climate change. The RCP scenario from the IIT Madras study indicates a decrease in average annual rainfall of 40-70 mm and an increase in high-intensity rainfall events, exacerbating extreme flood events. This is also evident from the recurrence and occurrence spatial maps, which demonstrate an increase in inundation areas due to climate change (Section 4.4.2.1).

Impact on water supply and wastewater

As temperatures increase, water usage also rises. The estimated demand for clear water includes an additional 10% buffer, which is vital for maintaining the distribution network and quickly addressing any interruptions or repairs. The Prakasam Barrage and the proposed Vykuntapuram Barrage are expected to meet the supply water demand for Amaravati. In existing settlements, groundwater is commonly used to supplement supply gaps. Once the water network is operational, groundwater conservation should be prioritized, especially as drought years are likely to increase. Reusing treated wastewater can help ease pressure on the water system during droughts. The water treatment plant in Venkatapalem is vulnerable to flooding, any failures could disrupt the drinking water supply for most of the city. Additionally, STPs in zones 10, 12, and 12a are at risk of flooding, requiring design improvements to minimize operational disruptions. Several water and wastewater pumping stations along Kondaveeti Vagu are also vulnerable to flooding, which could affect service even in non-risk areas. These stations should be designed with higher plinth levels to decrease flood impact, ensuring reliable operation during extreme weather events.

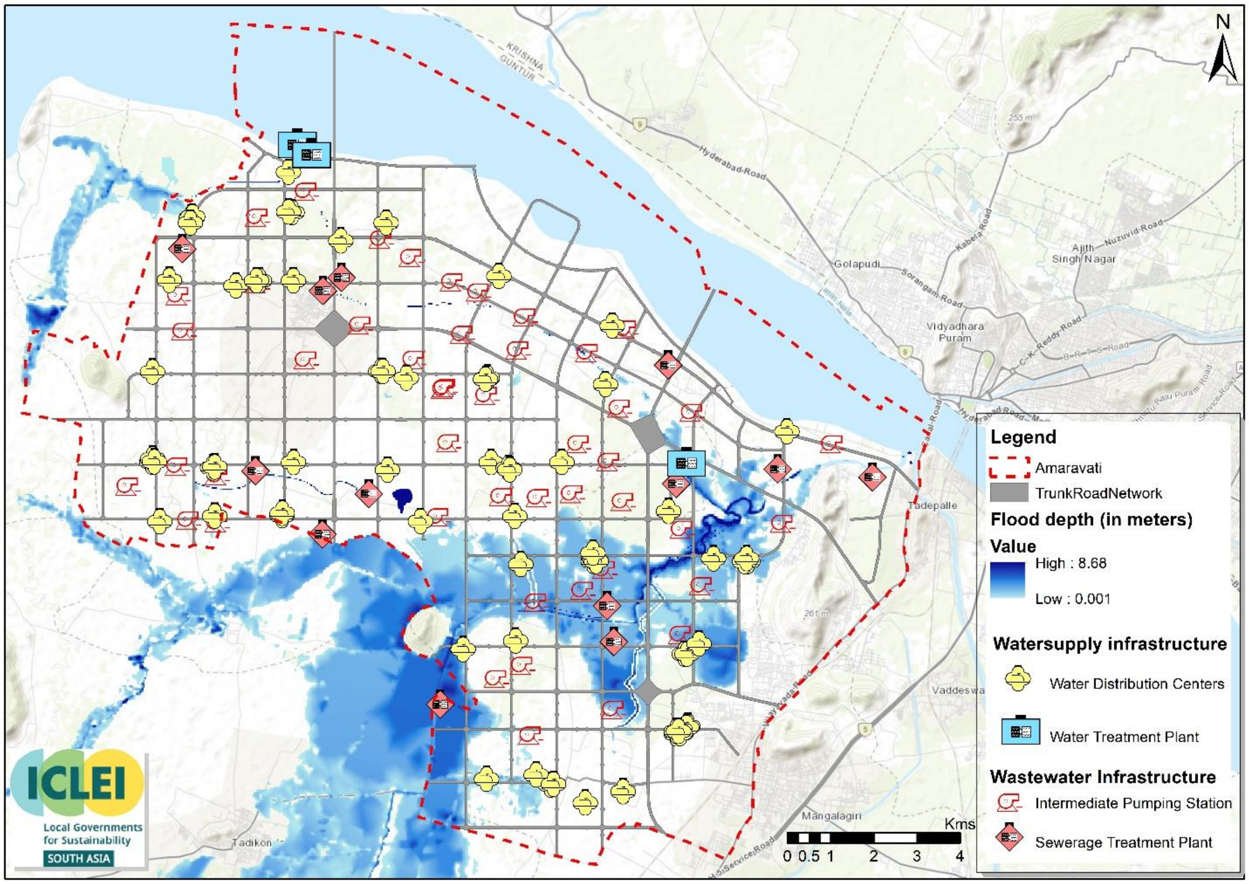

Figure 4-33 Water supply and wastewater infrastructure in the near future flood vulnerable areas.
Source: Prepared by ICLEI South Asia based on data received from APCRDA and ADCL.

Impact on mobility

Figure 4-34 shows that at least 12 out of the 15 proposed city bus depots lie in high heat hotspot (orange) areas. Extreme heat conditions are likely to shift commuters away from public transit and non-motorized transport modes towards private transit modes, especially cars and intermediate transit like taxis. In the absence of shaded bus stops, extreme heat can also affect commuters of the elderly age group, women, and children who remain highly vulnerable. Given that Amaravati is aiming for a 35% mode share for public transport and 40% for NMT by 2050, the city should ensure that, along with avenue plantations, footpaths can also include water kiosks and shaded rest areas.

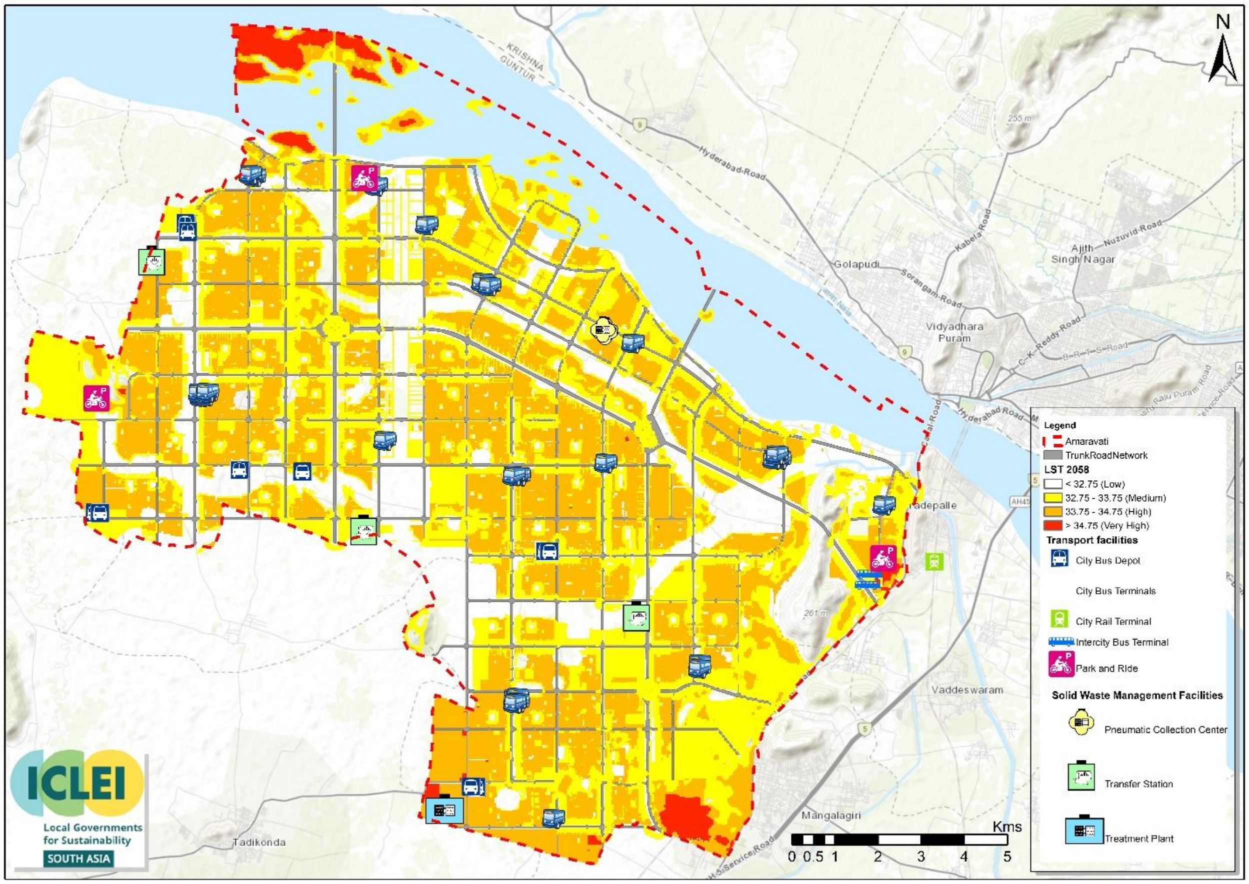

Figure 4-34 Transport and Solid waste management infrastructure in the vicinity of estimated LST hotspots for 2058

Source: Prepared by ICLEI South Asia based on data received from APCRDA.

The planned bus depots should have shading and fans where possible to minimize the impact of extreme heat on public transport users. The intercity bus terminal planned also falls under a very high heat zone, highlighting the need for adequate heat mitigation measures like shading and vegetation. Also, out of two proposed park and ride facilities, one falls under a very high heat hotspot, while another lies in a high heat zone. The city should ensure that these facilities have shading, to enable more users to avail this facility and increase last mile access for mass transit.

The high rainfall event in 2024 affected residents along the Krishna River basin, with 12 feet high water levels, and settlements were surrounded by water, leaving no emergency evacuation routes or communication, and resulting in residents being stranded and isolated.

In a future flooding scenario, roads E10, E11, E12, N3, and N10 are particularly vulnerable. Vulnerability is distributed along the Kondaveeti Vagu, putting nearby bus depots and terminals at risk of flooding. Since the Kondaveeti Vagu divides the city into two parts, flooding can disrupt connectivity entirely, delaying response efforts. Elevating transport hubs and road networks is necessary to reduce this vulnerability, and mechanical pumping measures may be used depending on the severity of the flooding.

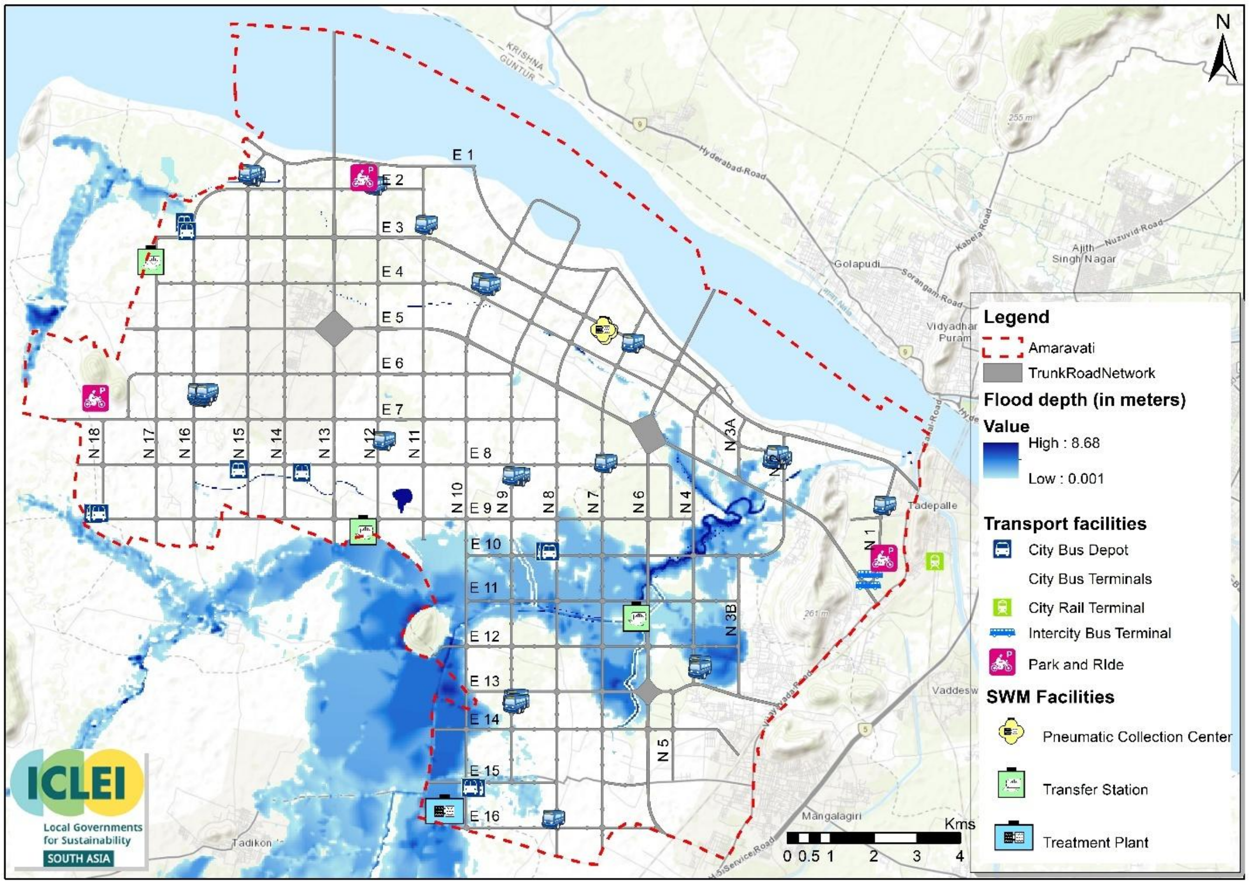

Figure 4-35 Transport and Solid waste management infrastructure in the near future flood vulnerable areas.

Source: Prepared by ICLEI South Asia based on data received from APCRDA and ADCL.

Impact on sanitation

The map indicates that the waste treatment facility and some of the transfer stations lie in high or very high heat hotspots (Figure 4-34). Extreme heat can impact both the infrastructure and operations of waste treatment plants and transfer stations. In terms of infrastructure, extreme heat can overheat equipment like shredders or conveyers particularly in the proposed Material Recovery Facilities (MRFs) located at bulk transfer stations. It can also lead to faster decomposition of wet waste, leading to foul odour and affect treatment efficiency through the proposed bio methanation and composting facilities.

Extreme heat can also affect worker health and productivity, leading to dehydration and fatigue, particularly for workers working outside. The city should ensure that these waste treatment facilities and transfer stations have adequate heat mitigation measures in place, such as insulated roofs, cooling and ventilation systems, along with rest zones and drinking water availability for workers.

The identified parcel of land designated for solid waste treatment facilities is prone to flooding, which could affect the entire city's waste management system since it is a centralized facility. Additionally, the transfer station intended to serve the southeastern and southern parts of the city is also at risk, further exacerbating waste management challenges. Transportation of solid waste from Amaravati city in the northern part of

Kondaveeti Vagu could be disrupted during surges in the Vagu. Water contamination of waste reduces processing efficiency for both wet and dry waste.

Increased frequency of waterlogging and changes in drainage patterns may pose risks to water contamination, particularly in Neerukonda and Kuragallu. Water logging can contaminate ground water, potentially impacting future water requirements. Prolonged waterlogging creates breeding grounds for disease causing vectors, risking public health through water borne and vector borne diseases.

Impact on social infrastructure

Social infrastructure especially the Anganwadis, schools and PHCs where the vulnerable groups like children, elderly and unhealthy people visit, when located in hotspots can pose a greater risk on their health. Currently existing and proposed health centres is serviceable[66] to only 19% of the Amaravati, which suggests requirement of more health facilities to come up spatially covering the entire city. The staff in the health facilities should conduct awareness programmes on safety precautions to be taken during hotter days and knowledge dissemination about the warnings issued by the IMD and State or District disaster management authorities. Also, 11 health facilities are falling in the high-risk hotspot area out of total 19[67] and 29 educational facilities out of 57[68] are falling in the high-risk hotspot area. Facilities located in the hotspot areas should include the thermal insulation features in the building infrastructure.

[66] HWCs should be located preferably within 1 kilometer radius from the periphery of under-served population in vulnerable pockets, Indian Public Health Standards, Health and Wellness centres Sub Health centres, Volume 4, 2022.
[67] 19 health facilities include 18 E Health centres and 1 PHC.
[68] 57 Education facilities include 30 Anganwadi centres, 24 schools and 3 school playgrounds.

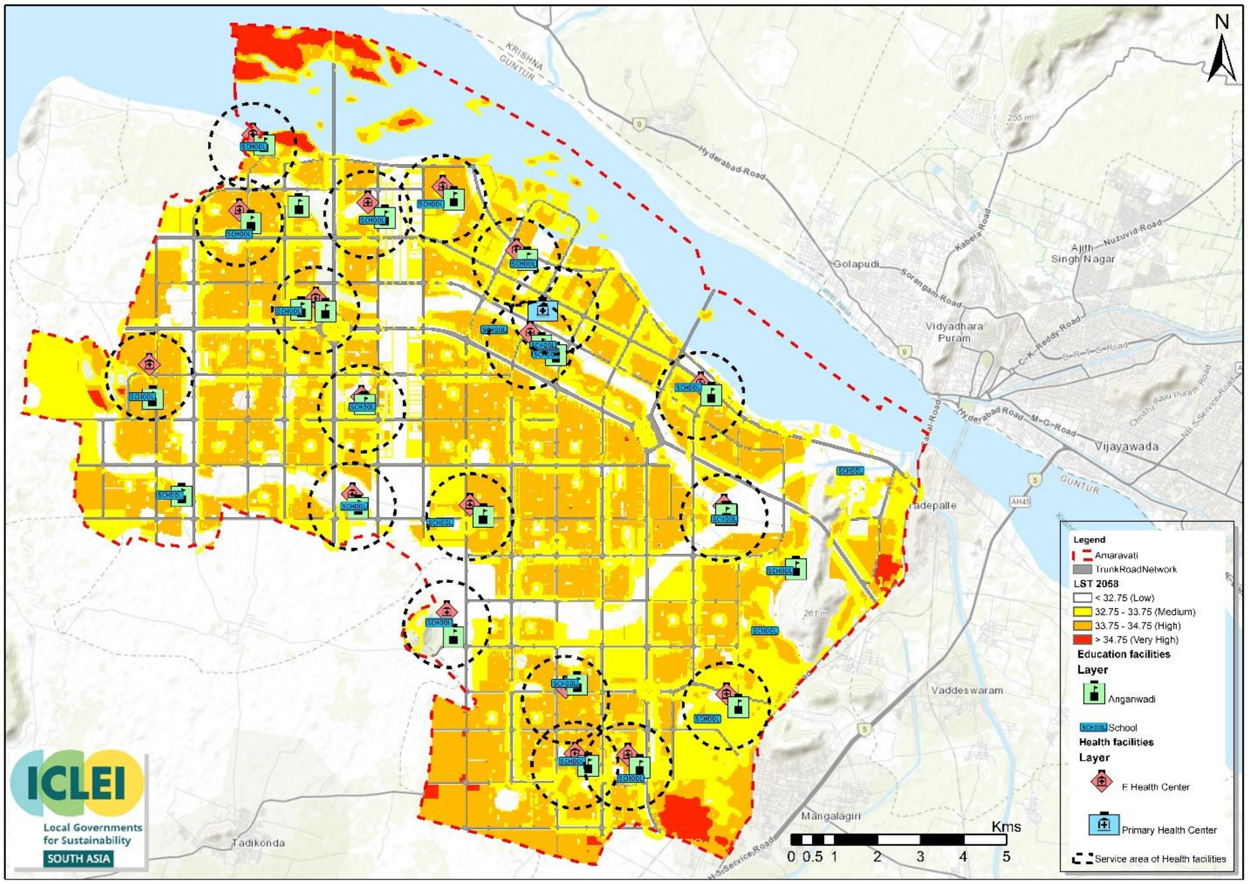

Figure 4-36 Social infrastructure (Health and Educational facilities) in the vicinity of estimated LST hotspots for 2058

Source: Prepared by ICLEI South Asia based on data received from APCRDA.

