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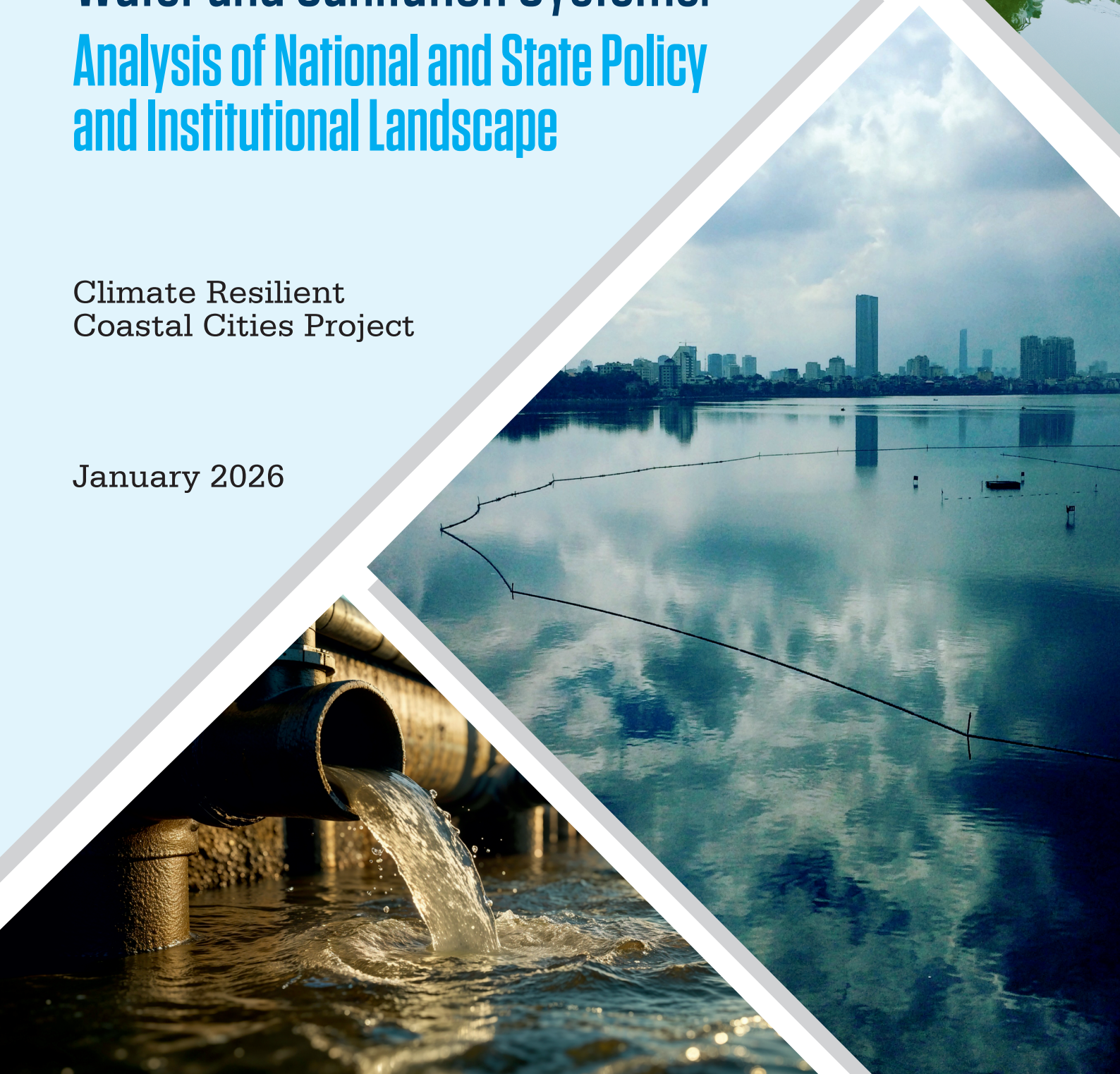
Towards Climate-Responsive Water and Sanitation Systems:

Analysis of National and State Policy and Institutional Landscape

Climate Resilient
Coastal Cities Project

January 2026



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The collective research work undertaken through this initiative represents an important step towards advancing climate-responsive water and sanitation planning along India's west coast. The findings and recommendations presented in this report are intended to support urban local bodies and policymakers in strengthening the resilience, adaptability, and sustainability of WaSH systems.

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Preface

Evidence indicates a marked increase in the frequency and intensity of cyclonic events along India's west coast, accompanied by rising sea levels, saline intrusion, and extreme rainfall. These climate-related pressures are being compounded by rapid urbanisation, population growth, and expanding economic activity in coastal cities, placing significant stress on freshwater aquifers and essential urban services such as water and sanitation. Recognising this, HSBC India, India Sanitation Coalition (ISC) at FICCI, the Ashank Desai Centre for Policy Studies (ADCPS) at Indian Institute of Technology - Bombay (IIT Bombay), and the Consortium for DEWATS Dissemination India (CDD India) formed a strategic partnership in July 2023 to address the emerging climate risks confronting coastal urban regions. This collaboration was formalised as the *Climate Resilient Coastal Cities (CRCC)* initiative in September 2023. Phase I of the initiative was implemented between September 2023 and December 2025 across four coastal states along India's western seaboard: Goa, Gujarat, Karnataka, and Maharashtra.