Educational and health facilities in the Neerukonda and Krishnayapalem villages are located in the flood vulnerable zone. These facilities which act as rehabilitation centers to relocate vulnerable groups when flooded will make immediate responses difficult to access. Also due to disrupted mobility networks leading to restricted mobility and limited access, vulnerable populations, particularly the elderly, women, and children, will face significant safety concerns.

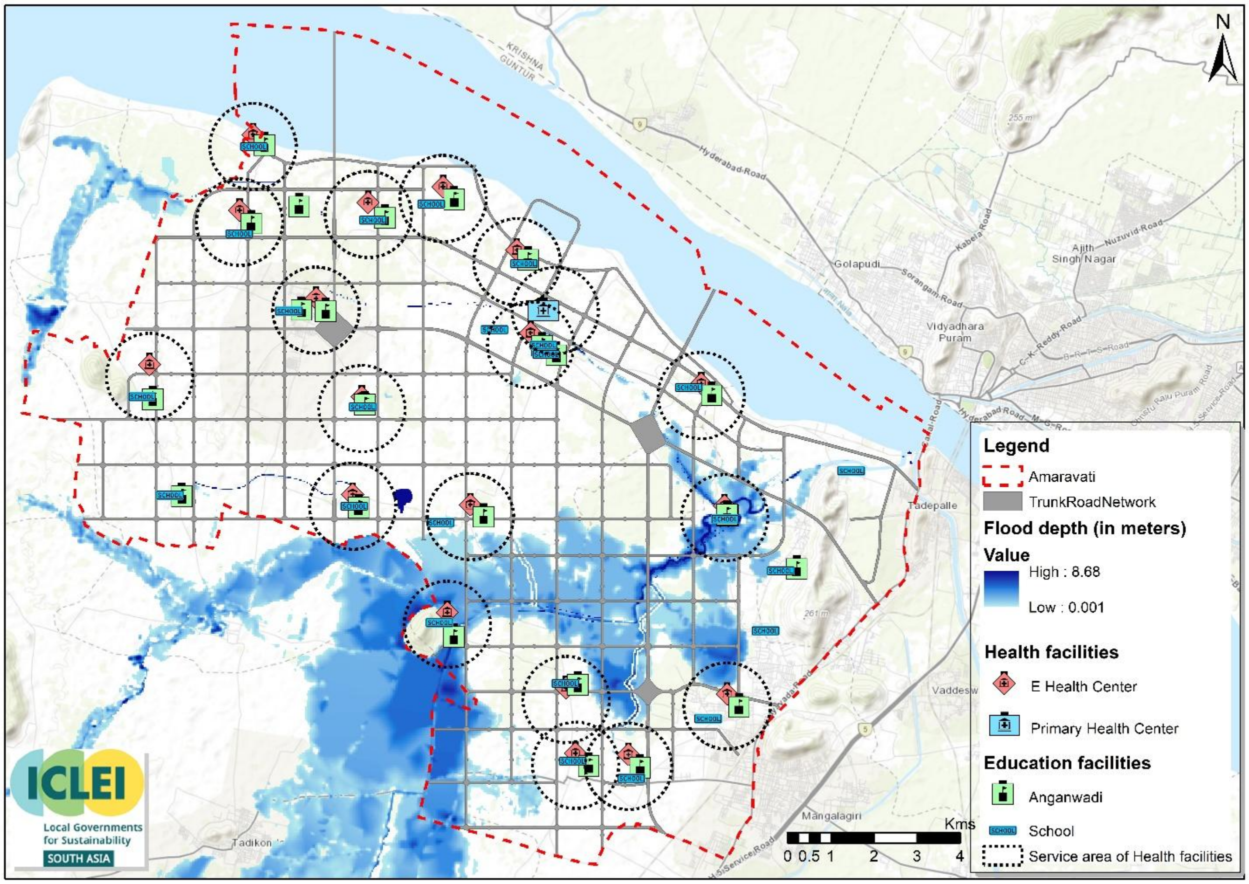

Figure 4-37 Social infrastructure (Health and Educational facilities) in the near future flood vulnerable areas.

Source: Prepared by ICLEI South Asia based on data received from APCRDA and ADCL.

4.5.2 Interventions for immediate term

To mitigate impacts on existing settlements, construction workers and other vulnerable groups while infrastructure development is underway, APCRDA could adopt interventions in phased manner in the immediate term.

- Temporary drainage systems can be constructed to ensure water is diverted effectively. Portable pumps can reduce prolonged water stagnation. Additionally, desilting activities in existing natural drainage channels (*vagus*) should be continued as per their standard operating procedure and any obstructions to be avoided if required proper diversion needs to planned, until permanent solutions are in place.
- Installing rainwater harvesting systems will help reduce surface runoff and decrease the pressure on vagus. Retention and detention ponds can regulate water flow, preventing excessive flooding. Permeable pavement solutions in new infrastructure developments will enhance water infiltration, reducing direct runoff into vulnerable settlements

- Deploying automated flood sensors in areas prone to waterlogging can provide real-time insights into water levels, enabling proactive and informed flood management. Hydrological modeling should be used to assess the waterlogging risks.
- Construction of embankments around *vagus* can help prevent excessive overflow into waterlogged prone areas
- An early warning system can be installed to help the residents prepare for potential waterlogging events and associated risks.
- Installing monitoring systems for both temperature and air quality in the identified baseline hotspots and communicating the information to the relevant stakeholders. This includes measures such as directing construction workforce to adjust working hours during peak heat hours and ensuring the provision of drinking water.
- Provide training for vulnerable groups on immediate response strategies in case of risks such as heat stroke. Additionally, capacity building of PHC staff to administer immediate first aid and conduct regular inspections to ensure safety precautions are followed at construction sites.
- Create shaded areas by prioritizing the development of green areas in the baseline hotspot areas.

4.6 Adaptive capacity analysis of vulnerable groups and stakeholders

Climate risks identified in different urban sectors and locations have implications for the existing local village community and population expected to move in over the years. It is therefore vital to address the readiness and capacity of these groups and stakeholders to address climate risks and the related fragility of urban systems. In this section, groups vulnerable to climate risks are identified and their adaptive capacities are assessed, especially for existing villagers, construction workers, children, and the elderly, who are more vulnerable. The capacity of supporting stakeholder groups, including government departments and the private sector, to manage climate risks and sectoral climate vulnerabilities is also assessed.

Vulnerability assessment involves identifying key stakeholders and actors for all the prioritized fragile urban systems and assessing their corresponding adaptive capacity. Based on the adaptive capacity, actors are categorised into two groups:

1. Vulnerable actors to the fragile urban systems and
2. Supportive actors towards building urban resilience.

The adaptive capacity analysis for actors, including the vulnerable groups and supporting stakeholders, is presented in Table 4-8. Annexure A gives further details of adaptive capacities of actors.

Table 4-8 Analysis of Adaptive capacity of identified actors

Urban System	Key Actors	Adaptive capacity (Score)	Adaptive capacity (Status)
Water Supply	APCRDA	27	High
	ADCL	27	High
	AP Irrigation Deptt.	18	High
	Youth	12	Medium

Urban System	Key Actors	Adaptive capacity (Score)	Adaptive capacity (Status)
	AP Ground water & Water Audit department	6	Low
	Existing Villagers	2	Low
	New Settlers	4	Low
	Elderly / Women / Children	1	Low
	Construction Workers	1	Low
	NGOs / SHGs	8	Low
Waste Water	APCRDA	27	High
	ADCL	27	High
	APPCB	18	High
	APIIC	12	Medium
	Existing Villagers	1	Low
	New Settlers	4	Low
	Elderly / Women / Children	1	Low
	Construction Workers	1	Low
	Youth	3	Low
Storm Water	APCRDA	27	High
	ADCL	27	High
	AP Irrigation Deptt.	27	High
	Existing Villagers	6	Low
	New Settlers	1	Low
	Elderly / Women / Children	1	Low
	Construction Workers	1	Low
	Youth	6	Low
Solid Waste Management	APCRDA	27	High
	ADCL	27	High
	New Settlers	9	Medium
	Youth	9	Medium
	Existing Villagers	6	Low

Urban System	Key Actors	Adaptive capacity (Score)	Adaptive capacity (Status)
	Elderly / Women / Children	4	Low
	Construction Workers	2	Low
Road and Transport	APCRDA	18	High
	ADCL	18	High
	APSRTC	18	High
	AP Roads & Buildings Deptt.	18	High
	Indian Railways	9	Medium
	RTO	9	Medium
	IPT Operators	2	Low
	IPT Users	2	Low
	Private Vehicle Users	6	Low
	Existing Villagers	1	Low
	New Settlers	6	Low
	Elderly / Women / Children	1	Low
	Construction Workers	1	Low
	Youth	4	Low
Biodiversity	APCRDA	18	High
	ADCL	18	High
	AP Forest Department	12	Medium
	Andhra Pradesh Greening & Beautification Corporation	4	Low
Public Health	Private Hospitals	27	High
	Govt. Hospitals	12	Medium
	PHCs	1	Low
	Elderly / Women / Children	1	Low
	NGOs / SHGs	2	Low

5 Greenhouse Gas Emissions Inventory

5.1 Introduction

Amaravati, the capital city of Andhra Pradesh, is being developed with a strong focus on environmental sustainability and planned urban growth. The city's larger vision is to develop not just as a world-class capital city in the State, but also as a symbol of a planned, future-ready urban centre in India. The city envisions integrating the best features of urban planning, sustainability, and effective governance to create an inclusive, highly liveable, and world-class urban ecosystem.

As the city's development progresses, the vision remains to create a sustainable, functional, and inclusive capital city that is underpinned by climate-sensitive and environmentally sustainable practices.

To establish the basis for Amaravati's climate strategies and greenhouse gas (GHG) emission reduction targets that will guide its future development, city-wide GHG emission estimates have been prepared for the base year 2024. To evaluate how emissions may evolve up to the city's ultimate planning horizon of 2058, scenario planning has been undertaken, evaluating both Amaravati's planned development trajectory and an alternative "what-if" case representing development as a brownfield city.

The GHG inventory provides an assessment of Amaravati's baseline emissions and the relative contribution of key sectors and activities within the city. In comparison, scenario planning helps to evaluate possible future emission pathways and identify sectoral contributions, supporting the formulation of targeted mitigation strategies and evidence-based climate action.

The GHG emission estimates for both the baseline year and future scenarios include emissions from stationary energy use in different types of buildings and from the transportation and waste sectors.

5.2 Methodology for GHG Emissions Inventory

Developing a GHG emission estimate involves a structured step-by-step process to ensure accuracy and reliability in measuring emissions. The GHG emission estimation process involves three key steps: planning and scoping the inventory framework, collecting and analysing sector-wise data, and reporting emissions in line with global standards.

This section provides an overview of the methodological approach followed for developing GHG emission estimates for Amaravati city.

5.2.1 GPC Framework

Amaravati's GHG emission inventory has been prepared following the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC),[69] a standardised framework that aligns with the Intergovernmental Panel on Climate Change (IPCC) guidelines.

[69] Greenhouse gas protocol, Global Protocol for Community-Scale Greenhouse Gas Inventories.

The GPC is a protocol standard, developed by C40, World Resources Institute, and ICLEI - Local Governments for Sustainability, that provides a robust framework for accounting and reporting city-wide GHG emissions. The GPC ensures consistency, scientific rigor, and comparability of emissions data across cities and towns globally.

5.2.1.1 Accounting and Reporting of GHG Emissions

GHG emissions in cities come from multiple sources, which are primarily categorised into stationary energy, transportation, and waste as per the GPC framework. Each sector contributes to overall emissions through fuel combustion, energy use, and waste decomposition processes. Activities taking place within a city can generate GHG emissions that occur inside as well as outside the city boundary. To distinguish among them, the GPC classifies emissions into three categories based on where they occur: scope 1, scope 2, or scope 3 emissions.

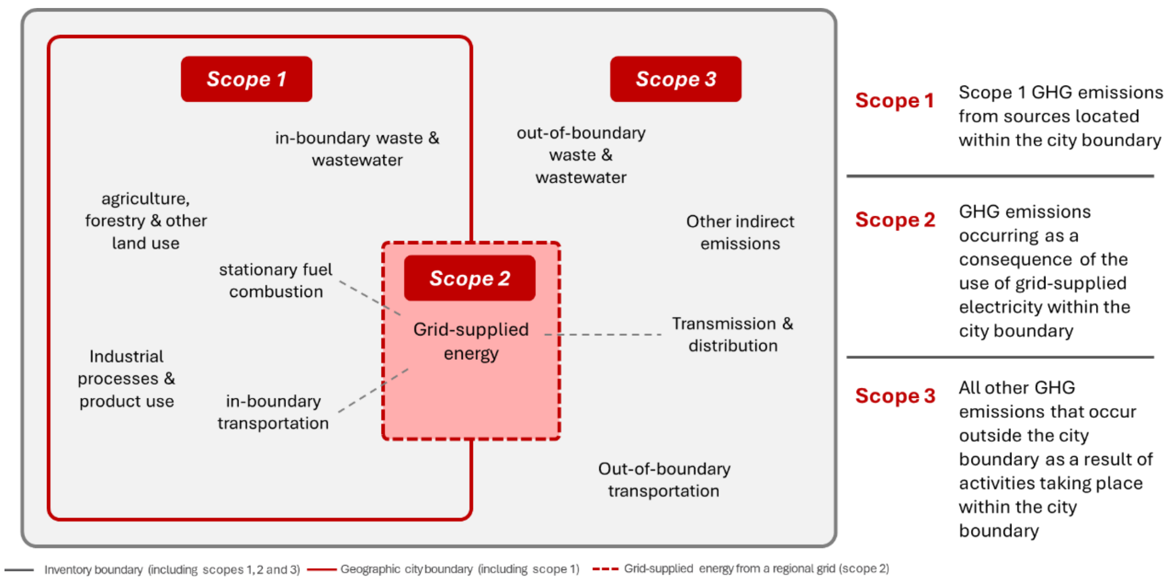

Figure 5-1 Scope-wise sources and boundaries of GHG emissions in GPC inventories[70]

The scopes framework helps to differentiate emissions occurring physically within the city (scope 1), from those occurring outside the city (scope 3), and from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (scope 2). Scope 1 emissions may also be termed "territorial" emissions because they occur discretely within the territory defined by the geographic boundary. Figure 5-2 illustrates which emission sources occur solely within the geographic boundary established for the inventory, which occur outside the geographic boundary, and which may occur across the geographic boundary.

Cities can account and report GHG emissions as per two levels of reporting prescribed by the GPC, demonstrating different levels of completeness, known as BASIC and BASIC+.

[70] Greenhouse gas protocol, Global Protocol for Community-Scale Greenhouse Gas Inventories.

- **BASIC level emissions:** The BASIC level covers GHG emissions from sources that occur in almost all cities, including stationary energy, in-boundary transportation, and emissions from in-boundary generated waste, including waste disposed outside the boundary. It offers a practical and structured approach for cities to begin tracking emissions and formulating mitigation strategies.
- **BASIC+ level emissions:** The BASIC+ level has a more comprehensive coverage of emissions sources. It includes the BASIC emission sources plus industrial processes and product use (IPPU), agriculture, forestry, and other land use (AFOLU), transboundary transportation, and energy transmission and distribution losses. This level reflects more challenging data collection and calculation procedures, with limited data and emission factors available in the Indian context, as well as at the regional level.

The BASIC level of GHG accounting is suitable for cities like Amaravati, which are initiating their climate action journey, ensuring methodological consistency while remaining feasible within existing data availability.

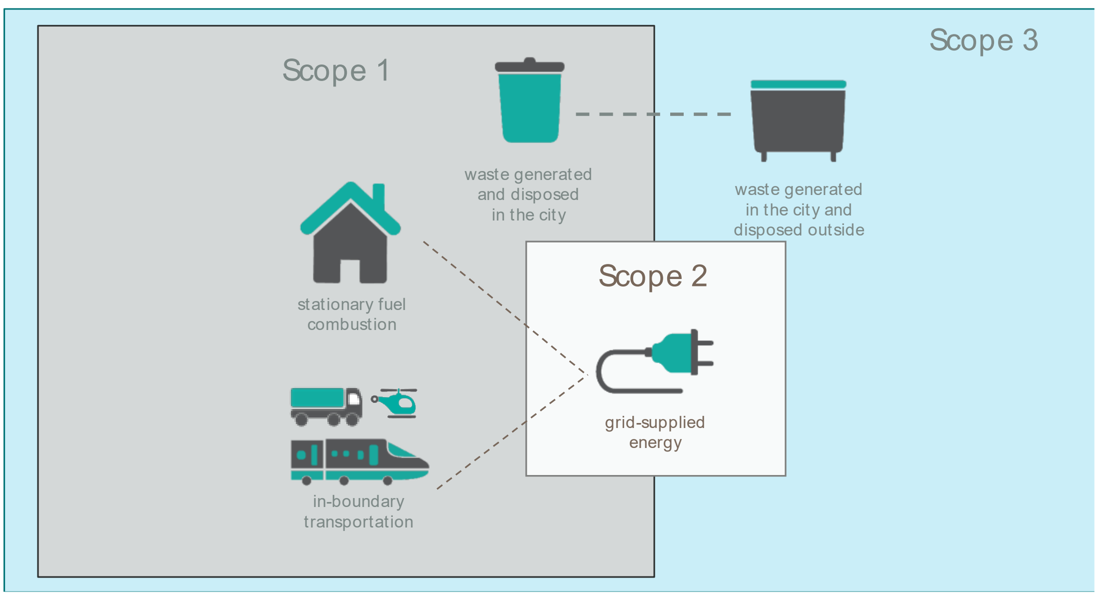

Figure 5-2 GPC reporting level - BASIC sources

5.2.1.2 Calculating GHG Emissions

GHG emissions are calculated by multiplying activity data by an emission factor (EF) associated with the activity, as depicted simplistically in the formula below.

Activity data is a quantity of an activity that results in GHG emissions during a given period of time (for example: kilowatt-hours (kWh) of electricity consumed within a year, fuel consumption, waste generation). Emission factors are used to calculate the quantity of GHG emissions generated for each unit of a specific activity (for example: tonnes of CO_2 equivalent emissions from the use of per unit of electricity, expressed as tCO_2e/kWh).

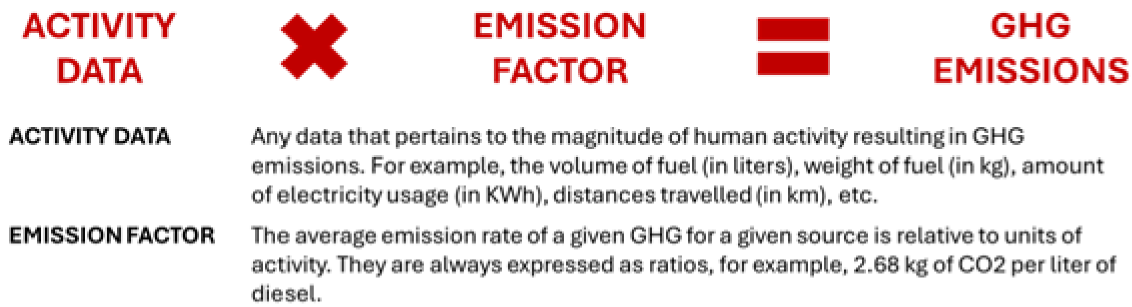

Figure 5-3 Formula for estimating GHG emissions

Once relevant activity data is collected, GHG emissions are calculated by applying relevant activity data. To ensure consistency, non-CO_2 gases like methane and nitrous oxide are converted into CO_2 equivalent (CO_2e) using Global Warming Potential (GWP) factors from IPCC guidelines.

5.3 GHG Emissions for Amaravati

The GHG emissions inventory for Amaravati has been prepared for the baseline year of 2024. The inventory has been developed in accordance with the GPC Framework. This inventory complies with the BASIC level reporting of the GPC, covering Scope 1 emissions from stationary energy sources and inbound transportation, Scope 2 emissions from grid-supplied electricity consumption, and Scope 1 and Scope 3 emissions from waste.

Details of the estimated emissions and the scoping process undertaken for developing Amaravati's GHG emission inventory are presented in the subsequent sections.

5.3.1 Scoping of Amaravati's GHG Emission Estimates

This section outlines the scope, sectoral coverage, boundary, data sources, and emission factors used in estimating Amaravati's GHG emissions.

5.3.1.1 Geographic Boundary and Coverage

The baseline GHG emission estimates have been prepared for the statutory jurisdiction of the Amaravati city boundary, spanning an area of 217.23 square kilometers.

The inventory includes and accounts for three major GHGs — carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) — in line with the GPC guidelines. Additionally, emissions will be reported in carbon dioxide equivalent (CO_2e), using GWP[71] values from the IPCC Fourth Assessment Report (AR4) to ensure consistency and comparability with India's national inventories – Biennial Update Reports (BURs) and National Communications (NATCOMs) to the United Nations Framework Convention on Climate Change (UNFCCC). The GWP values of CO_2, CH_4 and N_2O as per the IPCC AR4 are provided in Table 5-1.

[71] GWP reflects the climate change impact, in terms of the warming effect on the atmosphere, for each GHG with reference to CO_2.

Table 5-1 Global Warming Potential (GWP) values for GHGs

Greenhouse Gas	Global Warming Potential (GWP) [as per IPCC Fourth Assessment Report (AR4)]
CO_2	1
CH_4	25
N_2O	298

5.3.1.2 Time Horizon

Amaravati's GHG emissions have been accounted with FY 2024-25 as the base year or starting year to reflect the existing situation and serve as the reference point for future emissions projections.

5.3.1.3 GHG Emission Sources Covered

Amaravati's baseline GHG emission inventory follows the **BASIC level** of reporting as per the GPC framework. The BASIC level of reporting includes scope 1 and scope 2 emissions from **stationary energy** and **transportation**, as well as scope 1 and scope 3 emissions from **waste**[72]. It additional includes some BASIC+ emissions, where data is available, namely emissions from transmission and distribution losses associated with grid-supplied electricity and fugitive emissions from natural gas storage and distribution.

Table 5-2 Sectors and GHG Emission Sources included in Amaravati's Baseline Emission

Sector	Sub-sector/Sources
Stationary Energy	Residential Buildings; Commercial and Institutional Buildings/Facilities; Manufacturing Industries and Construction; Agriculture; Fugitive Emissions (from piped gas supply); T&D losses from grid electricity supply
Transportation	On-road and off-road transportation (including EVs); Metro; Rail (not included in baseline)
Waste	Solid Waste Disposal and Treatment (Composting, Bio methanation, Bio-CNG.); Waste incineration; Wastewater Treatment

Amaravati's GHG emission estimate adheres to the requirements of the GPC BASIC reporting framework. Based on Amaravati's current urban infrastructure, data availability, and institutional context, emission sources excluded from the scope and categorised elsewhere (within one of the sub-sectors noted above) are as follows:

- Fugitive emissions are not required to be reported in the GPC BASIC level framework. Fugitive emissions from mining and processing of coal and oil are excluded as such activity is not occurring within the city boundary at present. Fugitive emissions due to expected leakages from piped natural gas (PNG) distribution for energy use within the city have been included in the emission estimates for 2028 to 2058 (BAU projection and climate action scenario), when Amaravati is expected to have a piped gas distribution network.

[72] Scope 3 emissions from the waste sector refer to emissions resulting from the treatment and disposal of waste generated within the city but managed outside its geographic boundary.

- GHG emissions from the landing and take-off (LTO) of aircrafts within the city boundary are not occurring as a commercial airport does not exist within Amaravati's geographic boundary.
- Inland water navigation for transportation is not in use at present, and thereby related GHG emissions are not occurring in the base year. Waterborne navigation is not expected to be operational in the planning horizon as per existing information and plans. It is under consideration primarily for recreational purposes and therefore is considered not to occur or negligible.
- In the base year, on-road transportation emissions have been estimated using the fuel sales method, which considers the total fuel sold within city limits. This approach regards fuel sold as an indicator of transportation activities within the city in line with GPC guidance. Base year GHG emissions from off-road transportation are included in the emissions reported under on-road transportation, due to a lack of disaggregated data on fuel consumption for off-road transport within the city.

5.3.1.4 Emission Factors

Emission factors for grid electricity consumption have been sourced from the Central Electricity Authority (CEA) Reports on CO_2 Baseline Database for the Indian Power Sector (Version 20.0), which provides India-specific grid emission factors. For emissions from stationary and mobile fuel use, as well as the waste sector, a combination of IPCC default emission factors and those used in India's national GHG inventories (BURs and NATCOMs) has been used, ensuring alignment with both global and country-specific methodologies (see Annexure L).

5.3.1.5 Approach for Baseline GHG Emissions

Amaravati's GHG emissions for the base year of 2024-25 were estimated by gathering activity data from different data providers for the GHG emission sources included in the scope. The activity data was processed and utilised to estimate GHG emissions for the base year using calculators and appropriate emission factors through the Net-zero GHG Emissions Tool of ICLEI South Asia.

5.3.1.6 Data Collection and Sources

ICLEI South Asia with the support of the APCRDA team engaged with various data providers to source relevant activity data and information, both for the existing situation and prospective scenario. Necessary data requests to data providers were facilitated by APCRDA.

Activity data received was reviewed by ICLEI South Asia during the GHG emission inventory compilation process, with clarifications further sought from data providers to ensure that datasets were applied appropriately for Amaravati's boundary. Information on existing services and basic amenities such as household water supply, wastewater systems and solid waste management were validated in focus group discussions conducted in seven existing settlements in the capital city area. Various infrastructure plans and assessments prepared across sectors were also reviewed to identify and collate data and information for the prospective planning period of 2028 to 2058.

The sources of activity data and other relevant information used in the GHG emission estimation are summarised in Table 5-3.

Table 5-3 Sources of Activity Data for GHG Emission Estimations

Fuel Type	Sector	Source of Data
Electricity/Power	Residential; Commercial/Institutional Facilities; Industries; Agriculture, Forestry and Fishing Activities (i.e. mainly agriculture); facilities including Water Supply, Wastewater Management, Street Light, District Cooling, Other Utilities	Andhra Pradesh Eastern Power Distribution Company Limited (APEPDCL) Design Basis Report, Zone 7, Power & ICT; Power – Detailed Project Report, 2018; Inputs from ADCL
Diesel and Petrol	Community Transport, Commercial/Institutional Facilities, Manufacturing Industry and Construction	IOCL, HPCL, BPCL
LPG	Residential, Commercial/Institutional Consumers	IOCL, HPCL, BPCL
CNG	Transportation; Commercial consumers	IOCL
PNG	Residential, Commercial, Industries	Gas Master Plan Report
Transportation and Mobility		Draft Master Plan for Traffic & Transportation; Comprehensive Traffic and Transportation Study for APCRDA by JICA, 2022; Vahan Dashboard; MTMC; Inputs from APCRDA
Solid Waste Management		Mangalgiri-Tadepalli Municipal Corporation (MTMC); APCRDA; Solid Waste Master Plan, 2016; APCRDA's Request for Proposal (RfP) document for outsourcing of sanitation services, including solid waste management in 19 grama Panchayats (four clusters)
Wastewater management		MTMC; Wastewater - DPR, 2025; APCRDA and ADCL inputs
Water supply		MTMC; Water supply DPR, 2025

5.3.1.7 Key Assumptions

Most of the data used for the GHG emissions estimation was primarily sourced from data providers and available infrastructure and planning documents. In specific datasets where gaps were observed, suitable assumptions were used to close the datasets and prepare estimates for the appropriate calculation of Amaravati's GHG emissions for FY 2024-25. The key assumption made regarding GHG emissions is provided in Annexure B.

5.3.2 GHG Emission for Base Year 2024

The total GHG emissions of the Amaravati capital city area for the base year of 2024 are estimated to be 242,332 tonnes of carbon dioxide equivalent (CO_2e). The capital city area's per capita GHG emissions in the current scenario in 2024 stand at 1.31 tonnes of CO_2e.

The primary contributor to base year emissions is the Stationary Energy sector, which includes consumption of electricity and fuels in existing buildings and accounts for 80.4% of total emissions. The Transport sector accounts for about 13% of emissions, and the remaining 6.6% emissions result from the Waste sector in 2024.

Scope 1 emissions that occur within the city boundaries are driven by the stationary fuel combustion, transport, and domestic wastewater. Scope 2 emissions from electricity consumption are driven by demand for grid electricity. Scope 3 emissions are most significant in the waste sector, primarily due to the location of the waste-to-energy facility and disposal site, where municipal solid waste is currently managed, being situated outside of Amaravati's geographical boundary. Additionally, T&D losses from electricity consumption contribute to scope 3 emissions in the stationary energy sector.

Table 5-4 Sector-wise GHG emissions for Amaravati, 2024

Sector	**GHG Emission (tonnes of CO_2e)**				**Share**
	Scope 1	**Scope 2**	**Scope 3**	**Total**	
Stationary Energy	23,433	1,60,290	11,220	**1,94,944**	80.4%
Transportation	31,403	1.7	0.12	**31,405**	13%
Waste	7,613	-	8,370	**15,983**	6.6%
Total	**62,449**	**1,60,292**	**19,591**	**2,42,332**	**100%**

A break-up of GHG emissions for 2024 by sub-sector is presented in Table 5-5 and Figure 5-4. Emissions from the Stationary Energy sector are driven by energy consumption in residential buildings and in commercial and institutional buildings and facilities, which contribute to 42.4% and 32.9% respectively of the capital city area's total base year emissions. Industries have a share of 3.9% and agriculture accounts for 1.2% of the total emissions in 2024. Consumption of diesel, petrol and CNG in on-road vehicles leads to 13% of Amaravati's emissions. In the Waste sector, 3.5% of the capital city area's overall emissions are from solid waste and 3.1% result from wastewater.

Table 5-5 Break-up of Amaravati's sectoral GHG emissions for 2024

Sector and Sub-sector	**GHG Emissions (tonnes of CO_2e)**
Stationary Energy	**1,94,944**
Residential Buildings	1,02,863
Commercial and Institutional Buildings/Facilities	79,742
Industries	9,398
Agriculture, Forestry, and Fishing Activities (i.e. mainly agriculture)	2,941
Transportation	**31,405**
On-road Transportation	31,405

Sector and Sub-sector	GHG Emissions (tonnes of CO_2e)
Waste	**15,983**
Solid Waste	8,370
Wastewater	7,613
Total	**2,42,332**

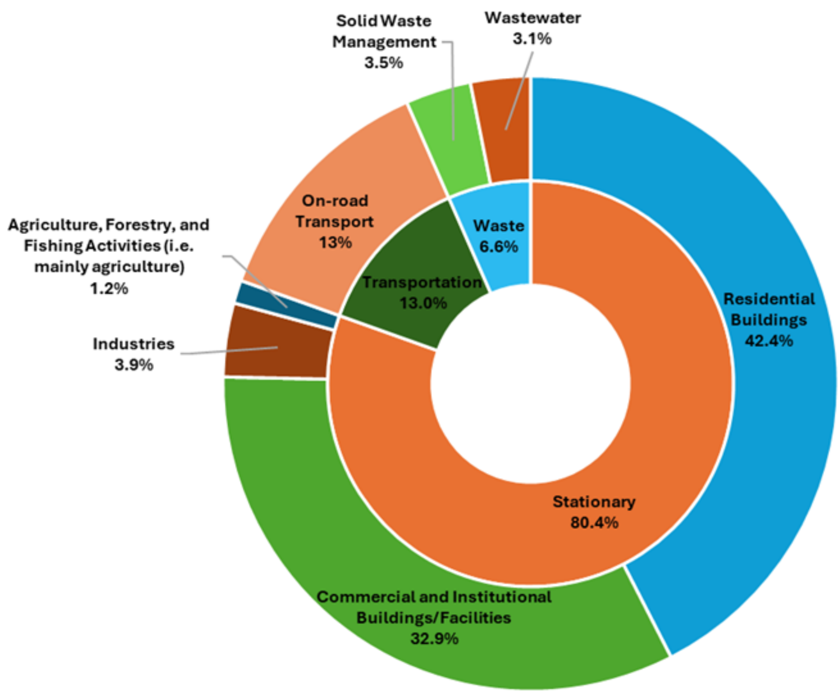

Figure 5-4 Sectoral share of GHG emissions 2024

5.3.3 *Insights on Sectoral GHG Emissions for 2024*

5.3.3.1 Stationary Energy

Stationary energy is the largest contributor to the capital city area's emissions in the base year. These emissions occur due to the consumption of electricity from the grid and the use of fuels (LPG and diesel) for end-uses such as cooking and power backup in buildings.

Figure 5-5 below shows the breakup of stationary energy-related GHG emissions from different sub-sectors in 2024. Residential households have the highest contribution to emissions from stationary energy, accounting for 52.8% of the emissions. Energy consumption in commercial and institutional buildings and facilities (such as public water works and street lighting) is also significant, with a share of 40.9%. Industrial units account for 4.8% of stationary energy emissions, while agricultural activity contributes 1.5%.

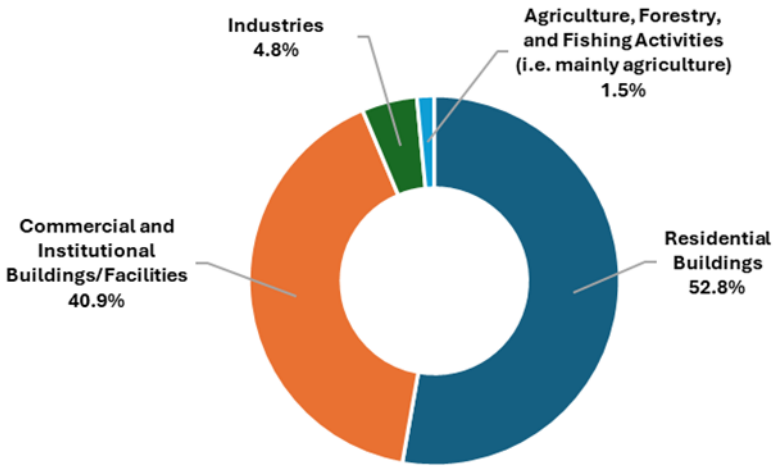

Figure 5-5 Stationary energy emissions by sub-sector 2024

In terms of energy source, electricity is the primary driver contributing to 88% of stationary energy-related emissions, while stationary fuels (LPG and diesel) contribute the remaining 12% of the emissions (see Figure 5-6).

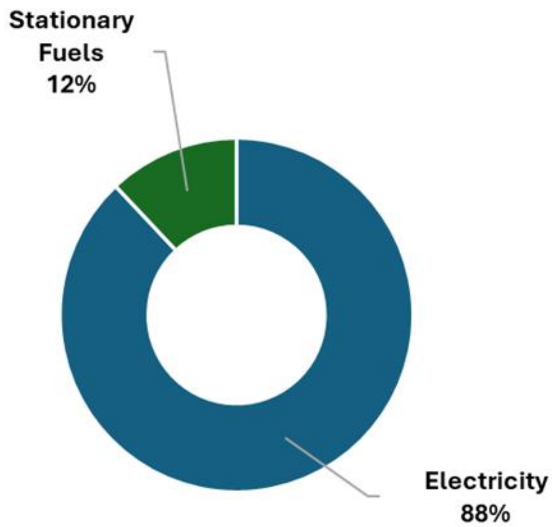

Figure 5-6 Stationary energy emissions energy source 2024

Of the total electricity consumption and associated GHG emission, 47.5% results from households, 45.2% from commercial and institutional buildings and facilities, 5.5% from the industrial sub-sector, and 1.8% from agricultural consumption (see Figure 5-7). With electricity almost solely contributing to most of the stationary energy emissions in buildings, the breakup of electricity consumption and emissions resembles that of overall energy consumption.

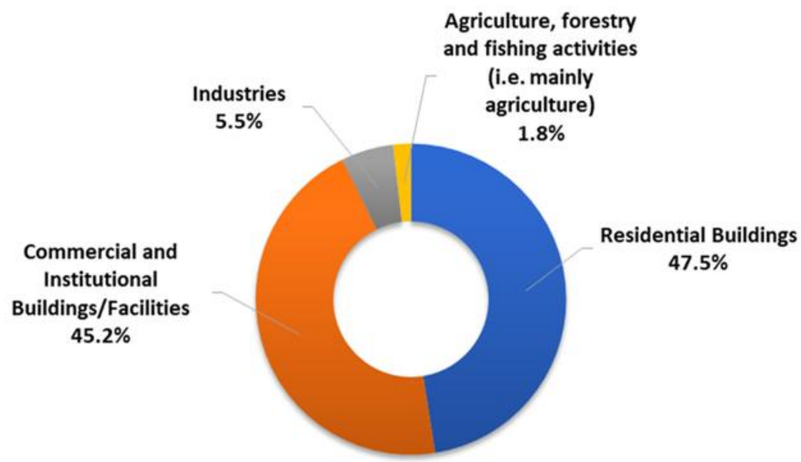

Figure 5-7 Sector wise share of electricity consumption and emissions, 2024

Stationary fuel (LPG, PNG, diesel etc.) consumption accounts for 12% of the stationary energy emissions. LPG consumption leads to 11.9% of emissions from stationary energy use, with a minimal amount of diesel use that occurs in commercial and industrial sub-sectors accounting for the rest.

5.3.3.2 Transportation

Private vehicles and intermediate public transport are prominent transportation modes within the capital city area at present, with the public transport system currently absent. Thereby, GHG emissions from the transport sector primarily result from fuel consumption in on-road vehicles, with a small portion of emissions resulting from electricity consumption for E-vehicles. A fuel sales approach has been used to estimate the GHG emissions from fuel consumption in on-road vehicles, with fuel sales data from fuel stations within the city boundary received from oil companies.

With a cumulative share of 99.9%, consumption of diesel and petrol contributes to nearly all the transport sector emissions in 2024, reflecting that a vast majority of the vehicles currently plying in the area are conventional vehicles. The consumption of CNG and electricity for charging electric vehicles is negligible in 2024.

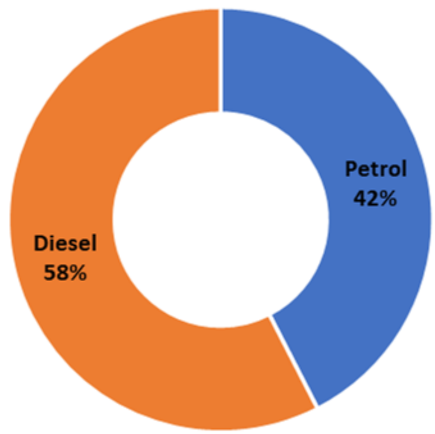

Figure 5-8 Transportation emissions by fuel type, 2024

Note: Emissions from CNG and electricity consumption in the transportation sector have not been included in the representation due to their negligible share.

5.3.3.3 Waste

The Waste sector includes GHG emissions from the management and disposal of municipal solid waste (MSW) and wastewater. Waste treatment produces GHG emissions through aerobic or anaerobic decomposition or incineration.

MSW accounts for 52% of the capital city area's waste sector emissions while domestic wastewater has a share of 48% (see Figure 5-9). The Mangalgiri-Tadepalli municipal corporation (MTMC) area and existing village settlements falling within Amaravati's boundary generate about 70 tonnes per day (TPD) of MSW. MTMC completed remediation of its waste disposal site located at Kolanukonda in 2023-24 and it has since been closed. Solid waste generated in the settlements is presently being transported and treated at the mixed-waste based waste-to-energy plant located at Guntur. No biological treatment facility such as anaerobic digestion or composting is currently operational and thereby GHG emissions from biological treatment of MSW are not occurring in the base year.

Households in the city boundaries use on-site sanitation in the form of septic tanks to discharge and collect domestic wastewater. Wastewater collection network and treatment facilities do not exist at present. Desludging operators collect sludge from septic tanks, and a dedicated faecal sludge treatment facility is not in place currently. Thereby, GHG emissions from domestic wastewater in 2024 are contributed solely by septic tanks.