Within this context, the CRCC initiative focuses on strengthening the climate resilience of Water, Sanitation, and Hygiene (WaSH) infrastructure and service delivery systems-critical foundations for public health, environmental sustainability, and the long-term viability of coastal urban settlements. The initiative adopts an integrated approach that combines applied research with targeted implementation to support informed planning and decision-making. The project was guided by four interrelated objectives: (i) assessing the climate resilience of WaSH infrastructure and services in selected coastal towns; (ii) analysing the water-energy-climate policy landscape relevant to coastal urban systems; (iii) designing and implementing targeted interventions to enhance resilience in priority locations; and (iv) developing practical, scalable recommendations to strengthen system-level climate resilience.

Under the CRCC initiative, ADCPS-IIT Bombay, as the core research partner, conducted town-level situation assessment studies along with national and state policy and institutional landscape analyses. The town studies assessed the status, challenges, risks, financial sustainability, and greenhouse gas (GHG) footprint of water and sanitation systems, and proposed recommendations to enhance the resilience of such systems. These studies were carried out in twelve towns-three each in Goa (Canacona, Mapusa, and Mormugao), Gujarat (Mandvi, Devbhumi Dwarka, and Valsad), Karnataka (Karwar, Kundapura, and Mangalore), and Maharashtra (Alibag, Ratnagiri, and Vengurla). The policy and institutional landscape analysis covered the national level and the four states, with the aim of examining how urban water, sanitation, and climate change policies interact to shape broader governance and planning frameworks for resilient urban water and sanitation systems. CDD India as a research and implementation partner focused on three coastal towns in Maharashtra (Dahanu, Guhagar, and Malvan), translating assessment findings into actionable Climate Resilient Sanitation Plans (CReSAPs) to support local implementation and decision-making.

Implementation activities under the CRCC initiative included policy consultations, capacity-building workshops, and field exposure visits for government officials and key local stakeholders, including Self-Help Groups (SHGs). These activities were jointly facilitated by CDD India, ADCPS-IIT Bombay and ISC. The initiative also enabled structured engagement with sector experts and practitioners. Complementing these efforts, CDD India led community-level mobilisation activities in the study towns, including awareness campaigns and tree plantation drives, to foster local ownership and strengthen community participation in climate resilience efforts.

India Sanitation Coalition (ISC) at FICCI has served as the anchor organisation for the initiative, leading advocacy and outreach efforts and supporting the dissemination of evidence, best practices, and policy-relevant insights. ISC has also contributed to the editorial review of the reports to enhance clarity, coherence, and accessibility. In addition, ISC has articulated the potential role of corporate actors in supporting similar climate-responsive WaSH initiatives in the future. HSBC India has provided financial support for the research, implementation, and outreach components of the initiative. In parallel, the initiative seeks to catalyse larger-scale investments in climate-resilient WaSH infrastructure by aligning with and leveraging resources already committed under the Swachh Bharat Mission (SBM) 2.0.

The findings and learnings from the initiative are being disseminated through a comprehensive suite of outputs comprising one National Report, four State Reports (Goa, Gujarat, Karnataka, and Maharashtra), and fifteen Town Reports-three each from Goa, Gujarat, and Karnataka, and six from Maharashtra. This report constitutes one of the twenty reports produced under the CRCC initiative.

It is hoped that the insights from the study will inform future policy and planning actions and investments aimed at strengthening climate-resilient water and sanitation infrastructure and services in India's coastal towns.

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Executive Summary

India, with just 2.3% of the world's land area, supports nearly one-sixth of the global population, placing immense pressure on its natural resources and infrastructure. Despite strides in poverty reduction, access to basic services like water and sanitation remains uneven, particularly in coastal urban areas that are also highly vulnerable to climate change. These regions face multiple risks—rising temperatures, erratic monsoons, intensifying cyclones, sea-level rise, and saline intrusion—all of which threaten public health and the sustainability of water and sanitation infrastructure. Small and medium coastal towns, in particular, are grappling with aging systems, limited resources, and weak institutional capacities, leaving them ill-equipped to respond to extreme weather events or long-term climate impacts. Meanwhile, urban areas contribute significantly to India's greenhouse gas emissions, with water supply and wastewater treatment emerging as key energy-intensive sectors.

As part of the HSBC India funded project *Climate Resilient Coastal Cities*, a landscape study on climate resilient water and sanitation infrastructure of four west coast states was conducted to understand and develop solutions towards building climate resilience in urban WaSH systems through both adaptation and mitigation strategies. The project, which covers 15 coastal towns across Goa, Gujarat, Karnataka, and Maharashtra aims to generate actionable, context-specific policy recommendations. Central to this effort is a detailed assessment of the policy and institutional landscape at the intersection of urban water, sanitation, and climate change, with a focus on identifying key gaps and overlaps. This report presents findings from national and four state-level reviews, contextualized through ground-level assessments conducted across 15 towns.

India's urban climate policy has historically prioritized *adaptation* over *mitigation*, primarily due to its developmental context and immediate vulnerabilities to climate stresses. This trend is reflected in national and state water, sanitation, and climate policies, which continue to focus on improving basic service access, especially in underserved regions. However, this adaptation-centric approach now requires a more balanced integration of *mitigation strategies*, particularly in the water and sanitation (WaSH) sector.

The sector's energy footprint offers a significant opportunity for climate mitigation, yet initiatives like the Municipal Energy Efficiency Programme remain limited in scope, focusing primarily on street lighting while neglecting the high energy demands of water and sewage systems. There is a critical need to mainstream mitigation into urban WaSH planning by integrating energy efficiency targets into municipal projects, mandating audits, and launching a national program to monitor GHG emissions from urban water systems.

Despite strong national policies promoting wastewater recycling, rainwater harvesting (RWH), and groundwater recharge, implementation across small and medium towns remains weak. The study across 12 towns shows that uptake of decentralized, climate-resilient approaches is low, and most urban areas still discharge untreated sewage due to limited sewerage networks and treatment

facilities. Initiatives like Atal Mission for Rejuvenation and Urban Transformation have expanded infrastructure, but the bias towards centralized systems continues to overshadow more sustainable, context-responsive models. RWH, in particular, remains underutilized despite national campaigns and subsidies. Strengthening the climate-health nexus through energy-efficient WaSH in health infrastructure and developing town-level data systems to monitor reuse, RWH, and energy use is essential for adaptive policymaking and to realize co-benefits.

On the disaster risk front, national frameworks like the National Policy on Disaster Management (2009) and state disaster management plans emphasize climate-proofing critical infrastructure, but state-level policies and ULB-level implementation remain inadequate. Retrofitting infrastructure post-disaster results in high public costs, which could be reduced through upfront investments in resilient designs. The study recommends mainstreaming disaster risk reduction into all water and sanitation planning, particularly at the ULB level, with regular updates to building codes, enhanced capacity-building, and adoption of ecosystem-based solutions like hazard zoning and watershed management. Effective coordination between national, state, and local bodies—supported by international collaborations can strengthen resilience efforts and reduce long-term vulnerabilities.

India's coastal regions face unique climate challenges—ranging from sea-level rise and salinity intrusion to erosion, pollution, and habitat degradation. However, there is no dedicated national mission addressing coastal climate change under the NAPCC. Although the National Water Mission and State Action Plans (SAPCCs) in states like Goa, Gujarat, Karnataka, Maharashtra touch on coastal adaptation, policy implementation is fragmented. Overlapping mandates and weak coordination between central and state agencies hinder integrated coastal governance.

The enforcement of Coastal Regulation Zone (CRZ) rules remains poor, and policy dilution has weakened ecological protections. Urban Local Bodies (ULBs) have limited involvement in climate planning and low awareness of climate initiatives. Planning remains siloed across sectors like tourism, housing, and fisheries, with little cross-sectoral integration or use of nature-based solutions. To strengthen resilience in coastal zones, the study recommends establishing a *dedicated national mission* for coastal climate adaptation and mitigation, enforcing CRZ norms, enhancing ULB capacity, and promoting risk-informed land use, ecological planning, and resilient infrastructure.

A key insight from the study is the significant institutional fragmentation in India's climate, water, and sanitation governance. While ministries and state-level organizations have defined mandates and many states have established climate cells to support integration, overlapping or disconnected responsibilities, the absence of dedicated budgets for climate action, the lack of climate cells at the town level, and the marginalization of ULBs in disaster planning have collectively weakened the alignment of adaptation and mitigation goals within water and sanitation policies and programmes. These institutional gaps are mirrored in the weak implementation observed across state and town-level studies.

This fragmented approach has also generated contradictory outcomes. For example, wastewater reuse projects are often constrained by the Pollution Control Board's stringent Zero Liquid Discharge (ZLD) norms— requiring 10 mg/L BOD and now tightened to 3 mg/L in Karnataka—which have pushed the adoption of costly and energy-intensive decentralized wastewater treatment technologies. Many of these systems are ultimately abandoned due to their high financial burden, especially in urban contexts where achieving true ZLD is highly challenging. Such contradictions not only undermine environmental objectives but also weaken mitigation outcomes.

At the same time, weak enforcement of groundwater regulations continues to hinder the uptake of recycling and reuse initiatives. The absence of a systems approach—one that links climate adaptation and mitigation within the water and sanitation sector—has led to missed opportunities, including access to carbon credits and the wider adoption of scalable nature-based solutions.

In conclusion, India's climate policy and institutional landscape for urban water and sanitation is extensive, encompassing numerous policies, programmes, schemes, and regulations addressing adaptation and mitigation. Yet, significant gaps remain in ensuring the resilience of critical infrastructure and services, particularly in coastal areas. At the state level, policies broadly align with the national climate framework while also reflecting state-specific priorities, such as Goa's tourism policy. Addressing these challenges requires moving beyond fragmented, adaptation-focused measures toward a cohesive, systems-based approach that integrates adaptation, mitigation, resilience, and sustainability. Strengthening mitigation efforts will also require empirical studies, including town-level GHG inventories. This transformation demands enhanced inter-agency coordination, dedicated climate cells, assured climate budgets at state and local levels, and greater support for decentralized innovation. Central to this effort are cities and urban centres, recognized as pivotal sites for climate action, making it essential to empower urban local bodies and citizens through strengthened institutional and financial capacities, meaningful participation in climate and disaster governance, and support for locally driven solutions. Only through such an integrated approach can India secure long-term climate resilience for its urban infrastructure and coastal ecosystems.

Section A: Study Overview

This section introduces the study, highlighting the rationale for focusing on India's west coast and, specifically, the urban water and sanitation sector in the context of climate change. It also outlines the data collection methods employed for the research.

1. Introduction

India accounts for just 2.3% of the world's land area, yet it is the 7th largest country globally and supports nearly one-sixth of the world's population. "To meet the needs of one-sixth of the humanity is the foremost priority of the Government of India. This poses its own challenges before the Nation to be able to maintain a sustainable development pathway and to harness its resources efficiently" (Ministry of Environment, Forest and Climate Change, 2023, p. xxxii). Further, according to the Government of India's SDG 2023 report, the country has made considerable progress in reducing multidimensional poverty (NITI Aayog, 2024). However, a significant portion of the population still lives below the poverty line and lacks access to basic services such as clean drinking water and sanitation.