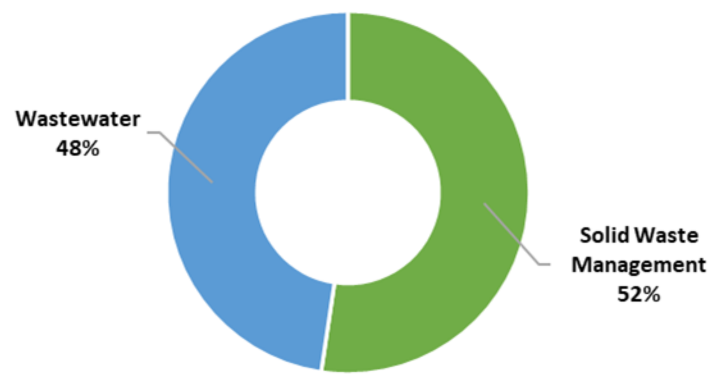

Figure 5-9 Waste emissions by sub-sector, 2024

6 Scenario Planning for Future Emissions Reduction in Amaravati

The baseline GHG emissions inventory helps understand the city's current emissions profile in 2024 as reflected in section 5. Since Amaravati is being developed as a greenfield city, with a significant share of the population and infrastructure yet to be instituted, the baseline GHG emissions need to be complemented by future GHG emissions scenarios to provide a complete picture of the long-term emissions trajectory. The GHG emissions are likely to grow as the city expands. Hence, it becomes essential to understand how these emissions could evolve and how the city can stay aligned with its climate goals. In this context, the development of future GHG emissions scenarios (scenario planning) is crucial to assess future emissions levels in Amaravati.

Scenario planning enables cities to evaluate possible future emissions pathways. It considers essential factors, including population growth, land use changes, infrastructure development, energy consumption, transportation demands, and waste generation. The overall emissions scenario planning process aims to demonstrate to city decision-makers and stakeholders how emission levels are expected to evolve in the future under different scenarios, providing an evidence base to determine the required levels of ambition, targets and climate actions. Scenario planning thus enables the city to assess the long-term implications of its development and climate strategies and actions.

Two different emissions scenarios have been developed for Amaravati using ICLEI South Asia's Net-zero GHG Emissions Tool**: i) Climate Action Scenario and ii) Business-as-usual (BAU) Scenario.** By comparing a business-as-usual growth path with low-carbon interventions identified in its city climate change action plan and master plan, Amaravati can evaluate trade-offs, prioritise mitigation actions, and align sectoral plans with its broader sustainability objectives. This approach supports Amaravati to set itself on a pathway that is resilient, forward-looking, and consistent with national and global climate commitments. Consultations were held with APCRDA and stakeholders in the process of identifying Amaravati's ambitious and practical climate targets and actions.

6.1 Scenarios Identified for GHG Emissions Reduction

The Climate Change Action Plan for Amaravati outlines two scenarios to represent the city's future GHG emissions levels (Figure 6-1). The BAU Scenario represents the baseline and is developed to reflect the future emissions pathway if Amaravati were developed in the same way as other existing, brownfield cities. The BAU scenario assumes no additional interventions or policy changes beyond current national and state policies and growth patterns. In comparison, the Climate Action Scenario represents sustainable, climate-responsive strategies and targets adopted by Amaravati across urban infrastructure and sectors through its Climate Change Action Plan, existing master plan, and infrastructure plans.

- **Climate Action Scenario:** The Climate Action scenario represents the city's expected level of GHG emissions, after the completion of its construction phase, i.e., once Amaravati is fully developed, with all climate strategies and actions outlined in its Climate Change Action Plan implemented. It reflects the level of emissions anticipated with the implementation of enhanced climate actions at the city scale, as compared to the BAU scenario. It considers the level of ambitions and targets outlined in the Climate Change Action Plan being realised. The climate targets and actions for Amaravati have been determined based on proposed plans and measures in Amaravati's planning and infrastructure documents, goals and targets of national and state policies, current status, level of adoption of solutions.

- **BAU Scenario:** The BAU scenario represent the level of GHG emissions in the future if Amaravati's development took place in the absence of climate and sustainable planning interventions, following conventional patterns similar to other brownfield cities. It assumes that no additional emissions reduction efforts and measures will be undertaken, beyond those already in place. The BAU Projection represents the 'business as usual' condition and serves as a reference point for assessing the impact of emissions reduction scenarios or pathways.

These scenarios form the strategic foundation of the CRCAP, guiding Amaravati in defining and prioritising emission reduction strategies and actions, while committing to a low-carbon, inclusive, and sustainable growth trajectory.

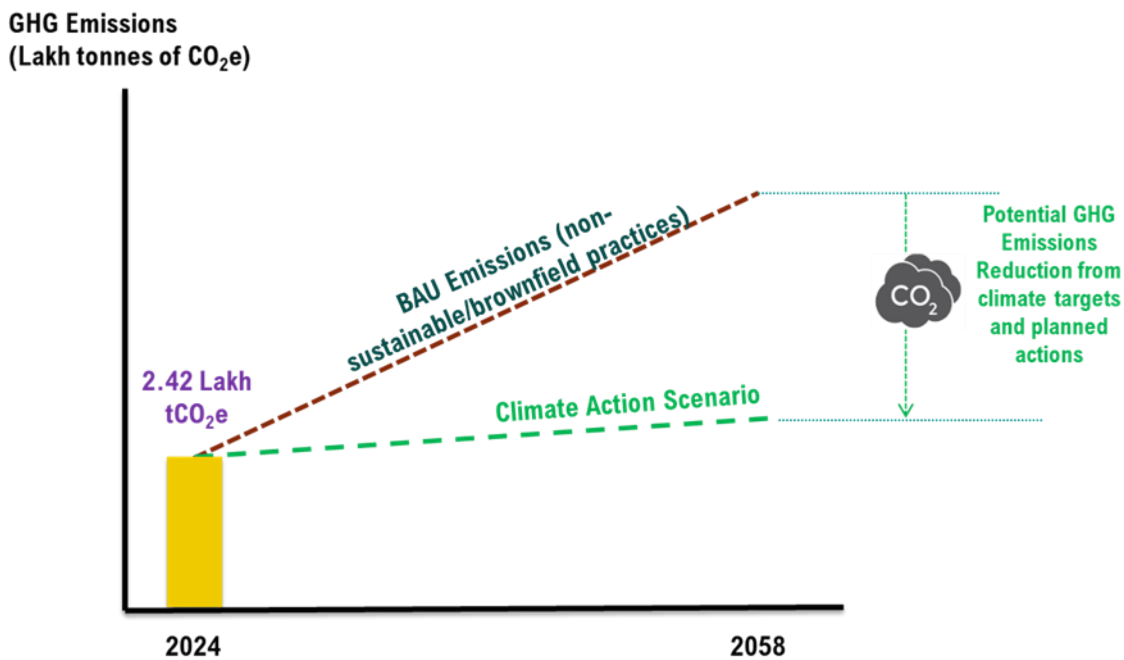

Figure 6-1 Illustrative Depiction of Climate Action Scenario compared to BAU Scenario

6.2 Key Assumptions for Scenario Planning

The scenario planning for Amaravati's GHG emissions is built on a set of assumptions across the key urban sectors: energy, transport, waste, and wastewater. These assumptions help define how emissions will evolve under both the BAU and Climate Action scenarios across the planning period, i.e., from 2028 to 2058.

For the Climate Action scenario, GHG emissions have been projected using Amaravati's population estimates, along with sectoral and infrastructure information currently available (e.g., power requirements, water demand, waste and wastewater generation and treatment, mobility-related metrics), as per the Master Plan and infrastructure plans. It thereby reflects the expected level of GHG emissions during Amaravati's construction phase, i.e., from 2028 to 2058.

The BAU scenario reflects a situation where no significant additional actions are implemented in Amaravati, and thereby the extent and scale of low-carbon actions are limited to current practices and much lower than the Climate Action scenario. For the BAU projections, emissions have been estimated using a combination of sector-specific data from baseline datasets and city documents as well as current trends in the state of Andhra Pradesh. For instance, solid waste generation figures for the years 2028, 2043, and 2058 have been sourced from the city's planning documents, while the expected processing percentages and technology-wise distribution in the absence of additional sustainable waste management measures have been assumed based on the state's current processing levels. These assumptions guide the projections and help ensure that the scenarios are realistic, consistent, and policy-relevant.

Key Assumptions in Scenario Planning

Assumptions – Climate Action Scenario (2028 to 2058)

Stationary Energy

- Power demand for Amaravati in 2058 has been sourced from the DBR report. To estimate electricity consumption (in million kWh), diversity factors provided in the Zonal Design Basis Report (DBR) have been applied. For the intermediate years, 2043 and 2028, electricity consumption has been interpolated based on estimated per capita electricity usage in 2058. T&D losses for electricity have been assumed to be 2.84% as per the DBR.
- Based on envisaged renewable energy (RE) integration to meet power demand as per inputs from APCRDA, it is assumed that 15%, 75%, and 100% of the total electricity consumption will be met through RE, including rooftop, ground-mounted, distributed, and off-site RE power purchases in 2028, 2043, and 2058, respectively.
- PNG consumption figures for 2028 and 2058 have been taken from the Gas Master Plan. Since the plan provides estimates only for 2020 and 2050, these figures have been assumed as proxies for 2028 and 2058, respectively. For 2043, PNG consumption has been estimated using the annual average growth rate (AAGR) and the average gasification rate between 2028 and 2058. As LPG-specific data are not available, LPG consumption has been estimated by assuming that LPG fulfils the remaining unmet gas energy demand (as per the gasification rate).
- Fugitive emissions from PNG distribution have been estimated by assuming a 0.6% loss of the total PNG supplied during distribution.
- Targets have been envisaged for the adoption of electric cooking in residential and commercial buildings, with power sourced from renewable energy, as a good practice to meet cooking energy requirements. Based on inputs from APCRDA, the envisaged targets for electric cooking in residential buildings are 5% of total energy demand for cooking by 2043 and 10% by 2058. For commercial and institutional buildings, the targets are 10% by 2043 and 15% by 2058 of the total cooking energy demand.

Transportation

- The modal share of transport for 2028, 2043, and 2058 has been estimated based on the trip type distribution between Internal-Internal (I-I), Internal-External (I-E), External-Internal (E-I), and External-External (E-E), as provided in the Traffic and Transport Master Plan. The mode-wise shares for each trip type have been incorporated with the provided distribution in the Plan to determine the overall modal shares. As the Transport Master Plan provides projections for 2020, 2035, and 2050, the corresponding information has been assumed to be applicable for 2028, 2043, and 2058 respectively. Additionally, for 2028, the modal share has been further adjusted (based on consultations with APCRDA) to reflect a lower public transport share. The adjustment has been made on the assumption that, during the initial construction phase, most trips will be from private vehicles as residential settlements gradually come up. This reliance on private cars is expected, as public transport uptake is likely to remain limited in this period, given the time required to establish the necessary ecosystem (e.g., terminals, route rationalisation, service frequency, etc.).

- Metro, bus, and rail-based public transport modes have been assumed to operate entirely on electricity across the planning period. For private vehicles, including cars, two-wheelers, and intermediate public transport (IPT) (taxis), the fuel mix has been estimated based on current and projected electric vehicle (EV) adoption. For 2028, EV penetration has been calculated based on observed trends in Vijayawada and Guntur, as well as targets outlined in Andhra Pradesh's EV Policy, 2024. For 2043 and 2058, the fuel mix has been projected in alignment with national-level targets set by the Government of India (and similar targets outlined in the Net-Zero Action Plan for Vijayawada), as well as the widespread promotion of electric vehicles as envisaged in Amaravati.
- It is assumed that renewable energy will supply 20%, 40%, and 60% of the electricity required to operate EVs in Amaravati in 2028, 2043, and 2058, respectively, based on discussion with APCRDA.

Waste

- Solid waste generation across the planning period has been estimated based on the per capita waste generation. For 2028, per capita waste generation has been assumed at 0.43 kg per capita per day, consistent with baseline estimates. For 2058, per capita waste generation is expected to increase to 0.8 kg per capita per day, based on the Solid Waste Master Plan, which references the CPHEEO guidelines. Waste generation for 2043 has been interpolated using an AAGR of 2.87% between 2028 and 2058, as discussed and confirmed with city officials.
- Estimations of municipal solid waste processing quantities from 2028 to 2058 are based on waste composition and using per capita generation value as per the Solid Waste Master Plan, 2016. In 2028, all waste is assumed to be sent to Waste-to-Energy (WtE) facilities in line with the city's current plans as per inputs by APCRDA. By 2043, WtE capacity is assumed to remain at 2028 levels, with the remaining waste diverted to processing routes based on composition—such as MRFs, composting, and bio-methanation. For 2058, processing capacity is projected to scale up from 2043 levels, with additional treatment through RDF supply to cement plants and the introduction of Bio-CNG facilities. Additionally, it is assumed that 10% of the rejects from the processing facilities, along with all the inert waste, will be directed to a scientifically managed sanitary landfill.
- Mitigation or GHG emission reduction impacts due to co-benefit of energy generation and avoided emissions from solid waste processing infrastructure—including waste-to-energy, bio-methanation, bio-CNG, RDF generation, and recycling—have been incorporated into the emissions estimates.

- Wastewater generation has been estimated by assuming that 80% of the water supplied, after accounting for losses, is discharged as wastewater. To meet CPHEEO norms, an additional 10% of the estimated wastewater has been added to account for possible groundwater infiltration as per the Wastewater DPR 2025, resulting in the final wastewater generation figure.
- For wastewater treatment, 100% sewage network coverage and treatment have been assumed, based on discussions with APCRDA (in line with Wastewater DPR, 2025) and the city's plan for phased development of sewage treatment plant (STP) capacity to cater to projected domestic wastewater volumes. Three treatment technologies identified by APCRDA as per the Wastewater DPR 2025 include SBR (Sequencing Batch Reactor), MBBR (Moving Bed Biofilm Reactor), and A2O (Anaerobic-Anoxic-Oxic). At present, the distribution of treatment capacity and implementation plan across these identified technologies is yet to be finalised by APCRDA. Therefore, the distribution or share of these technologies in the total wastewater treatment capacity has been assumed based on typical system characteristics. It is assumed that SBR and MBBR will function as aerobic systems (noting that SBR can also operate anaerobically), while A2O will operate anaerobically. An equal split of 33.33% across all three technologies has been assumed, resulting in an overall treatment distribution of approximately 66.7% aerobic and 33.3% anaerobic processes throughout the planning period.
- For estimating N_2O emissions from wastewater, per capita protein consumption has been assumed at 20.71 kg per person per year for 2028, based on state-level consumption data from the NSSO report[73]. From 2043 onwards, protein consumption is projected to increase to 28.24 kg per person per year, in line with dietary standards recommended by the Indian Council of Medical Research (ICMR)[74].
- Mitigation impacts from the planned reuse of treated water as per Wastewater DPR 2025 have been accounted for in the overall emission estimates.

Assumptions – BAU Scenario (2028 to 2058)

Stationary Energy

- The assumptions related to electricity demand estimation, T&D losses, PNG consumption, and fugitive emissions from PNG distribution remain the same as outlined in the climate action scenario.
- For the BAU scenario, renewable energy (RE) integration targets for electricity have been assumed to be **3.88% in 2028, 19.60% in 2043, and 44.44% in 2058**. These targets have been derived from Andhra Pradesh's Renewable Purchase Obligation (RPO) trajectory. To arrive at these target numbers, the RPO trend for the state was projected geometrically up to 2058. From the projected RPO levels for 2028, 2043, and 2058, the current RPO level, i.e., 20%, was subtracted and treated as a delta. This gave us the additional RE share required for each year. This approach was used since the current RPO baseline is already reflected in the state's grid electricity emission factor. By treating it as a delta, only the incremental renewable energy beyond the current target is considered, which reflects the actual additional renewable capacity the state would need to add in the future. The approach helps quantify the GHG mitigation potential associated with this additional RE integration.

[73] Nutritional Intake in India 2011-12 National Sample Survey Office.
[74] Dietary Guidelines for Indians, Indian Medical Council Research, 2024.

- No targets are envisaged for electric cooking in the BAU scenario.

Transportation

- The modal share for the BAU scenario has been developed using a combination of Amaravati's projected modal share for 2028 and the existing modal share of Vijayawada. This approach assumes that if Amaravati had not been developed, the designated area would likely have been integrated into Vijayawada or developed in a similar brownfield manner. However, elements from Amaravati's planned mobility structure have still been reflected in the BAU modal share, such as the inclusion of the metro/rail system in the modal share by 2058. The detailed year-wise modal share used for the BAU scenario is provided in Annexure F.
- Metro, bus, and rail-based public transport systems are assumed to run entirely on electricity across the planning horizon (2028, 2043 & 2058). For private vehicles, including cars, two-wheelers, and intermediate public transport (such as taxis and autos), the fuel mix has been estimated based on the state's EV policy and projected EV adoption trends. For the estimation, the EV share was first calculated as a proportion of the total vehicle population in the state for the years 2028, 2043, and 2058, and category-wise (car, 2W, 3W) splits were applied based on current EV distribution trends. The final fuel mix assumed for private vehicles under the BAU scenario is presented in Annexure I.
- In line with trends seen in other brownfield cities, no dedicated renewable energy supply has been considered for EV charging in the BAU scenario. Electricity consumed by EVs is assumed to be drawn entirely from the grid supply.

Waste

- Per capita waste generation assumptions remain the same as the climate action scenario, 0.43 kg/day in 2028 and 0.8 kg/day in 2058, with interpolation for 2043 using AAGR of 2.87%.
- In 2028, 100% of solid waste is assumed to be processed via Waste-to-Energy (WtE) facilities. For 2043 and 2058, processing is split between WtE, composting, and biomethanation based on the current processing mix in Andhra Pradesh. No additional methane recovery or advanced bio-CNG systems are considered.
- Wastewater generation and treatment assumptions are the same as the climate action scenario, based on 80% of water supply with 10% infiltration, and 100% coverage and treatment using SBR, MBBR (aerobic), and A2O (anaerobic) technologies in equal proportion (33.3% each). However, no methane capture is assumed from anaerobic treatment in the BAU scenario.
- Per capita protein consumption is assumed to be the same as in the climate action scenario (20.71 kg in 2028, 28.24 kg from 2043 onward), based on NSSO and ICMR data.

6.3 Climate Action Scenario

The Climate Action Scenario envisions implementation of Amaravati's climate strategies and actions in its Climate Change Action Plan across its proposed development timeline of 2028 to 2058. It represents the city's expected lower level of GHG emissions that would result from the low-carbon and climate-oriented planning approach outlined across sectors. Data for the planning period has been sourced from planning and infrastructure documents, with assumptions made for any missing datasets.

Results and Highlights

As Amaravati develops and its population expands from 4.49 lakh persons in 2028 to 39.95 lakh persons in 2058, the trend of GHG emissions is correspondingly seen to increase over this period. GHG emissions for the city in the Climate Action scenario are projected to reach 12.45 lakh tCO_2e by 2058, compared to 8.12 lakh tCO_2e in 2028. A sectoral breakup of Amaravati's GHG emissions during the planning period is presented in Table 6-1 and Figure 6-2 below.

Table 6-1 Sector-wise GHG emission estimates under the Climate Action Scenario, 2028 - 2058

Sector	GHG Emission (tonnes of CO_2e)		
	2028	2043	2058
Stationary Energy	6,92,862	10,36,106	8,53,140
Transportation	77,821	1,62,665	2,33,094
Waste	41,153	69,222	1,59,031
Total	**8,11,837**	**12,67,992**	**12,45,265**

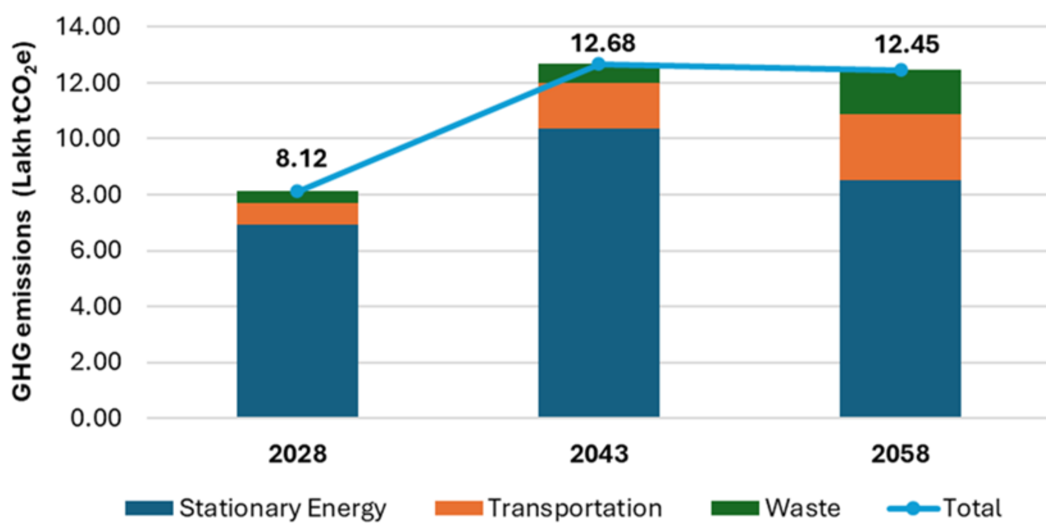

Figure 6-2 Projected trend of GHG emissions under the Climate Action Scenario, 2028- 2058

In the Climate Action scenario, Amaravati's per capita emissions are estimated to be 0.31 tCO_2e by 2058. As compared to its baseline per capita emissions of 1.31 tonnes of CO_2e in 2024, the per capita emissions in the scenario in 2058 represent a significant decline (approx. 76%). This trend substantiates and reflects the low-carbon and sustainable approach that underpins Amaravati's planning, especially considering the capital city area's current primarily greenfield and rural context and the scale of infrastructure improvement, urbanisation, and transformation that Amaravati's development will bring to the region. Amaravati's per capita emissions post its complete development in 2058, under this scenario, are estimated to be much lower when compared to per capita emissions of other national and international brownfield cities (see Table 6-2).