This combination of high population density and lack of basic services heightens India's vulnerability to climate change impacts, making it imperative to address both developmental gaps and climate resilience in an integrated manner.

In climate change context, the country is seventh-most exposed and vulnerable country to climate extremes[i]. For India, the average air surface temperature increased by approximately 0.7 degrees Celsius between 1901 and 2018 (Krishnan, 2020). The sea level in the northern Indian Ocean accelerated to 3.3 mm per year from 1993 to 2017. Precipitation during June to September decreased by about 6% from 1951 to 2015, particularly over the Indo-Gangetic plains and the Western Ghats (ibid). Additionally, there has been a notable increase in the frequency of natural disasters in India in recent decades especially post 2005 (Mohanty & Wadhawan, 2021). With high risk of concurrent flood incidents, country is among the most vulnerable countries to climate change as per IPCC sixth assessment report. This is especially true for the large coastal population (171 million population in coastal districts). India is highly susceptible to cyclones and their related dangers such as storm tide, intense winds, and substantial rainfall. More than 300 extreme events have hit the country in recent decades, causing losses of more than INR 5,600 billion (Mohanty, et al., 2020). A recent evaluation indicates that more than 75% of districts in India, including 95% of coastal districts, are hotspots for extreme events (Mohanty, et al., 2020).

West Coast: Increasing Climate Risks

While the east coast has been more exposed to tropical cyclones, recent years show a greater number of tropical cyclones (TC) forming in the Arabian Sea (west coast) (Deshpande, et al., 2021). In recent years, the Arabian Sea has emerged as a key region for the formation of tropical cyclones, which have led to severe impacts across western coast of India (Thomas & Lekshmy, 2022). Between 2001 and 2019, the Arabian Sea region has witnessed a 52% surge in the occurrence of cyclonic storms, whereas the Bay of Bengal (east coast) has experienced

an 8% decline (Deshpande, et al., 2021). Coastal districts of Gujarat specifically have become increasingly vulnerable to tropical cyclones (Boragapu, Guhathakurta, & Sreejith, 2023). This increase in the frequency and intensity of cyclones in the Arabian Sea has been attributed to rapid rise in sea surface temperatures (Deshpande, et al., 2021). Further, west coast states are more exposed to sea level rise; every one-metre rise in sea level can inundate almost 5,763 km^2 of land (Woodruff, BenDor, & Strong, 2018). The situation is further aggravated by significant loss of mangrove ecosystems, which are projected to continue declining beyond 2100, as per UNFCCC-IPCC 2023 report.

Climate Risks and Water and Sanitation Infrastructure and Services: Amplifying Inequalities

Access to basic services such as housing, improved sanitation, and safe drinking water forms the first line of defense against the potential impacts of climate change. These services are essential for enhancing people's resilience and adaptive capacity. Especially following climate hazards such as heavy rainfall, ensuring access to appropriate and reliable WaSH services plays a vital role in protecting populations from water-related diseases and flooding (Carlton, et al., 2014).

Further exacerbating the risks posed by climate change is the inadequate infrastructure and services in critical areas such as housing, sanitation, water, and public health, particularly for socio-economically disadvantaged groups (Rumbach, 2018); (Yenneti, Tripathi, Wei, Chen, & Joshi, 2016). This is particularly critical in small towns, which are already finding it challenging to provide universal access to water and sanitation services (Central Pollution Control Board , 2021), and are now exposed to climate change-related risks. The climate change induced water stress and insecurity can increase the incidences of waterborne infectious diseases, thereby, hindering or reversing advancements made in related Sustainable Development Goals (SDG) targets and amplifying inequalities (Braks & Husman, 2013). The IPPC views universal access to WaSH i.e., achievement of SDG 6.1, 6.2, as a critical adaptation strategy, with high confidence (Caretta, 2022) and low-regret adaptation measure (Cutter, et al., 2012)[ii]. Further, SDG 1 (No Poverty) is found to be statistically linked to SDG 6 (Clean Water and Sanitation), as reducing poverty enhances adaptive capacity in alignment with the Paris Agreement's adaptation goals (Pradhan, 2019). Likewise, achieving SDG 3 (Good Health and Well-being) depends heavily on reliable access to water and sanitation infrastructure (Delany-Crowe, Marinova, Fisher, McGreevy, & Baum, 2019). The Intergovernmental Panel on Climate Change (IPCC) recognizes universal access to water, sanitation, and hygiene (WaSH)—as targeted in SDGs 6.1 and 6.2—as a critical, low-regret adaptation strategy, supported by high confidence (Caretta, 2022) (Cutter, et al., 2012). Moreover, ensuring universal access to WaSH not only contributes directly to SDG 11 (sustainable cities and communities) but also promotes social equity and environmental sustainability.

Studies have predicted substantial economic losses across various sectors in India due climate change (Chaturvedi, 2015) ; (Kumar & Maiti, 2024). For Mumbai, the economic damages (building foundation damages) for the period till 2050 due to sea- level rise could amount to Rs 1,501,725 crores (Kumar, Jawale, & Tandon, 2008). Further, a 2.5% decrease in growth rate is expected with one-degree Celsius temperature increase for India (Jain, O'Sullivan, & Taraz, 2020). Such economic losses may ensue from the diminished functionality of the infrastructure and, consequently, the provision of related services (Kreibich, et al., 2014) such as critical services like water and sanitation. For example, in Alibag (a small coastal town in Raigad district, Maharashtra) power lines were damaged, which led to the disruption of water supply. This lasted for 8 hours since the town did not have necessary alternative infrastructure to restore the power supply. 2018 Kerala floods led to a loss of water and sanitation infrastructure worth 160 million USD (Parida, 2015). The compromised sanitation infrastructure often contaminates water sources which leads to the outbreak of waterborne diseases and poses severe health risks to communities.

In this context, IPCC underscores the importance of making WaSH infrastructure climate-resilient (Ben A. Smith, 2015); (Ashfaq Ahmad Shah, 2020). Resilient infrastructure systems should not only be able to absorb and resist the impacts of disasters but also ensure uninterrupted service delivery during crises. Moreover, they must recover quickly in a manner that reduces future vulnerabilities. Integrating resilience into the design, planning, and operation of water and sanitation systems is critical for safeguarding public health and ensuring sustainable service delivery in a changing climate. Further, beyond implementing new infrastructure, the expansion and replacement of existing WaSH systems offer crucial opportunities to integrate climate-resilient approaches and reduce greenhouse gas (GHG) emissions (Boholm & Prutzer, 2017), (Dickin, Bayoumi, Giné, Andersson, & Jiménez, 2020).

Cities as Site of Action

Globally cities are increasingly acknowledged as site for climate action, both in terms of adaptation and mitigation, as they house over half of the global population and generate more than 75% of CO2 emissions (Hong, Hui, & Lin, 2022)**.** Same holds true for Indian cities. As centres of high population density and high economic growth, Indian cities are a significant contributor to climate change and are also particularly vulnerable to its consequences.

While Indian cities make 60% per cent contribution to the gross domestic product (GDP) and are considered "engines of growth" (United Nations, 2018) as cited in (NITI Aayog ; Asian Development Bank, 2022), the cities are under immense pressure due to increasing population, industrialization and land-use change which have compounding impact on climate change risks.

The Indian cities are also sites for mitigation efforts as economic and population growth centres leading to heightened energy consumption and GHG emissions. Although India contributed 7.5 per cent of the world's total emissions (53.85 billion ton CO_2eq) in 2022, **the per capita emissions were 2.9 ton** CO_2eq (World Bank, 2024). The contribution from urban centres is **nearly 44 per cent of India's emissions, emanating from transport, industry, buildings, and waste** (NIUA, 2024)**.** Sectoral estimates for 2018 reveal that the **waste sector contributed ~3.88% of emissions (114.50** Mt CO_2eq) towards total GHG emissions of 2953 Mt CO_2eq (GHG platform India, 2018). Within waste sector, domestic wastewater discharge and treatment contributed 63.76 Mt CO_2eq forming 55.6% of the emissions from the waste sector. The contribution from urban sector is 38.7% (ibid). Further, energy is a key-input for supplying water to the cities and for managing the wastewater. The water services entail significant GHG emissions associated with energy use in addition to various direct and indirect emissions from water and sanitation. Climate change impacts further intensify the energy and carbon footprint associated with urban water management.

Climate Change as a Complex Problem – Multitude of Institutions

Climate Change governance that spans fragmented institutional landscapes with overlapping mandates and competing interests, makes coordinated responses particularly challenging. The moral and ethical dimensions of climate change (Conradie, 2020), along with its interlinkages across diverse policy domains (Weaver, Moyle, McLennan, & Casali, 2023), further reinforce its wickedness.

This is particularly important in the water and sanitation domain, where climate adaptation and mitigation efforts intersect with urban infrastructure planning, energy consumption, public health imperatives, and environmental standards. **This complexity necessitates coherent, cross-sectoral engagement and policy alignment among institutions** (Kivimaa, 2022).Interventions in these domains require the active participation of multiple actors and institutional mechanisms to avoid fragmented efforts and unintended consequences. The 2015 Paris Agreement too underscores this need for integration by urging countries to "integrate adaptation into relevant socioeconomic and environmental policies and actions, where appropriate" (United Nations, 2015, p. 9). Likewise, the SDGs include Indicator 17.14, which calls for enhancing policy coherence for sustainable development (UNEP, n.d.).

Climate Resilient Coastal Cities Project

A landscape study on climate resilient water and sanitation infrastructure across four west coast states was initiated under the *Climate Resilient Coastal Cities* project – a collaborative initiative of HSBC India, the India Sanitation Coalition (ISC) at FICCI, the Ashank Desai Centre for Policy Studies at IIT-Bombay (henceforth will be referred to as IIT-Bombay, unless specified otherwise) and CDD India. The project focuses on both adaptation and mitigation

strategies to enhance the climate resilience of urban water and sanitation infrastructure and services. It aims to generate actionable policy recommendations that are firmly grounded in local contexts and practical realities. Additionally, the project examines the policy and institutional landscape at the intersection of urban water, sanitation, and climate change, identifying gaps, overlaps, and opportunities for greater coherence and integration. **The project focuses on 15 coastal towns in Maharashtra, Gujarat, Goa, and Karnataka.**

Among the selected states, Karnataka and Maharashtra ranks among India's top four most climate-vulnerable regions (Mohanty & Wadhawan, 2021). Gujarat with a 1,600 km-long coastline[iii]—the longest in India—and nearly 9.9 million people living across 40 coastal talukas, faces heightened exposure to climate-related hazards such as sea-level rise, cyclones, storm surges, strong winds, heavy rainfall, and salinity ingress. Goa too is highly vulnerable, with projections indicating that a 1-meter rise in sea level could affect nearly 7% of its population, potentially submerging key coastal areas. Across the four states, a total of 15 towns were selected for the study (see Annexure I for the list and selection criteria). IIT-Bombay followed a two-step selection process. First, a set of criteria was developed through a comprehensive review of relevant literature. This was used to curate a preliminary list of potential towns. In the second step, consultations were held with the respective State Swachh Bharat Mission (SBM-Urban) Directors to finalise the selection of the 12 towns. CDD-India selected an additional 3 towns from Maharashtra.