Table 6-2 Amaravati's Per Capita GHG Emissions Compared to Indian and Global Cities

City	Per Capita GHG Emissions (tCO_2e)	Year
Amaravati	1.31	2024
	0.31	2058
Ahmedabad	2.1	2021-22
Chennai	1.9	2018-19
Coimbatore	1.75	2021-22
Hyderabad	2.48	2022-23
Mumbai	1.8	2019
Vijayawada	1.85	2021-22
Bangkok	7.39	2024
London	3.2	2022
Los Angeles	5.4	2020
Montreal	13	2019
New York	11	2019
Singapore	12.3	2021

In 2058, GHG emissions in the Climate Action scenario are expected to be primarily driven by stationary energy consumption in buildings and utilities, which are anticipated to account for about 78.5% of the city's total emissions. The transportation sector is likely to contribute approximately 17% of the emissions in 2058. In comparison, the remaining 4.5% of the emissions are expected to come from the waste sector, including solid waste and wastewater management (Table 6-3 and Figure 6-3).

Table 6-3 Amaravati's sectoral GHG emissions under the Climate Action Scenario, 2028 - 2058

Sector and Sub-sector	GHG Emissions (tonnes of CO_2e)		
	2028	2043	2058
Stationary Energy	**6,92,862**	**10,36,106**	**8,53,140**
Residential Buildings	2,71,054	3,93,737	2,47,639
Commercial and Institutional Buildings/Facilities	3,23,495	4,74,380	3,50,822
Industries	97,679	1,65,216	2,49,058
Agriculture, Forestry, and Fishing Activities (i.e. mainly agriculture)	-	-	-
Fugitive Emissions (from piped gas supply)	634	2,772	5,622
Transportation	**77,821**	**1,62,665**	**2,33,094**
On-road Transportation	77,821	91,504	1,11,959
Rail/Metro	-	71,161	1,21,136
Waste	**41,153**	**69,222**	**1,59,031**
Solid Waste	36,042	52,904	1,23,245
Wastewater	5,111	16,318	35,786
Total	**8,11,837**	**12,67,992**	**12,45,265**

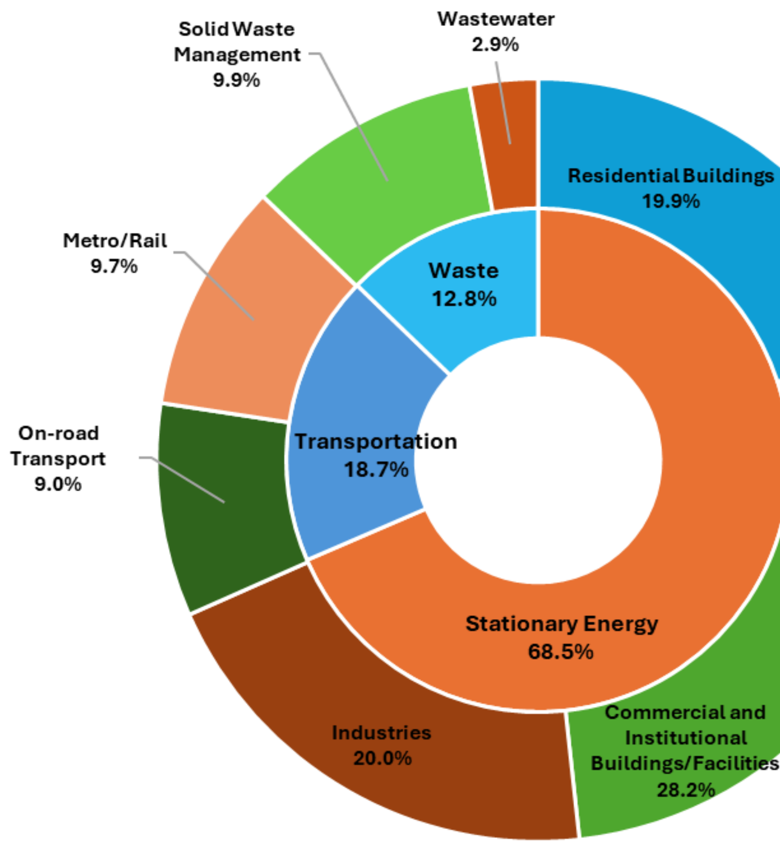

Figure 6-3 Sectoral share of GHG emissions in Amaravati under the Climate Action Scenario, 2058

Note: Fugitive emissions occurring from leakages in PNG supply have not been included in the representation due to its negligible share

With regard to energy use in buildings and facilities, the commercial and institutional buildings and facilities are projected to be the most significant contributors, with a share of 28.2% in total city-wide emissions by 2058. In contrast, emissions from residential buildings are estimated to contribute to 19.9% of Amaravati's GHG emissions by 2058. This is followed by the industry sub-sector, which is expected to contribute around 20% of the total emissions. The remaining 0.4% of the emissions are estimated to result from fugitive sources due to leakages in the PNG supply.

With Amaravati expected to house 39.95 million inhabitants by 2058, the resulting demand and increase in residential housing, utilities, and services, as well as commercial activities and institutional establishments, will drive energy use and resulting emissions. However, the city has committed to adopting measures to optimise energy use in the building sector. Solar integration in the building sector is planned, which will contribute significantly to the decarbonisation of the electricity mix. The city is also prioritising energy-efficient buildings through compliance with the Energy Conservation Building Code (ECBC) and adoption of green certification systems across its building stock. These considerations have been factored into the GHG estimate for the city under this climate action scenario.

The transport sector is estimated to contribute 17% of Amaravati's GHG emissions by 2058. The city is prioritising a multi-modal public transport system alongside non-motorised transport (NMT) options such as walking and cycling. By 2058, public transport and NMT are projected to account for approximately 70% of the modal share. This demonstrates the city's commitment to a significant shift toward low-carbon mobility. Additionally, the city aims to achieve 100% electrification of public transport systems and private internal vehicles, also ensuring that 60% of the required electricity is sourced from renewable energy. However, despite these progressive initiatives, transport emissions are still expected to rise in absolute terms, mainly due to urbanisation and an increase in overall travel demand.

The resident population allied with commercial, institutional, and industrial activities will lead to significant solid waste generation. GHG emissions will also result from the considerable volume of domestic wastewater generated, with infrastructure in place to manage wastewater through a city-wide underground sewage network and treatment facilities.

In the Climate Action Scenario, the primary sources of GHG emissions in Amaravati are projected to be PNG, electricity used for transport, and waste management activities. PNG is expected to remain the dominant contributor, accounting for approximately 68.5% of the emissions; 100% of the emissions from stationary energy use (considering fugitive emissions will arise due to PNG consumption only). Electricity consumption in the transport sector, largely from metro and electric vehicle operations, is estimated to contribute around 18% of total emissions, while waste management processes, including both solid waste and wastewater treatment, will account for about 12.8%. In comparison, emissions from transport fuels such as diesel and petrol are projected to be minimal, representing only 0.7% of total emissions, reflecting the city's strong shift toward electrified and low-carbon mobility systems.

6.3.1 Insights on Sectoral GHG Emissions for 2028 to 2058 – Climate Action Scenario

6.3.1.1 Stationary Energy

In the Climate Action Scenario, stationary energy is expected to be the largest contributor to Amaravati's projected emissions over the planning horizon of 2028 to 2058, as is the case in its base year emission profile. With an influx of population, growing footprint of buildings and infrastructure, demand for utilities, the energy demand, and GHG emissions from stationary energy are expected to increase from 6.93 lakh tCO_2e in 2028 to 10.36 lakh tCO_2e in 2043. However, despite continued growth in population and infrastructure beyond 2043, overall emissions are projected to decline slightly to 8.53 lakh tCO_2e by 2058 (see Figure 6-4). This reduction is attributed to higher adoption of renewable energy sources, enhanced energy efficiency measures in buildings and utilities, and supporting interventions such as improved demand management.

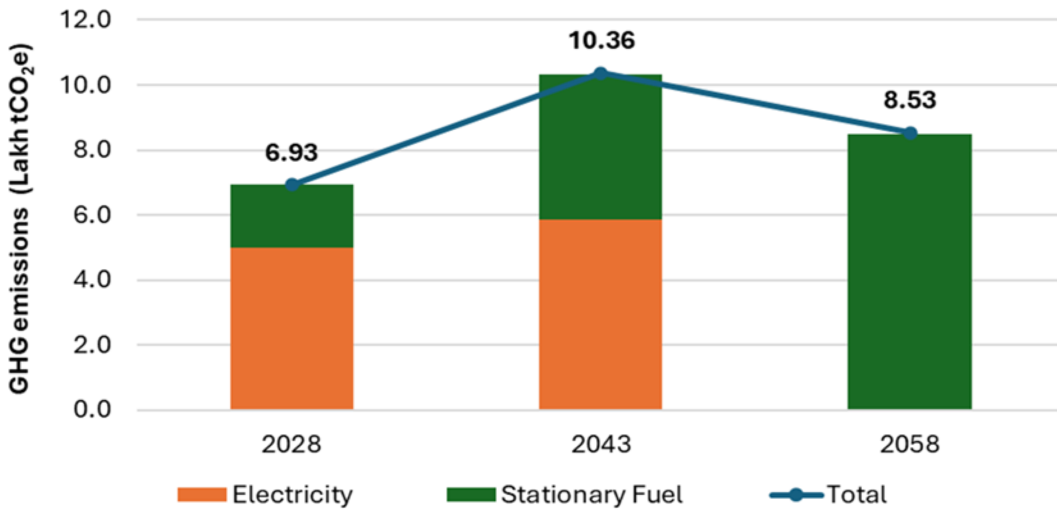

Figure 6-4 Projected trend of GHG emissions in the stationary energy sector under the Climate Action Scenario, 2028 - 2058

Note: Fugitive emissions occurring from leakages in PNG supply have not been included in the representation due to its negligible share

In 2058, commercial and institutional buildings and facilities are expected to be the largest contributor to GHG emissions from stationary energy use, accounting for 42% (see Figure 6-5). Residential buildings and industries will each account for 29% of stationary energy emissions by 2058.

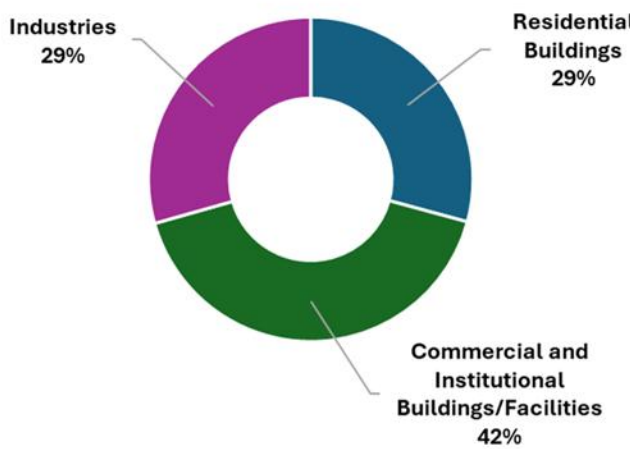

Figure 6-5 Stationary energy emissions by sub-sector under the Climate Action Scenario, 2058

Note: Fugitive Emissions have not been included in the representation due to their negligible share.

Electricity and PNG will be the primary energy source to meet energy demand in buildings and facilities. PNG will account for 100% of GHG emissions from the stationary energy sector in 2058. The contribution of electricity to sectoral emissions will be zero due to the city's plan to source 100% of its electricity from renewable energy sources by 2058.

By 2058, the city's total power demand is projected to reach 2,726.9 MW (see Annexure C), with a power density of 12.56 MW per square kilometer, comparable to global cities like New York or Tokyo. The resulting electricity consumption by 2058 is estimated to be 10,484.9 million kWh, increasing more than 11 times from 920.3 million kWh in 2028. Demand in commercial buildings is expected to account for 46% of electricity consumption in the stationary energy sector in 2058 (see Figure 6-6). Residential Buildings are expected to be the second-largest consumer, with a share of 37%, followed by the industrial sub-sector with a share of 17%. As Amaravati develops into an urban centre, agricultural power consumption within its boundaries is projected to decrease and have a negligible share in GHG emissions by 2058.

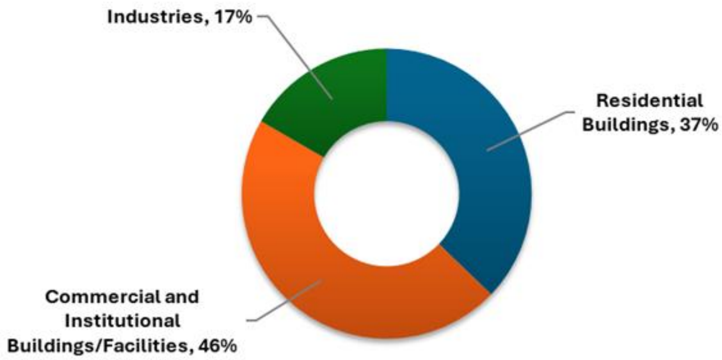

Figure 6-6 Sector-wise electricity consumption and GHG emissions in the stationary energy sector under the Climate Action Scenario, 2058

A city-wide PNG distribution network is planned in Amaravati by 2058 to meet the energy requirements of domestic, commercial, and industrial users. The gas network will be expanded over time, leading to a transition from an energy mix of 50% PNG and 50% LPG in households in 2028 to a 100% PNG and LPG phase-out by 2058. This energy transition to relatively cleaner PNG will result in lower emissions for every unit of energy demand over this time horizon.

PNG consumption-related emissions will be driven by the commercial and institutional buildings and facilities, as well as the residential buildings sector, from 2028 to 2058. Commercial and institutional buildings and facilities will likely account for 44% of the GHG emissions from PNG use by 2058. In comparison, residential and industrial consumers will contribute 29% of the emissions by 2058 (Figure 6-7). As noted earlier, the contribution of LPG consumption to energy demand and resulting GHG emissions is expected to decrease from 45% in 2028 to 0% in 2058.

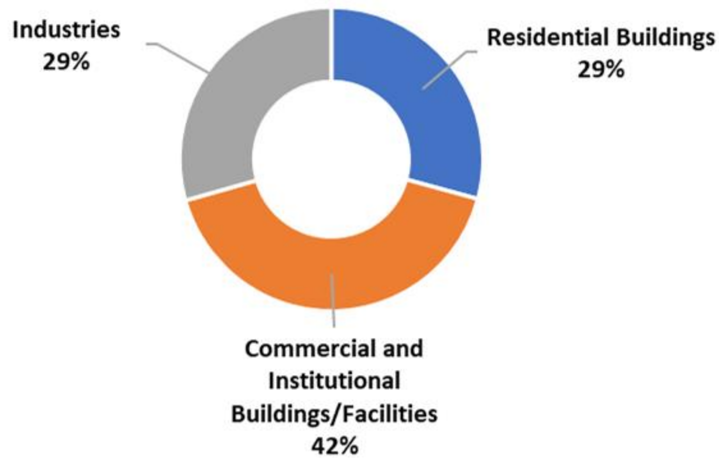

Figure 6-7 GHG emissions from PNG consumption in the stationary energy sector under the Climate Action Scenario, 2058

Additionally, fugitive emissions from expected leakages from PNG distribution within the city have been accounted for in the emission estimates for the period 2028 to 2058. However, they are not represented in the charts due to their negligible share.

Amaravati has laid out specific design targets and mandates for energy efficiency and renewable energy, which are to be integrated into its infrastructure plans. Solar PV has been identified as a major contributor to the city's power mix. The city aims to achieve a 100% renewable energy-based electricity supply for its projected total energy demand by 2058. For 2028 and 2043, the electricity contribution from renewable energy is assumed to be 15% and 75%, respectively (see Annexure D). Additionally, the city has set targets to meet a certain portion of the cooking energy demand through electricity powered by renewable energy sources.

The city has also mandated that buildings follow the ECBC codes and obtain green certifications through LEED, GRIHA and IGBC, and LEED standards. In this context, city-wide electricity savings of about 15% have been assumed in the building sub-sector (residential, commercial & institutions and industries)[75]. In addition, Amaravati has planned to implement District Cooling Systems (DCS) to serve major commercial and institutional areas. DCS will provide centralised cooling to multiple buildings, reducing the need for individual air conditioners and saving significant amounts of electricity. In addition, Amaravati has also laid out plans for digital and integrated energy management through the deployment of Supervisory Control and Data Acquisition (SCADA) systems.

These considerations have been made for establishing the emissions estimates for the climate action scenario. These actions significantly lower Amaravati's projected energy demand and support its transition toward a more sustainable and resilient future between 2028 and 2058.

[75] According to IGBC Green New Buildings and Net-Zero frameworks, buildings can achieve 20–30% savings (IGBC Green New Buildings Rating System, Version 3.0, Abbreviated Reference Guide, September 2016). In comparison, LEED projects often deliver 18–39% improvements. Taking into account both the certification levels (which are being mandated for buildings in Amaravati), real-world operational gaps, partial coverage, varied building types, and behavioural factors, a 15% reduction has been assumed overall.

6.3.1.2 Transportation

Amaravati's mobility strategy focuses on ensuring the significant use of public and NMT modes (see Annexure F). The development of integrated multi-modal transport infrastructure for alternative travel options, as well as smart and accessible transport infrastructure for NMT, is planned.

In the Climate Action scenario, GHG emissions from Amaravati's transport sector are projected to increase over the planning period, reflecting the city's rapid growth and rising travel demand. In 2058, emissions from the transport sector are projected to reach around 2,33,094 tCO_2e from 77,821 tCO_2e in 2028. Of this, approximately 48% is expected to come from on-road transport such as public buses, private vehicles, cars, and taxis, while the remaining 52% will be from metro and rail services, indicating a significant push for public transport in the city (see Figure 6-8).

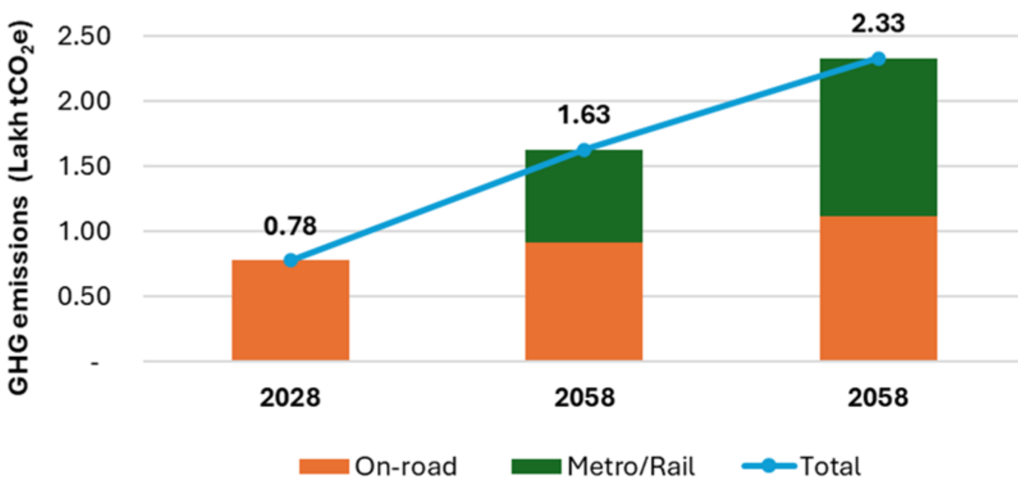

Figure 6-8 Projected trend of GHG emissions in the transport sector under the Climate Action Scenario, 2028–2058

Despite this push for public transport and NMT modes, GHG emissions persist due to the city's plan for widespread electrification of transport systems and the relatively high GHG emission factor of grid-based electricity under India's power mix. However, the city plans to progressively integrate renewable energy into the electricity required for EV operations. Targets have been set to source 20% of the electricity from renewable energy by 2028, further increasing it to 40% by 2043, and reaching 60% by 2058. This phased approach reflects the expected scaling up of renewable energy generation capacity alongside EV adoption, ensuring that the transition to electric mobility is aligned with broader decarbonisation goals.