The current report presents the findings of a review study aimed at understanding the current national policy and institutional landscape related to urban water, sanitation, and climate change. It explores how these policies interact, where overlaps or disconnects occur, and the extent to which they are aligned. The analysis focuses on national-level ministries and institutions, each operating within distinct mandates—an approach referred to as *horizontal coherence*. Additionally, examples from policy implementation at the state and town levels are used to highlight challenges in *vertical coherence*—the policy alignment between different tiers of governance.

The following sections of the report are structured as follows: Section A outlines a brief introduction to the study and the methodology adopted to achieve the stated objectives**. Section B** provides a brief discussion on climate change scenario for India and examines the status of urban water and sanitation services in India—particularly in the context of rapid urbanization and rising service demand. **Section C** presents a detailed assessment of the national institutional landscape, followed by an in-depth review of policies and programmes in three domains: adaptation, mitigation, and infrastructure resilience, as well as policies specifically targeting coastal areas. **Section D** provides concise overview of the policy and

institutional landscape across four states (refer state reports for details). The final section, **Section E**, synthesizes the findings and offers national-level recommendations.

2. Methodology

The study drew on research and analysis from the research and implementation partners – Ashank Desai Centre for Policy Studies (IIT-Bombay) and CDD India. IIT-B conducted a comprehensive national and state-level policy and governance analysis, as well as town assessments, of four states (Goa, Gujarat, Karnataka, and Maharashtra) and 12 towns (Canacona, Mormugao, Mapusa, Dwarka, Mandvi, Valsan, Mangaluru MC, Kundapura TMC, Karwar CMC, Alibag, Ratnagiri, and Vengurla). Meanwhile, CDD India employed a participatory approach to assess the vulnerabilities and adaptation strategies of three towns in Maharashtra: Dahanu, Malvan, and Guhagar.

IIT-Bombay

Primarily, IIT-Bombay relied on secondary data sources and semi-structured interviews with experts from think tanks and Ministry of Housing and Urban Affairs (MoHUA). They also carried out town-level assessments that offered critical insights into ground realities. Overall data collection methods used are outlined in Table 1.

- **Desk Review:** A comprehensive desk-based review was undertaken using national and state-level portals to compile an inventory of key policies and programmes related to urban water, sanitation, and climate change. The review examined how climate policies integrate water and sanitation concerns, and vice versa. It also facilitated the mapping of relevant stakeholders and their institutional roles in service delivery. In addition, the review provided an overview of the status of urban water and sanitation infrastructure and services in the state, alongside data on climate exposure, vulnerability, and projected impacts at state and district levels—particularly valuable given the absence of such data at the town scale.

- **Semi-structured Interviews:** To complement the desk review, semi-structured interviews were carried out with key stakeholders and subject-matter experts to capture contextual insights on policy and institutional frameworks governing water and sanitation and climate change in the state. The study also draws on town-level

assessments conducted in 12 towns, which included field investigations and interviews with Urban Local Body (ULB) officials and district disaster management authorities. These town-level assessments provided a grounded understanding of how state and national policies are being implemented at the local level (details on methodology and findings are presented in the respective town assessment reports).

Table 1: IIT-Bombay Data Collection

Sl. No.	Objective	Data Collection Method	Data Sources
1.	To understand climate change projections, impacts and vulnerability	Secondary Data through Literature Review	Government reports: state climate change action plan, vulnerability assessment reports, Energy Department, Niti Ayog
		Stakeholder semi-structured Interviews at town level	State and town water and sanitation utilities, District Disaster Officials of 12 towns
		Interviews with affected population	All 12 towns
		Sample Household Survey	Alibag town (pilot study)
2	To understand status of urban water and sanitation services in study area	Secondary Data through literature review, data collection from ULBs	• CPCB inventory report, State government reports, non-government sources (PAS website) • Collection from water and sanitation utilities of 12 towns
		Interviews with affected population	All 12 towns
		Sample Household Survey	Alibag town (pilot study): 321 HHs - out of total 4985 HHs
3	To understand linkages between climate change and urban water and sanitation policies	Secondary Data/information through Literature Review	Various sectoral reports, policy documents, programme evaluation reports - health, sanitation, water, climate change, environmental pollution, energy, building buy-laws, urban development
		Stakeholder semi-structured Interviews	State and town water and sanitation utilities, District Disaster Officials of 12 towns
			Expert interviews working in water and sanitation , interviews with think tanks- World Resource India, CEEW, MoHUA
		Interviews with affected population	All 12 towns

4	To map current institutional environment	Secondary Data through Literature Review	State Department website on health, sanitation, water, climate change, environmental pollution, energy, building buy-laws, urban development
		Stakeholder semi-structured Interviews	State and town water and sanitation utilities, District Disaster Officials of 12 towns
5	To map current financial sources for climate change and water and sanitation	Secondary data through literature Review, data collection from ULBs	SBM (urban), MoHUA website, State Urban Development Department website

CDD India

A structured mixed-methods approach involving both primary research and secondary desk research was used to gain a deep understanding of the three towns of Dahanu, Malvan, and Guhagar. Primary household surveys captured detailed information on WaSH infrastructure, water access, sanitation practices, waste management, and climate change perceptions among residents. Additional surveys examined agriculture and plantation practices, tourist accommodation and perceptions, and water quality including salinity levels across multiple sources. Stratified random sampling was employed to ensure representative results, with standardized digital tools (Survey2Connect and Survey123) used for data collection.

To complement these surveys, Key Informant Interviews and Focus Group Discussions with fisherfolk provided insights on livelihoods, WaSH access, and vulnerability to natural hazards. Secondary research analysed 30 years of rainfall and temperature data from IMD to identify long-term climatic shifts and localised impacts. Together, these methods generated a comprehensive evidence base to understand service gaps, climate risks, and emerging challenges in the three towns.

Study Limitations

The findings presented in this report should be viewed in consideration of a few study limitations: **Representation of Urban Areas** – fifteen towns (three each of Goa, Gujarat, and Karnataka; and six towns for Maharashtra) were examined in greater detail to illustrate local realities. While these case examples provide valuable insights, they may not fully represent the diversity of conditions across all urban areas in the state unless specified otherwise. **Differences in Research Focus –** The research implementation partners had differing research objectives. Consolidation of information has therefore been undertaken to the best extent possible, though some variation in comparability may remain. **Scope of the Report –** The study focuses on selected aspects of the water and sanitation sector that are most relevant for climate resilience and service delivery. It is not intended as an exhaustive review of the

entire WaSH space but highlights priority areas where policy attention can strengthen outcomes. **Data Availability** – The study relies primarily on secondary research, and the extent of analysis is therefore dependent on the quality and availability of published data and literature. Wherever possible, secondary information has been supplemented with primary inputs.

Section B: India Overview - Climate Change Scenario and Status of Water and Sanitation Services

This section provides a brief overview of the current and projected climate change scenario in the country, followed by an assessment of the status of urban water and sanitation services and infrastructure including greenhouse gas emissions from the sector, while highlighting the key challenges.

1. Climate Change Scenario in India

India's Third National Communication to the UNFCCC (Ministry of Environment, Forest and Climate Change, 2023) outlines the current climate change scenario in the country. These are highlighted below:

Rising Temperatures in India

India's annual mean temperature has steadily increased over the period 1901–2022. This rising trend is more pronounced for maximum temperatures, which have increased at a rate of 1.0°C per 100 years, compared to minimum temperatures (Ministry of Environment, Forest and Climate Change, 2023). Such climate impacts extend to economic performance as well. According to a study by Jain, O'Sullivan, and Taraz (2020), a one-degree Celsius rise in temperature could reduce India's growth rate by 2.5%. (Jain, O'Sullivan, & Taraz, 2020).

Record Warm Decades and Years

The last decade (2012–2021/2013–2022) was the warmest on record since 1901, with temperature anomalies averaging 0.37°C and peaking at 41°C above the long-term average. Of the last 15 years (2008–2022), 11 have ranked among the warmest years in India's recorded history (Ministry of Environment, Forest and Climate Change, 2023).

Regional Variations in Monsoon Rainfall

The India Meteorological Department (IMD), notes a significant decrease in Southwest Monsoon rainfall between 1989 and 2018 in several states, including Uttar Pradesh, Bihar, West Bengal, Meghalaya, and Nagaland. This has led to a decline in annual rainfall in these regions. Moreover, several districts across the country have exhibited significant shifts in both monsoon and annual rainfall patterns during this period (Ministry of Environment, Forest and Climate Change, 2023).

While some regions have witnessed declining rainfall, others have experienced an increase in the frequency of heavy rainfall days. This includes parts of Gujarat (Kutch and Saurashtra), southeastern Rajasthan, northern Tamil Nadu, northern Andhra Pradesh, southwestern Odisha, as well as certain areas in West Bengal, Manipur, Mizoram, Konkan and Goa, and Uttarakhand (Ministry of Environment, Forest and Climate Change, 2023).

Increasing Frequency of Extreme Precipitation and Flooding Events

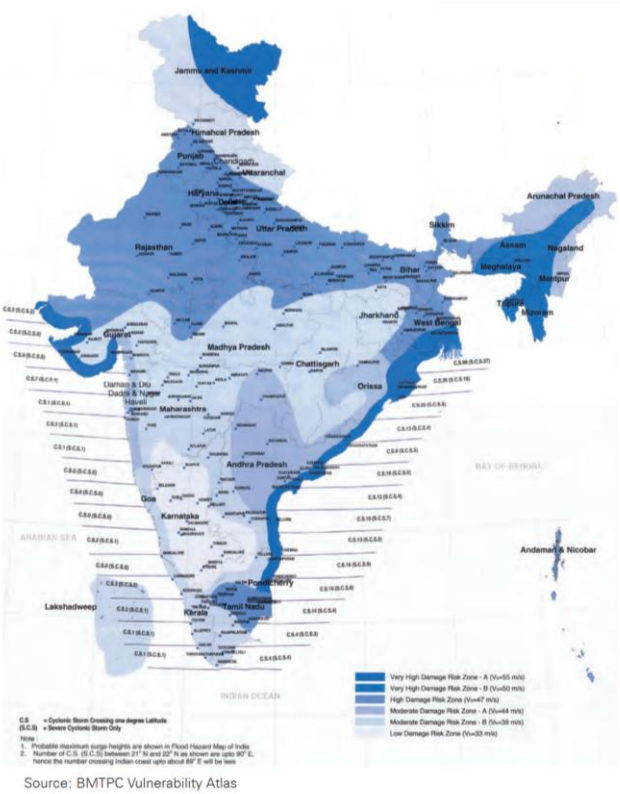
Several parts of India experienced extreme precipitation and severe flooding in 2020 and 2021. According to a study conducted by the National Remote Sensing Centre (NRSC)/ISRO, the number of states affected by major floods has almost doubled—from 8 in 2017 to 15 in