The projected emissions from the transport sector between 2028 and 2058 are illustrated in Figure 6-8 and summarised in Table 6-4 below. Of the total GHG emissions from the transport sector, electricity is projected to contribute 97%, while the remaining 3% are attributed to transport fuels. The emissions from transport fuels are expected to persist even with the city's target of achieving 100% electrification of its vehicle fleet, as vehicles from external trips, beyond the city's regulatory control, may continue to rely on conventional fuels.

Table 6-4 Projected GHG emissions from the transport sub-sector under the Climate Action Scenario, 2028 - 2058

Sub-sector	GHG Emissions (tCO_2e)			
	2028	2043	2058	Share in 2058
On-Road	77,821	91,504	1,11,959	48%
Rail/Metro	-	71,161	1,21,136	52%
Total	**77,821**	**1,62,665**	**2,33,094**	**100%**

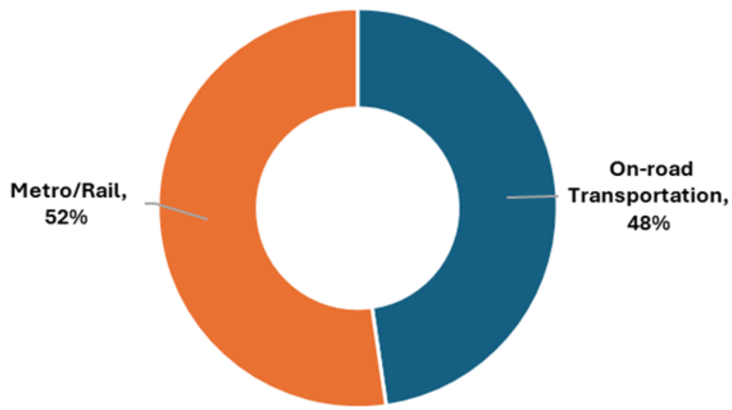

Figure 6-9 Share of on-road and metro/rail modes in transportation emissions under the Climate Action Scenario, 2058

Amaravati's transport planning is centred on creating an efficient and low-emission mobility system. The city has planned for a high-capacity public transport network based on Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT)/Metro. A walkable, compact, and transit-oriented development (TOD) model is being adopted, which will be supported by a strong feeder bus system, intermediate public transport (IPT), and multimodal terminals for smooth transfers. Dedicated cycling and pedestrian infrastructure are also being planned citywide, along with universal street design standards that prioritise safety and accessibility and promote NMT modes.

The integration of electric mobility solutions into the city's overall transportation framework is a high priority on Amaravati's mobility planning agenda. The city has outlined a goal to achieve 80% of passenger trips through NMT, MRT, and electrically powered vehicles by 2050 (see Annexure F). This initiative also creates an opportunity to integrate renewable energy into charging infrastructure, offering the city a significant pathway to advance low-carbon mobility.

These considerations have been factored into the Climate Action scenario while estimating GHG emissions from the transport sector. The assumptions regarding modal share, electric vehicle adoption, and the use of renewable energy for charging have been aligned with Amaravati's sustainable mobility vision. As a result, the emission estimates reflect the city's planned shift toward cleaner transportation modes, increased public transportation usage, and a higher share of non-motorised and electric mobility.

6.3.1.3 Waste

By 2058, the waste sector under the climate action scenario is expected to contribute approximately 4.5% of the city's total emissions. GHG emissions from Amaravati's waste sector are projected to rise over the planning period, from 41,153 tCO_2e in 2028 to around 1,59,031 tCO_2e by 2058.

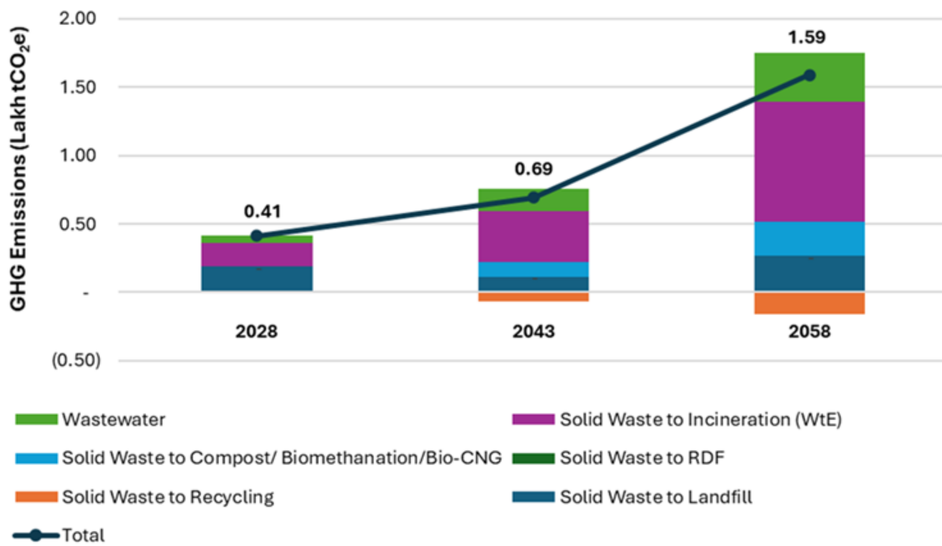

Figure 6-10 Projected trend of GHG emissions in the waste sector under the Climate Action Scenario, 2028–2058

Note: Although the stacked bar in the figure adds up to a higher value (1.7 Lakh tCO_2e in 2058), the total emissions are depicted as 1.59 Lakh tCO_2e due to negative emissions from solid waste treatment processes.

By 2058, solid waste is expected to represent 77% of total waste sector emissions (1,23,245 tCO_2e), while wastewater is projected to account for the remaining 23% (35,786 tCO_2e). A sub-sector breakdown of waste emissions is provided in Table 6-5 below.

Table 6-5 Projected GHG emissions from the Waste sub-sectors under the Climate Action Scenario, 2028 - 2058

Sub-sector	GHG Emissions (tCO_2e)			
	2028	2043	2058	Share in 2058
Solid Waste	36,042	52,904	1,23,245	77%
Wastewater	5,111	16,318	35,786	23%
Total	**41,153**	**69,222**	**1,59,031**	**100%**

Amaravati is estimated to generate 3,955 tonnes per day (TPD) of municipal solid waste (MSW) by 2058[76]. Of this, approximately 2,028 tonnes will be wet waste (51%), and 1,927 tonnes (49%) will be dry waste, which includes recyclables, combustibles, and inert waste (based on the waste composition for Hyderabad as assumed in the Solid Waste Master Plan, 2016). Figure 6-11 below depicts the trend of waste generation and the processing value chain in Amaravati, considered under the climate action scenario.

[76] Total waste generation in the city for 2058 is estimated based on population projections for 2058 and per capita waste generation considered in the SWM Master Plan, 2016.

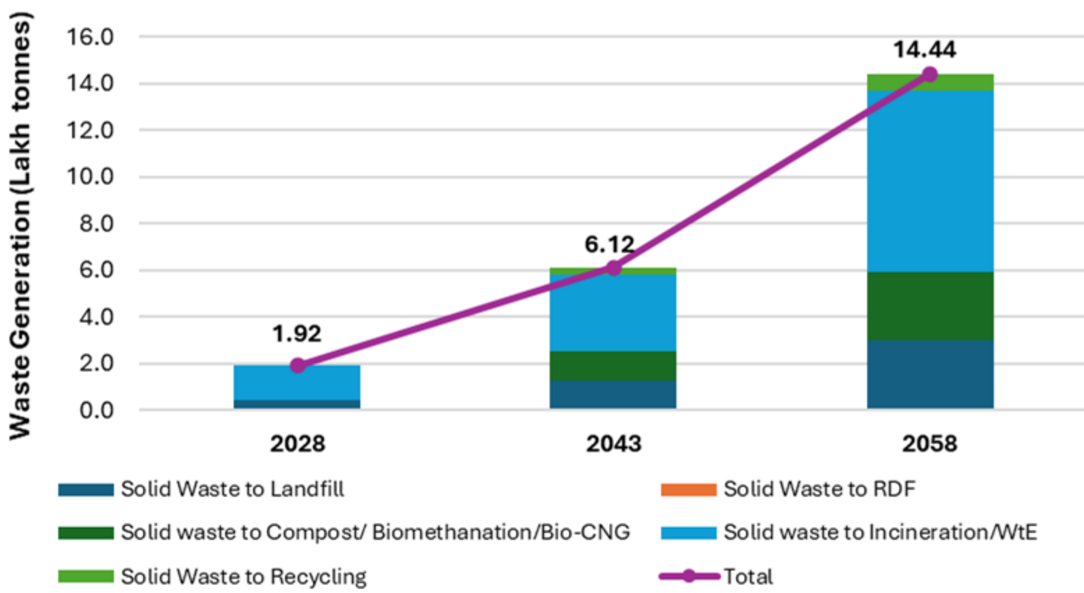

Figure 6-11 Trend of solid waste generation and processing under the Climate Action Scenario, 2028–2058

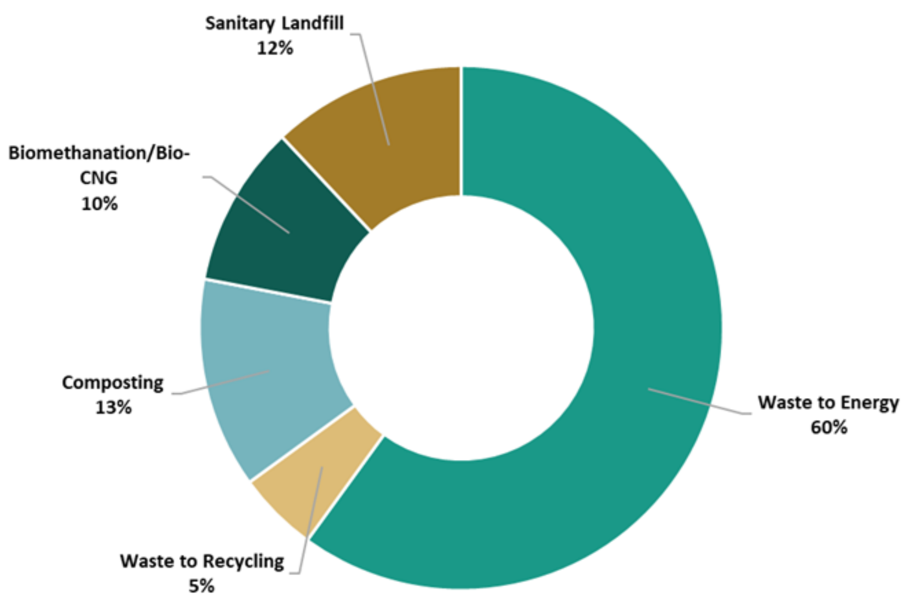

Figure 6-12 Distribution of solid waste by treatment type under the Climate Action Scenario, 2058

From a waste processing perspective, it is assumed that by 2028, all waste will be sent directly to Waste-to-Energy (WtE) facilities for processing, as per the city's current plan, with only inert waste and rejects being sent to the landfill. From 2043 onwards, Amaravati is expected to transition towards a more integrated and low-carbon waste processing system, although WtE will continue to manage the majority of the city's waste. The city plans to introduce Material Recovery Facilities (MRFs) for sorting dry waste and producing RDF, along with biological treatment facilities such as composting, biomethanation, and Bio-CNG plants for processing wet waste. Scientific landfilling is also proposed for managing inerts and rejects (see Annexure K).

By 2058, as illustrated in Figure 6-12, WtE will continue to constitute the dominant share of the waste processing mix (around 60%). In comparison, other low-emission processes such as composting (13%), biomethanation/Bio-CNG (10%), recycling (5%), and sanitary landfilling (12%) will be incorporated into the system. The gradual diversification of waste processing methods, particularly the introduction of biological treatment and material recovery, is expected to contribute to a significant reduction in methane emissions from the sector compared to a scenario where all waste is processed through WtE or sent to landfill.

Wastewater emissions in Amaravati in this scenario are projected to increase from 5,111 tCO_2e in 2028 to approximately 35,786 tCO_2e by 2058. Methane emissions are expected to be approximately – 38,195 tCO_2e, while nitrous oxide (N_2O) emissions are estimated to be about 73,981 tCO_2e (Table 6-6). A negative trend in methane emissions is observed; this reduction is expected from the recovery of methane from anaerobic STPs and its subsequent utilisation for biogas-based energy generation.

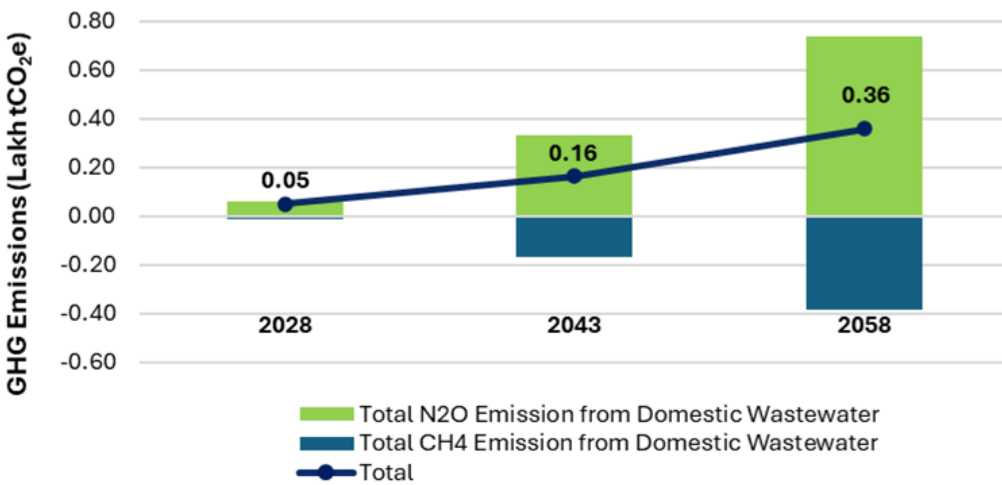

Figure 6-13 Trend of GHG emissions from domestic wastewater under the Climate Action Scenario, 2028–2058

Note: Although the stacked bar in the figure adds up to a higher value (0.7 lakh tCO_2e in 2058), the total emissions are depicted as 0.36 lakh tCO_2e due to negative contributions of methane emissions due to its recovery and reuse in wastewater treatment.

Table 6-6 Projected GHG Emissions from domestic wastewater in Amaravati in the Climate Action Scenario, 2028 to 2058

GHG Type	GHG Emissions (tCO_2e)		
	2028	2043	2058
Total CH_4 Emission from Domestic Wastewater	-994	-16,828	-38,195
Total N_2O Emission from Domestic Wastewater	6,104	33,145	73,981
Total	**5,111**	**16,318**	**35,786**

Amaravati has committed to achieving 100% sewerage network coverage and full treatment of wastewater generated in the city, which is expected to help reduce untreated discharge and associated emissions. Under this scenario, it is assumed that 66.7% of the wastewater will be treated through aerobic processes and the remaining 33.3% through anaerobic systems. The city has also set the objective of achieving 100% sewage treatment, which is expected to further contribute to emissions reduction.

Overall, these measures will help Amaravati establish a cleaner, more climate-resilient waste management system, significantly reducing emissions as the city continues to develop. However, there are opportunities to further reduce these projected emissions, particularly in the wastewater sub-sector, through interventions such as increasing the share of anaerobic treatment systems with methane recovery.

6.4 Business-as-Usual (BAU) Scenario

The BAU scenario represent the level of GHG emissions in the future if Amaravati's development took place in the absence of climate and sustainable planning interventions, following conventional patterns observed in other brownfield cities. It assumes that no additional emissions reduction efforts and measures will be undertaken, beyond those already in place.

This scenario serves as a reference point for assessing the impact of alternative low-carbon strategies adopted by the city as compared to conventional development practices. The BAU scenario assumes "what if" Amaravati were developed not as a sustainable, planned city, no additional emissions reduction efforts and measures will be undertaken, beyond those already in place.

Results and Highlights

In the BAU scenario, GHG emissions in Amaravati are expected to reach approximately 62.79 lakh tCO_2e by 2058. While in 2028 and 2043, emissions are projected to be around 8.13 lakh tCO_2e and 25.46 lakh tCO_2e, respectively. The estimated per capita emission of Amaravati in the BAU scenario is estimated to be 1.57 tCO_2e by 2058. A sectoral representation of Amaravati's GHG emissions in the BAU scenario from 2028 to 2058 is presented in Table 6-7 and Figure 6-14 below.

Table 6-7 Sector-wise projected GHG Emissions in the BAU Scenario in Amaravati, 2028-2058

Sector	GHG Emission (tonnes of CO_2e)			Share - 2058
	2028	2043	2058	
Stationary Energy	**8,22,521**	**25,80,616**	**50,86,174**	**81.0%**
Residential Buildings	3,32,877	11,20,122	18,16,512	28.9%
Commercial	3,73,323	10,82,687	23,24,190	37.0%
Industries	1,15,687	3,75,035	9,39,850	15.0%
Fugitive	634	2,772	5,622	0.1%
Transportation	**79,656**	**2,87,726**	**7,10,347**	**11.3%**
On-road Transportation	79,656	2,87,726	5,48,635	8.7%
Rail/Metro	-	-	1,61,712	2.6%
Waste	**82,118**	**2,09,848**	**4,82,237**	**7.7%**
Solid Waste	36,042	64,239	1,52,996	2.4%
Wastewater	46,076	1,45,609	3,29,241	5.2%
Total	**9,84,295**	**30,78,190**	**62,78,757**	**100%**

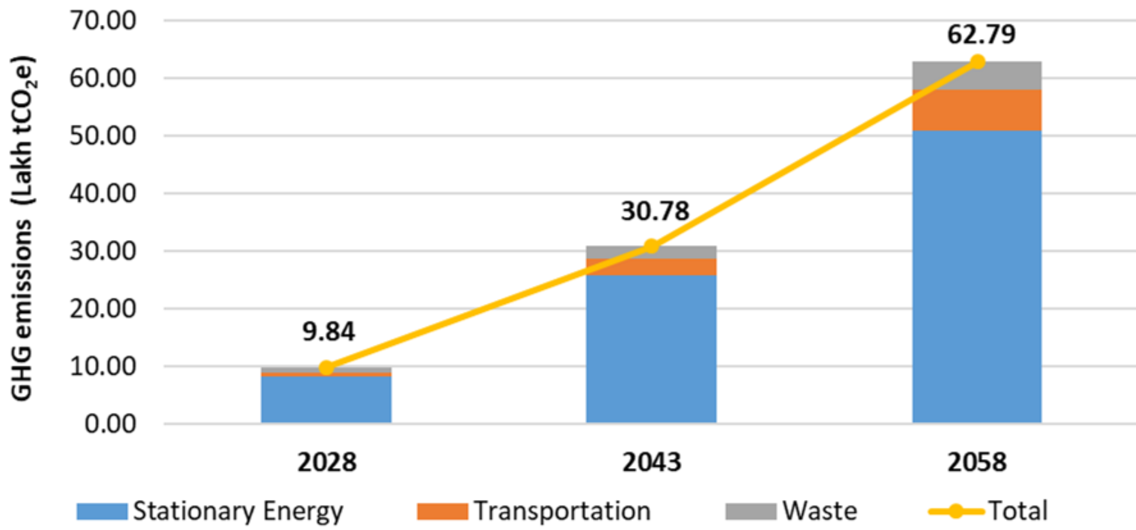

Figure 6-14 Projected Trend of GHG emissions for Amaravati under the BAU Scenario, 2028–2058

Stationary energy is expected to be the dominant source of emissions in Amaravati under the BAU scenario. Emissions from the stationary energy sector are projected to increase from 8.23 lakh tCO_2e in 2028 to more than 50.86 lakh tCO_2e by 2058, accounting for about 81% of the city's total emissions, in contrast to 68.5% in the Climate Action scenario.

The higher level of emissions in the BAU scenario, compared to the Climate Action scenario, is primarily attributed to Amaravati's continued dependence on PNG and grid-based electricity. In contrast to the Climate Action scenario, the uptake of renewable energy in the stationary energy sector under the BAU scenario is assumed to remain limited, with renewables projected to contribute only 3.9% of the total electricity consumption in 2028, 19.6% in 2043, and 44.4% by 2058, in line with Andhra Pradesh's Renewable Purchase Obligation (RPO) trajectory (see Annexure D). In addition, the adoption of ECBC norms and green building certifications such as LEED, GRIHA, and IGBC is assumed to remain limited in the BAU scenario. Accordingly, a city-wide electricity saving of only about 5% has been considered across the stationary energy sector, as compared to 15% in the climate action scenario.

All considerations concerning the expansion of the PNG network, including the transition from LPG to PNG, the sectoral distribution of PNG consumption, and the related emissions, are assumed to remain unchanged in the BAU scenario compared to the Climate Action scenario. Additionally, no target for electric cooking has been specified in the BAU scenario. Electricity is thus estimated to be the dominant emission source in the stationary energy sector, contributing about 82% of total sectoral emissions, while PNG is expected to account for the remaining 18%. This represents a significant contrast to the Climate Action scenario, where 100% of the stationary energy emissions are projected to arise from PNG consumption.

Transport sector emissions in the BAU scenario are projected to contribute 11.3% of the emissions by 2058, rising steeply, from 79,656 tCO_2e in 2028 to 7,10,347 tCO_2e in 2058. In 2058, on-road transportation, including private vehicles and buses, is expected to account for the largest share of sectoral emissions, at 77% of the total, while rail/metro is estimated to account for the remaining 23%. As compared to the

Climate Action scenario, emissions from the transport sector under the BAU scenario are projected to be substantially higher, nearly three times higher. This is primarily due to the lower assumed share of PT and NMT, 42% compared to 71% in the Climate Action scenario, and a correspondingly higher share of private transport, 58% compared to 29% in the Climate Action scenario. The difference is further highlighted by the assumed fuel mix and the relatively limited adoption of EVs in the BAU scenario compared to the Climate Action scenario. The detailed modal share and fuel mix projections for the BAU scenario across the planning period are presented in Annexure F and Annexure I, respectively.

EV adoption is assumed to be 100% in public transport, similar to the Climate Action scenario; however, EV adoption in private vehicles follows state-level trends. Renewable energy supply for EV charging has not been considered, consistent with current patterns in brownfield cities. The assumptions used for estimating the fuel mix and modal share are provided in Section 6.2.

The remaining 7.7% of the emissions in 2058 in the BAU scenario are estimated to come from the waste sector. By 2058, the waste sector emissions are projected to be 482,237 tCO_2e in the BAU scenario, which is approximately three times the emissions from the sector in 2058 in the Climate Action scenario. Wastewater emissions are projected to dominate the waste sector in 2058, making up about 68% of total emissions, in contrast to 23% in the Climate Action scenario.

In the BAU scenario, 43% of Amaravati's waste is projected to be processed through Waste-to-Energy (WtE), which is 17% lower than in the Climate Action scenario. Composting is estimated to constitute a significantly higher share, at 37% (compared to 13%), while bio-methanation/bio-CNG processing, a cleaner option with methane recovery potential compared to composting, is estimated to account for a much lower share, at 3% (compared to 10%). Sanitary landfilling and recycling are estimated to account for 12% and 5%, respectively. The estimated limited adoption of low-emission and energy-recovering technologies is expected to contribute to higher GHG emissions from solid waste under the BAU scenario.

Under the BAU scenario, wastewater-related emissions are projected to reach 3,29,241 tCO_2e by 2058. While 100% sewerage coverage and treatment are assumed, similar to the Climate Action scenario, the key difference lies in the absence of methane recovery or energy generation from anaerobic treatment. Consequently, methane emissions are estimated at 2,55,260 tCO_2e in 2058, compared to –38,195 tCO_2e in the Climate Action scenario, leading to significantly higher overall emissions from the wastewater sub-sector.

6.5 Comparison between Climate Action Scenario and BAU Scenario

Figure 6-15 presents the comparative GHG emission trajectories for Amaravati under the BAU and Climate Action scenarios during the period 2028–2058. In the BAU scenario, total GHG emissions are projected to increase from 9.84 lakh tCO_2e in 2028 to 30.78 lakh tCO_2e in 2043 and further to 62.79 lakh tCO_2e by 2058, primarily due to population growth, rising energy demand, and a continued dependence on conventional energy sources.

In contrast, under the Climate Action scenario, GHG emissions are projected to rise at a much slower rate, from 8.12 lakh tCO_2e in 2028 to 12.68 lakh tCO_2e in 2043, stabilising around 12.45 lakh tCO_2e by 2058, driven by increased renewable energy adoption, energy efficiency measures, and a larger modal share of sustainable transport. The implementation of low-emission technologies, improved waste management systems, and enhanced energy efficiency across sectors contributes significantly to this lower emissions trajectory.

As illustrated in Figure 6-15, by 2058, Amaravati is projected to achieve an overall emissions reduction of 80.2% (50.33 lakh tCO_2e) compared to the BAU scenario, with reductions of 17.5% in 2028 and 58.8% in 2043 along the way**.** This puts Amaravati well in line with the state's net-zero ambition.

The Climate Action Scenario results in the following levels of emission reduction compared to BAU levels:

- **GHG emissions in 2028:** *17.5% lower* than BAU
- **GHG emissions in 2043:** *58.8% lower* than BAU
- **GHG emissions in 2058:** *80.2% lower* than BAU

With implementation of its climate actions, Amaravati's **per capita emissions** are estimated to be **0.31 tCO_2e by 2058**. This is much lower than the existing baseline situation, with per capita emissions of 1.31 tonnes of CO_2e in 2024 and represents a significant decline (about 76%), especially considering the infrastructure improvement and transformation that the capital city will bring to the region.

Through the low-carbon and climate-oriented planning approach under its CCAP, Amaravati's per capita emissions on completion of its development in 2058 are estimated to be much lower as compared to that of brownfield Indian and global cities (see Table 6-3).

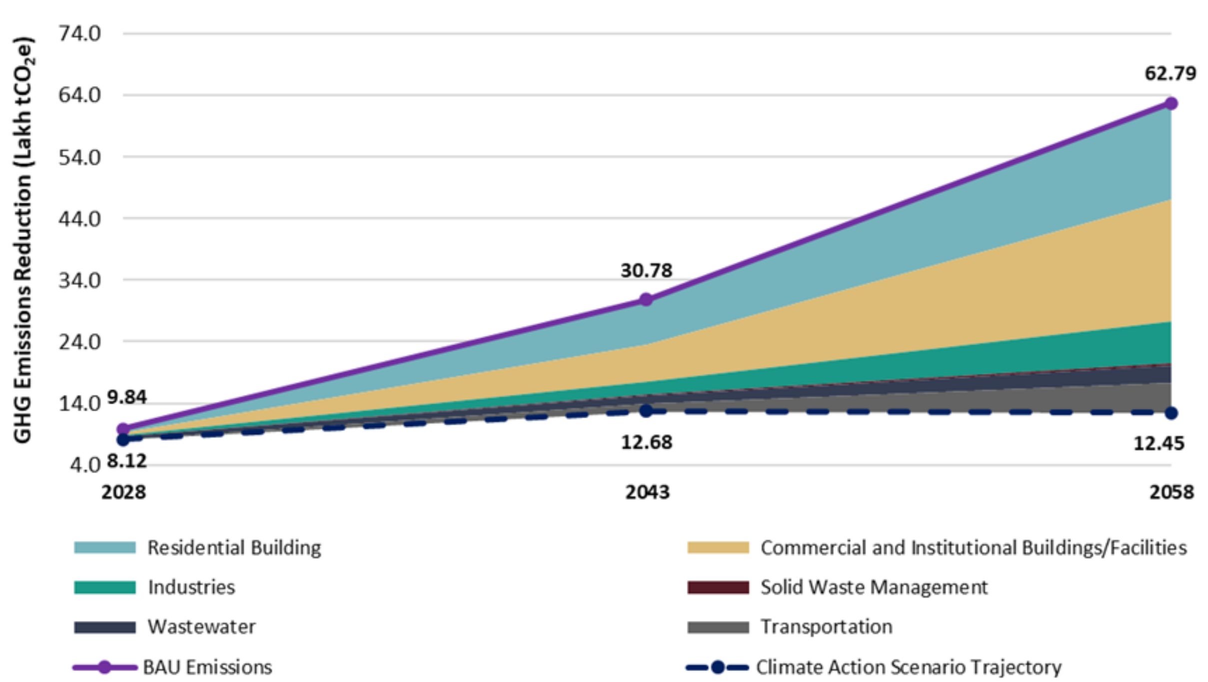

Figure 6-15 GHG Emissions reduction potential of actions in the Climate Action Scenario compared to the BAU Scenario, 2028 - 2058

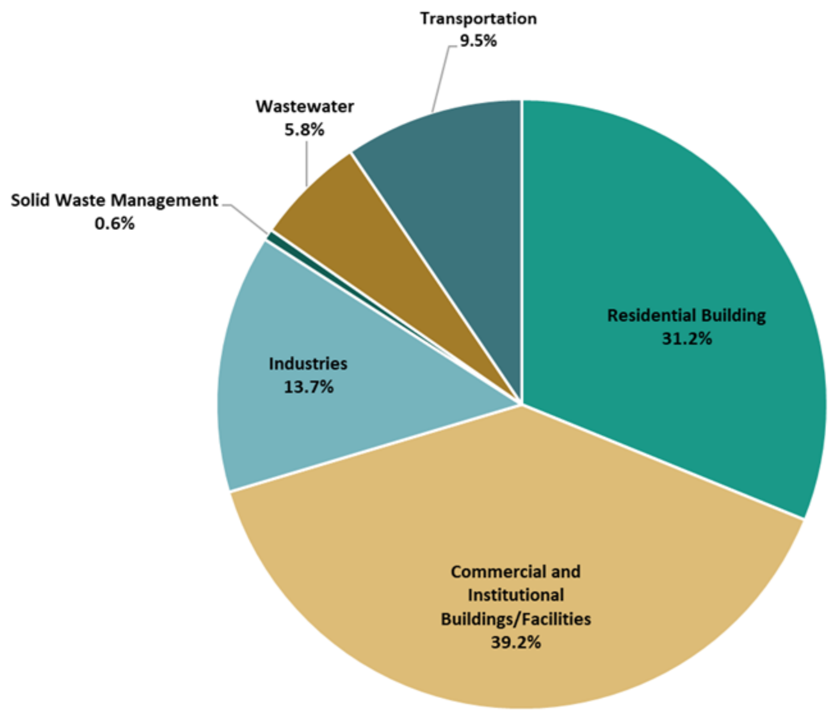

Figure 6-16 Sector contribution to GHG emissions reduction from the BAU levels, 2058

Amaravati's emission reduction from BAU levels is expected to be primarily driven by interventions in the stationary energy sector. The sector is estimated to contribute over 84.1% of the total reduction potential in 2058. Of this, the commercial and institutional buildings/facilities sub-sector is expected to contribute 39.2% of the total emissions reductions, followed by residential buildings with 31.2% contribution and industries with 13.7% contribution (Figure 6-16). The transport sector is estimated to contribute 9.5% of the total emissions reductions, driven by increased adoption of electric vehicles and modal shifts towards public and non-motorised transport. The waste sector (wastewater and solid waste management) is estimated to account for 6.4% of the reduction potential through improved treatment technologies and resource recovery.

Per capita emissions follow a similar downward trend under the climate action scenario, falling from 1.31 tCO_2e in 2024 (baseline) to 0.31 tCO_2e by 2058. In contrast, the BAU scenario projects per capita emissions to be 1.57 tCO_2e by 2058. This comparison underscores the transformative impact of sustained climate action measures in achieving deep decarbonisation across sectors, as opposed to the emission-intensive growth pathway under the BAU scenario.

7 Way Forward

Amaravati, as a planned greenfield capital city, is envisioned to embody principles of environmental sustainability, quality infrastructure, and resilient urban systems. The city's strategic location on the Krishna River, along with proximity to Vijayawada and Guntur, ensures strong multimodal connectivity and the foundations for an economic, administrative, and knowledge-driven urban hub. Its Master Plan prioritizes several sustainability measures including water security, decentralized wastewater management and reuse, robust stormwater infrastructure, integrated solid waste management, and buildings and transport systems powered by renewable energy. Environmental compliance with NGT and EC directives is achieved through robust land use and zoning regulations norms that preserve blue and green networks, wetlands, and forests, embedded with nature-based climate resilience measures.

This Volume I of the Climate Change Action Plan for Amaravati outlines the comprehensive Climate Risk and Vulnerability Assessment, which identifies climate projections indicate rising temperatures up to 2.4°C by mid-century, increasing frequency of extreme rainfall events, along with significant shifts in rainfall pattern and flood risks, particularly in rapidly urbanizing, low-lying regions, including areas alongside the Kondaveeti Vagu and Pala Vagu.

The climate risk and vulnerability assessment, based on current conditions and future scenarios, reveals that climate change presents substantial challenges to Amaravati. It identifies areas of physical and social infrastructure that are susceptible to hazards, emphasizing that vulnerable communities—such as the elderly, children, and migrant workers—are at the greatest risk from heatwaves and floods. This information guides targeted strategies to reduce vulnerability. Urban systems are increasingly stressed, with higher temperatures directly affecting vital services like water and healthcare. Additionally, sectors like transport, wastewater, and solid waste management experience indirect impacts.

The analysis further indicates that government institutions possess greater adaptive capacity, whereas vulnerable groups, including the elderly, children, women, and construction workers, are less equipped to cope with climate risks. While public agencies are relatively well-equipped, consistent capacity-building efforts are required for them and vulnerable communities. To strengthen the resilience of urban infrastructure and communities, APCRDA must adopt a proactive and holistic approach to both mitigate and adapt to identified climate risks. The assessment underscores the necessity for immediate, targeted interventions such as enhanced stormwater networks, rapid heat and flood response protocols, and climate resilience of social infrastructure. Also, the adoption of nature-based solutions, such as the integration of green corridors with rain gardens and bioswales, the use of permeable surfaces, and the widespread adoption of rainwater harvesting, should be prioritized, especially in high-risk neighbourhoods. These strategies should be seamlessly integrated into ongoing development programs and projects, rather than functioning as standalone projects. Implementation should be phased according to the vulnerability to heat hotspots and waterlogging, with immediate attention given to those areas most at risk, followed by subsequent interventions in other settlements as required.

The GHG emissions inventory estimates Amaravati's current baseline per capita GHG emissions at 1.31 tCO_2e, with stationary energy demand primarily from buildings being the largest contributor to emissions, followed by transport and waste. With an Amaravati adopting an ambitious climate action pathway, including widespread renewable energy integration, energy-efficient buildings compliant with ECBC/LEED/GRIHA/EDGE norms, electrified public and private transportation, and circular waste management, Amaravati can cut per capita emissions from 1.57 tCO_2e in the BAU scenario to 0.31 tCO_2e by 2058. This represents an 80% reduction from the BAU scenario baseline, leading to much lower per capita emissions than comparable Indian and international cities. Sectoral strategies focus on advancing toward 100% renewable energy, implementing a city-wide PNG network, increasing the adoption of electric vehicles, and modal shifts towards public and non-motorised transport. It also includes decentralised STPs with methane recovery and shifting towards segregated and decentralized waste processing designed for methane capture.

To address its climate vulnerability and GHG emissions trajectory, Amaravati should establish a regular monitoring and updation process for its demographic, urban systems, climate risk and vulnerability and GHG emissions datasets, thereby creating robust, coordinated data management systems. Climate adaptation and mitigation must be mainstreamed into all infrastructure and zoning regulations, supported by strong cross-sectoral linkages and alignment among departments and stakeholders. Capacity building for local institutions and vulnerable communities is imperative, along with phase-wise prioritization of climate actions and scalable intervention models. Periodic stakeholder engagement, including government bodies, civil society, academia, the private sector, and vulnerable communities, will ensure participatory planning and the effective formulation and implementation of climate-resilient projects. The establishment of integrated monitoring, evaluation, and reporting frameworks will be critical to track climate risks and emissions, support evidence-based decision making, and facilitate iterative improvements.

Building on information presented in this Volume I report, Volume II of the Amaravati's City Climate Change Action Plan elaborates on climate strategies and actions, along with quantitative targets, across nine key sectors, covering energy and buildings, water supply, wastewater, stormwater, solid waste, transportation, urban greening and biodiversity, health and air quality. For instance, the energy and buildings strategy aims to achieve 100% renewable electricity for all buildings and utilities by 2058, supported by the deployment of energy-efficient appliances and mandatory green certifications for new constructions. In the water sector, the city aims to reduce non-revenue water to below 10%, ensure all connections are metered, install rainwater harvesting in every property, deploy SCADA, and have all water utilities operate on efficient and renewable power.

Each of these strategies, actions, and targets is aligned with national and state policies and targets, and with local infrastructure plans, policies, and ongoing projects. The action table specifies action descriptions and rationale, indicative implementation locations, implementing entities, climate-resilience benefits, robust monitoring indicators, and lessons drawn from international and Indian good practices. A practical governance framework is designed to facilitate and support the phased implementation of proposed climate actions. The governance and coordination structure that includes relevant public departments and stakeholders will enable strategic policy coordination, project prioritization, and interdepartmental collaboration. The framework emphasizes mainstreaming climate considerations into all planning processes, from zoning and design approvals to procurement, operations, and maintenance. These climate interventions are implemented through an Integrated Command and Control Centre, which mainstreams the climate-resilient infrastructure framework. This framework incorporates performance measurement indicators to ensure monitoring and evaluation of climate action implementation. Amaravati's phased and integrated approach to climate resilience, developed with robust baseline assessments and sectoral strategies, will achieve its goal of becoming a climate-resilient, net-zero, inclusive, and liveable model city for India and the world.

Annexure A. Analysis of Adaptive Capacities of Identified Actors

Actors' capacities rating and scoring against the three criteria - Capacity to Organise and Respond, Resources, and Access to Information, to determine the capacity of a particular actor is Low, Medium or High is indicated in the Table A-1 below.

Table A-1 Actors' Capacities Rating and Scoring

Key Capacities of Actors	Score
Capacity to Organise and Respond	
Low capacity to organise and re-organise in response to threat or disruption	1
Medium capacity to organise and re-organise in response to threat or disruption	2
High capacity to organise and re-organise in response to threat or disruption	3
Resources	
Low access to the resources necessary to respond (manpower, technology, funds)	1
Medium access to the resources necessary to respond (manpower, technology, funds)	2
High access to the resources necessary to respond (manpower, technology, funds)	3
Access to Information	
Low availability of data and information necessary to develop effective plans and actions and to improve responses to disruptions	1
Medium availability of data and information necessary to develop effective plans and actions and to improve responses to disruptions	2
High availability of data and information necessary to develop effective plans and actions and to improve responses to disruptions	3

Based on the Adaptive Capacity Scores of each of the actors, for a particular fragile system, you can determine which actors have a High, Medium and Low adaptive capacity.

Table A-2 Levels of Adaptive Capacity of Urban Actors

Adaptive Capacity Score	Level of Adaptive Capacity
1 – 8	Low
9 – 17	Medium
18 – 27	High

Actors with a **'Low'** level of adaptive capacity would be those who need to be ***specifically targeted*** in the *actions* (or resilience strategies) that are undertaken to reduce the fragility of the identified urban system.

Actors with a **'High'** level of adaptive capacity can be engaged in the proposed actions, as they can respond to the impacts of the fragile systems. Similarly, those falling in the **'Medium'** category may also need to be specifically targeted *or* can be engaged in the proposed actions, depending on which end of the range they are closer to, i.e., closer to the 'low' category or closer to the 'high' category.

Table A-3 Scoring of Actors

Urban System	Key Actors	Capacity to organize and respond	Access to resources	Access to information	Adaptive capacity (Score)	Adaptive capacity (Status)
		A	B	C	A x B x C	
Water Supply	APCRDA	3	3	3	27	High
	ADCL	3	3	3	27	High
	AP Irrigation Deptt.	2	3	3	18	High
	Youth	3	2	2	12	Medium
	AP Ground water & Water Audit department	1	2	3	6	Low
	Existing Villagers	2	1	1	2	Low
	New Settlers	1	2	2	4	Low
	Elderly / Women / Children	1	1	1	1	Low
	Construction Workers	1	1	1	1	Low
	NGOs / SHGs	2	2	2	8	Low
Waste Water	APCRDA	3	3	3	27	High
	ADCL	3	3	3	27	High
	APPCB	2	3	3	18	High
	APIIC	2	3	2	12	Medium
	Existing Villagers	1	1	1	1	Low
	New Settlers	2	2	1	4	Low
	Elderly / Women / Children	1	1	1	1	Low
	Construction Workers	1	1	1	1	Low
	Youth	3	1	1	3	Low
Storm Water	APCRDA	3	3	3	27	High
	ADCL	3	3	3	27	High
	AP Irrigation Deptt.	3	3	3	27	High
	Existing Villagers	3	2	1	6	Low
	New Settlers	1	1	1	1	Low

Urban System	Key Actors	Capacity to organize and respond	Access to resources	Access to information	Adaptive capacity (Score)	Adaptive capacity (Status)
		A	B	C	A x B x C	
	Elderly / Women / Children	1	1	1	1	Low
	Construction Workers	1	1	1	1	Low
	Youth	3	2	1	6	Low
Solid Waste Management	APCRDA	3	3	3	27	High
	ADCL	3	3	3	27	High
	New Settlers	3	3	1	9	Medium
	Youth	3	3	1	9	Medium
	Existing Villagers	2	3	1	6	Low
	Elderly / Women / Children	2	2	1	4	Low
	Construction Workers	1	2	1	2	Low
Road and Transport	APCRDA	3	3	2	18	High
	ADCL	3	3	2	18	High
	APSRTC	3	3	2	18	High
	AP Roads & Buildings Deptt.	3	3	2	18	High
	Indian Railways	3	3	1	9	Medium
	RTO	3	3	1	9	Medium
	IPT Operators	2	1	1	2	Low
	IPT Users	2	1	1	2	Low
	Private Vehicle Users	3	2	1	6	Low
	Existing Villagers	1	1	1	1	Low
	New Settlers	3	2	1	6	Low
	Elderly / Women / Children	1	1	1	1	Low
	Construction Workers	1	1	1	1	Low
	Youth	2	2	1	4	Low
Biodiversity	APCRDA	3	3	2	18	High
	ADCL	3	3	2	18	High

Urban System	Key Actors	Capacity to organize and respond	Access to resources	Access to information	Adaptive capacity (Score)	Adaptive capacity (Status)
		A	B	C	A x B x C	
	AP Forest Department	3	2	2	12	Medium
	Andhra Pradesh Greening & Beautification Corporation	1	2	2	4	Low
Public Health	Private Hospitals	3	3	3	27	High
	PHCs	1	1	1	1	Low
	Govt. Hospitals	3	2	2	12	Medium
	Elderly / Women / Children	1	1	1	1	Low
	NGOs / SHGs	2	1	1	2	Low

Annexure B. Key assumptions in GHG emission estimation

Assumptions – Base year 2024

Stationary Energy

- The electricity consumption dataset received from the DISCOM covers both the MTMC area and the villages under the Amaravati city area. However, since only one-third of the current MTMC population falls within the Amaravati city boundary, the dataset has been scaled down using per capita consumption to estimate electricity use specific to the city.
- Transmission and distribution (T&D) losses for electricity have been assumed at 7% as per inputs from DISCOM and associated emissions have been accounted for in the estimates.

Waste

- Solid waste generation for 2024 includes contributions from both the MTMC and the village settlements within the capital city area. Per capita waste generation is estimated at approximately 0.43 kg per person per day.
- Wastewater generation has been estimated based on the assumption that 80% of the total water supply is discharged as wastewater. While data on water supply were available for the MTMC area, the village-level supply has been estimated using a per capita water consumption rate of 70 litres per capita per day (LPCD).

Annexure C. Power Demand of Amaravati in 2058

Classification	Estimated Power Demand (MW)
Residential	1076.6
Commercial	521.4
Government / Institutional	21.3
Industrial	498.9
AGC (Excluding DC)	169.3
Startup Area	202.4
Residential area in commercial & Industrial Zones	36.5
Utilities (Including District Cooling System)	123.2
Line losses @2.84%	77.5
Total Demand	**2726.9**

Annexure D. Renewable Energy (Solar PV) Integration Target for Amaravati in the Planning Period

The table below illustrates the percentage of projected electricity consumption in the city targeted from renewable energy sources in the planning period in Amaravati; in both BAU and Climate Action Scenarios.

Parameter	Climate Action Scenario			BAU Scenario		
	2028	2043	2058	2028	2043	2058
Percentage of electricity consumption targeted from renewable energy (%)	15%	75%	100%	3.88%	19.60%	44.44%

Annexure E. Electric Cooking Target for Amaravati

The table below presents the targeted share of cooking energy demand expected to be met through electricity (powered by renewable energy sources) during the planning period in Amaravati, under both the BAU and Climate Action Scenarios.

Residential Sub-sector

Parameter	Climate Action Scenario			BAU Scenario		
	2028	2043	2058	2028	2043	2058
Percentage of energy demand for cooking met by electricity (%)	-	5%	10%	-	-	-
Percentage of electricity for cooking sourced from renewable energy (%)	100%	100%	100%	-	-	-

Commercial and institutional buildings/facilities sub-sector

Parameter	Climate Action Scenario			BAU Scenario		
	2028	2043	2058	2028	2043	2058
Percentage of energy demand for cooking met by electricity (%)	-	10%	15%	-	-	-
Percentage of electricity for cooking sourced from renewable energy (%)	100%	100%	100%	-	-	-

Annexure F. Estimated Modal Share of Transportation in Amaravati

The table below highlights the estimated modal share distribution across different transport modes, including private vehicles, public transport, and NMT, in both the BAU and Climate Action Scenarios.

Mobility Profile	Climate Action Scenario			BAU Scenario		
	2028	2043	2058	2028	2043	2058
Non-Motorised Transport (Walk + Cycle)	20%	24%	25%	20%	20%	20%
Private Vehicles	56%	30%	29%	58%	58%	58%
Public Transport	24%	46%	46%	22%	22%	22%

Note:

- *In the BAU scenario, the modal share is assumed to remain largely consistent across the planning period.*
- *Only bus-based public transport systems are assumed for 2028 and 2043, while by 2058, metro services are expected to be established, accounting for 45% of the total public transport share.*

Annexure G. Estimated Trip Generation Rates for Amaravati

Parameter	Units	Value
Average trip generation	trips/person/day	1.5

Note: The trip generation rate has been assumed to be constant throughout the planning period in both the Climate Action and BAU scenarios.

Annexure H. Estimated Fuel-Mix of the Vehicles/Transport Modes in Amaravati – Climate Action Scenario

Fleet mix by fuel	2028				2043				2058			
	Petrol	Diesel	CNG	Electric	Petrol	Diesel	CNG	Electric	Petrol	Diesel	CNG	Electric
2-Wheeler	64%	-	-	36%	10.5%	-	-	89.5%	4%	-	-	96%
Car	38%	48%	7%	7%	12%	15%	2%	71%	3%	4%	1%	92%
Bus	-	-	-	100%	-	-	-	100%	-	-	-	100%
Metro	-	-	-	100%	-	-	-	100%	-	-	-	100%
Rail	-	-	-	100%	-	-	-	100%	-	-	-	100%
Taxi/Cabs	-	-	-	100%	-	-	-	100%	-	-	-	100%

Annexure I. Estimated Fuel-Mix of the Vehicles/Transport Modes in Amaravati – BAU Scenario

Fleet mix by fuel	2028				2043				2058			
	Petrol	Diesel	CNG	Electric	Petrol	Diesel	CNG	Electric	Petrol	Diesel	CNG	Electric
2-Wheeler	96%	-	-	4%	79.2%	-	-	20.8%	62%	-	-	38%
Car	40%	51%	6%	2%	37.7%	48.7%	3.7%	9.4%	35%	46%	1%	17%
Auto-Rickshaw	-	-	97%	3%	-	-	82.7%	17.3%	-	-	68%	32%
Bus	-	-	-	100%	-	-	-	100%	-	-	-	100%
Metro	-	-	-	100%	-	-	-	100%	-	-	-	100%
Rail	-	-	-	100%	-	-	-	100%	-	-	-	100%
Taxi/Cabs	40%	51%	6%	2%	-	-	90%	9%	-	-	82%	17%

Annexure J. Renewable Energy (Solar PV) Integration Target for Transportation in Amaravati (2028-2058)

The table below presents the estimated share of renewable energy in meeting the electricity demand of the transport sector in Amaravati under both the BAU and Climate Action scenarios.

Parameter	Climate Action Scenario			BAU Scenario		
	2028	2043	2058	2028	2043	2058
Percentage of electricity consumption targeted from renewable energy (%)	20%	40%	60%	0%	0%	0%

Annexure K. Solid Waste Processing in Amaravati (2028-2058) in the Planning Period

Climate Action Scenario

Type	2028		2043		2058	
	Tonnes	Percentage	Tonnes	Percentage	Tonnes	Percentage
Waste to Energy (WtE)	462	88%	998	60%	2,354	60%
Waste to Recycling	-	-	89	5%	210	5%
Composting Plant	-	-	212	13%	500	13%
Biomethanation/Bio-CNG	-	-	170	10%	400	10%
Sanitary Landfill	66	12%	208	12%	491	12%

BAU Scenario

Type	2028		2043		2058	
	Tonnes	Percentage	Tonnes	Percentage	Tonnes	Percentage
Waste to Energy (WtE)	462	88%	718	43%	1,692	43%
Waste to Recycling	-	-	89	5%	211	5%
Composting Plant	-	-	621	37%	1,464	37%
Biomethanation/Bio-CNG	-	-	41	2%	98	2%
Sanitary Landfill	66	12%	208	12%	491	12%

Note:

- *In 2028, all waste is assumed to be processed through Waste-to-Energy (WtE) facilities as per the city's initial waste management plan.*
- *Approximately 10% of rejects from the treatment facilities are estimated to be sent to the sanitary landfill, in addition to the inert waste.*

Annexure L. Emission Factors

Emission factors have been maintained consistently across the planning period, both BAU and Climate Action Scenario, to ensure methodological uniformity and facilitate accurate comparison with the baseline year.

Emission Factors for Fuels and Grid-Electricity			
Fuel	**Emission factor per unit of fuel**	**Unit**	**Source**
LPG	2.98	tCO_2e/tonne	IPCC
PNG	0.00189	tCO_2e/cubic metre	IPCC
Petrol	2.30	tCO_2e/kilolitre	IPCC
Diesel	2.85	tCO_2e/kilolitre	IPCC
CNG (cubic m)	0.0021	tCO_2e/cubic metre	IPCC
Grid – Electricity (2023-24)	727.00	tCO_2e/million kWh	Central Electricity Authority (CEA) - CO_2 Baseline Database for the Indian Power Sector, version 20.0, 2024 Available at: https://cea.nic.in/wp-content/uploads/2021/03/User_Guide_Version_20.0.pdf

Emission Factors for Biological Treatment of Waste (IPCC Default)				
Type of Biological Treatment	CH4 Emission Factors (g CH4/kg waste treated)		N2O Emission Factors (g N2O/kg waste treated)	
	on a dry weight basis	on a wet weight basis	on a dry weight basis	on a wet weight basis
Composting	10.00	4.00	0.60	0.24
Anaerobic digestion at biogas facilities	2.00	0.80	Assumed negligible	Assumed negligible

Methane Correction Factor (MCF) for Landfill (IPCC Default)	
Type of Site	(MCF) Default Values
Managed – anaerobic	1

Annexure M. Minutes of Focus Group Discussions

Village: Rayapudi

Location: Grama Sachivalayam, Rayapudi

Date: 02/06/2025

Participants: Ms. Gowri Shanti, MPDO, Panchayat Secretary, ICLEI SA team, 40 villagers

Discussion points:

- **Flood Impact:** The fisherman colony is vulnerable to flooding. During the rainy season, water surrounds the area for 2 to 4 days every year. During the September 2024 floods, water levels rose as high as 1.5 meters, around 135 families were relocated to rescue shelters by the government. Accessibility of the community is disrupted due to the flood water on the road connecting this area with other parts of the village. The severity of flood events was exacerbated by the diversion of Pala Vagu for the construction of E1 road. Inadequate maintenance of the lock gates at the Pala vagu outfall into the Krishna River can worsen the situation, timely operation could help reduce flood impact.
- **Impact of infrastructure construction on Flooding:** Abbarajupalem is experiencing waterlogging due to the diversion of Pala vagu for the trunk road network construction. No intermediate measures are taken to let the flow of storm runoff into the downstream. Encroachments of the existing natural drainage further increase flood severity. Due to the lack of funds as the village became part of Amaravati, minor measures like the construction of ditches to divert the flood water are also not possible. Additionally, the construction of the seed access road without provisions for stormwater passage has led to dependency on the mechanical pumps.
- **Recommended Interventions for flood management:** Strengthening and repair works for embankments damaged during the 2024 floods. Repair and maintenance works of the lock system in Pala Vagu to be completed before the onset of monsoon. Desilting of the vagus to improve the runoff flow and reduce waterlogging.
- **Temperature Rise:** Villagers reported experiencing higher temperatures over the years and perceived a correlation between rising temperatures and the decline in agricultural activities.

- **Water supply:** The village has abundant water supply from the ground water resources and the quality of the water supplied is suitable for potable needs.
- **Wastewater Management:** The street-level surface drainage network is in place, whereas drainage along the main R&B road is missing, resulting in waterlogging at the nodes of streets. Although all households are equipped with septic tanks, faecal sludge is often discharged untreated by desludging vehicles into Pala Vagu on the village outskrits.
- **Solid waste management**: Services are provided by the APCRDA, with collection activities done by the Panchayati sanitary staff.
- **Health:** Auxiliary Nurse Midwife (ANM) conducts the fever surveys during the rainy season or after the event of flooding. The village lacks a PHC, residents travel to Mangalagiri and Vijayawada for medical care.
- **Pollution:** Residents in the villages are experiencing the severity of air pollution due to the ongoing construction activities. Currently, there are no air monitoring sensors in the village to measure pollution levels.
- **Disaster Management:** Village has an audio alert system that provides instructions/ warnings to the residents before the event. Residents also receive information through mobile SMS from the Andhra Pradesh State Disaster Management Authority.

Village: Borupalem
Location: Panchayat Office, Borupalem
Date: 02/06/2025
Participants: MPDO, Panchayat Secretary, ICLEI SA team, 40 villagers
Discussion points:

- **Severe Flooding:** In 2019, Peddalanka faced severe flooding, with water levels rising upto 12 feet, submerging homes for an entire week. The village was entirely surrounded by water, cutting off communication and evacuation routes, leaving residents stranded. Kotha Colony was the worst affected, with 60 families waterlogged for a week.
- **Transport:** The only available modes of transport are two-wheelers and autos; however, autos become inaccessible when the roads are covered with silt. In the recent 2024 flooding event, houses were demolished, forcing residents to be evacuated by helicopter to shelters in Vijayawada. Presently, the village doesn't have an ambulance services, posing a serious risk during emergencies.
- **Maintenance of Natural drain :** Poor maintenance of Pala vagu has been a main reason for recurrent waterlogging since 2019. The absence of major drainage network prevents effective stormwater discharge from secondary drains. Residents depend on pump motors to drain the water from the houses, which often results in waterlogging in neighbouring houses.
- **Social infrastructure:** The village doesn't have high and upper primary schools, students travel to Mangalagiri for education. NGOs such as the Rotary Club and Arsyam Center have supported the village by renovating local schools and community centers.
- **Health**: Prolonged waterlogging for 4 to 5 days leads to the spread of fever cases among residents.
- **Community Livelihoods**: Following the land pooling of villages in the capital city, many residents from Borupalem, along with those from nearby areas such as Dondapadu and Abbarajupalem, have moved to other areas to continue farming.

- **Role of Youth in Disaster Management:** Presently, there is no disaster response training provided to youth. Given the lack of communication during disasters, training youth could significantly improve emergency response.

Village: Neerukonda
Location: Panchayati Office, Neerukonda
Date: 02/06/2025
Participants: Panchayat Secretary, ICLEI SA team, 14 villagers
Discussion points:

- **Water Supply & Quality:** In Neerukonda extracted groundwater is reportedly contaminated with high fluoride levels. Hence, residents buy their drinking water from the NTR Sujala water plant.
- **Solid Waste Management:** Five sanitation workers collect and transport waste using tricycles to nearby dumper bins. Sometimes these staff are deputed to nearby villages, causing manpower shortage and irregular waste collection.
- **Flood occurrence due to the growth of weed plants:**
- During the 2024 floods, the SC colony was severely affected, with water levels reaching 3–4 feet and remaining for up to 15 days. Overflowing of the Kondaveeti Vagu and blockage caused by aquatic weeds delayed runoff discharge by 4–5 days.
- **Livelihood:** Following the land pooling and restricted farming activities, approximately 200 residents are working as supporting staff at SRM University.
- **Health:** The residents travel to Mangalagiri for medical services due to the absence of primary healthcare facilities.

Village: Velagapudi
Location: Sachivalayam Office, Velagapudi
Date: 02/06/2025
Participants: MPDO, Panchayat Secretary, ICLEI SA team, 20 villagers
Discussion points:

- **Monitoring of encroachments around water bodies:** The Severity of flooding is increasing due to the rising encroachments along the vagus. Strict monitoring is required to monitor the development nearby the vagus and water bodies.
- **Education**: The absence of a local high school forces residents to travel to Mandadam for secondary education.
- **Healthcare:** Without a primary health centre in the village, residents travel to Thulluru for medical services.
- **Power Supply:** The current electrical infrastructure is limited to single-phase power. In the absence of three-phase power, there have been outages.

Village: Krishnayapalem
Location: Panchayat Office, Krishnayapalem
Date: 03/06/2025
Participants: Admin Secretary, ICLEI SA team, 12 villagers
Discussion points:

- **Flood Risk:** No flooding events have been reported since 1950, after the convergence of two water channels, namely Kondaveeti Vagu and Pala Vagu.
- **Water Supply & Quality:** The village lacks a local source of potable water, residents purchase RO water for daily consumption.
- **Education:** Only one elementary school is available locally, while primary school students travel to Penumaka
- **Healthcare Access:** With no hospital in the village, residents travel to Mangalagiri for treatment at AIIMS and private hospitals
- **Desludging Practices leading to contamination of water:** Every household is equipped with a septic tank, and desludging operators collect sludge from septic tanks. However, there are instacnes of operators dumping the faecal sludge untreated in open fields or vagus near the village. The probability of contamination of water sources as these vagus outflows into the Prakasam barrage, which is the water supply source for Vijayawada.

Village: Penumaka
Location: Sachivalayam Office, Penumaka
Date: 03/06/2025
Participants: Panchayat Secretary, Admin Secretary, TDP local leader, ICLEI SA team, 30 villagers
Discussion points:

- **Flood Risks and Management:** The lift pumping station at Undavalli effectively prevents flooding in Penumaka village. During backflow of water from the vagus due to overflow of the Krishna River, motor pumps are used to divert water into the nearby agricultural fields. The primary cause of flooding is due to irregular cleaning of the vagus.
- **Livelihood & Skill Development:** After land pooling, livelihood opportunities have declined due to lack of skills. Residents suggested establishing a skill development centre to enhance employment opportunities. Additionally, special support for women, such as assistance in purchasing sewing machines will support their livelihood till they acquire skills for other opportunities. Residents also suggested to recruit the village residents for gardening and greening initiatives in the development of Amaravati.

Mangalagiri- Tadepalli Municipal Corporation (MTMC) : Babunaiahnagar colony
Location: Babunaiahnagar Sachivalayam Office, MTMC
Date: 03/06/2025
Participants: Ward Admin Secretary, ICLEI SA team, 20 residents
Discussion points:

- **Impact of flooding on low-lying areas:** The Bapunaiahnagar colony area has a low-lying geography and is poorly connected to drainage systems, resulting in frequent flooding. The absence of a dedicated stormwater outlet has exacerbated the flooding.
- **Health:** Babunaiahnagar is served by two primary health centers. For advanced medical care, residents travel to nearby facilities such as the Government General Hospital (GGH) and NRI public hospitals.