2021 (Ministry of Environment, Forest and Climate Change, 2023). These events were driven not only by intense rainfall but also by glacial bursts, flash floods, and avalanches. This underscores a growing trend in the geographic spread and intensity of flood impacts across the country. The resulting impact included significant loss of life and widespread damage to agricultural land, public infrastructure, and private property across many districts. For instance, 2018 Kerala floods led to a loss of water and sanitation infrastructure worth 160 million USD (Parida, 2015).

Trends in Weather-Related Shocks and Disasters

The Arabian Sea has emerged as a key region for the formation of tropical cyclones, which have led to severe impacts across western coast of India (Thomas & Lekshmy, 2022). The Arabian Sea region has witnessed a 52% surge in the occurrence of cyclonic storms in the recent period (2001–2019) (Deshpande, et al., 2021). **As shown in Figure 1 below, all western coastal states—except Gujarat—fall under the moderate damage risk zone for winds and cyclones.** In addition to floods and heavy rainfall, various parts of India experienced other extreme weather events between 2019 and 2021. These included snowfall, lightning strikes, thunderstorms, hailstorms, and dust storms—each causing localized disruptions and damages (Ministry of Environment, Forest and Climate Change, 2023).

Figure 1: Winds and Cyclone Zones of India



Source: BMTPC Vulnerability Atlas

Source: BMPTC Vulnerability Atlas in (National Disaster Management Authority, 2019)

2. Status of Urban Water and Sanitation Services in India

Water Stress

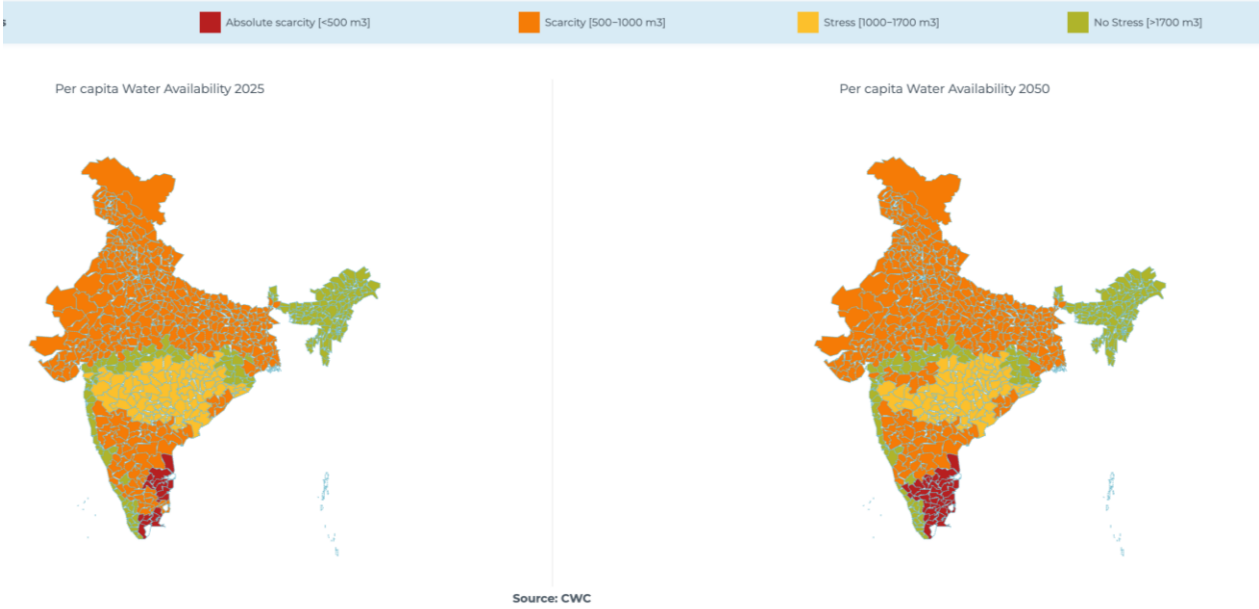
India is ranked as the 24th most water-stressed country in the world in 2023 (World Population Review, 2023). About twelve states and union territories, including Gujarat and Maharashtra—both project states—fall under the category of extremely high baseline water stress in 2023 (WRI, 2023). In terms of ground water extraction, approximately 22% of the 'assessment units' (blocks, talukas, watersheds) in the country fall under the overexploited and critical category for groundwater extraction (Central Ground Water Board, 2019). Groundwater availability is also threatened by the increasing instances of pollution.

Water Supply and Demand

According to the 2011 Census, India's urban population stood at 377.2 million, reflecting an annual exponential growth rate of 2.76% during the decade 2001–2011 (National Institute of Urban Affairs, 2011). As per projections by the National Institute of Urban Affairs (2022), India's urban population was estimated to be 469.9 million in 2021, expected to rise to 558.9 million by 2031 and 600.9 million by 2036. The level of urbanization, which stood at 31.1% in 2011, is projected to increase to 34.5% in 2021 and 37.9% by 2031 (National Institute of Urban Affairs, 2022).

Country has the highest urban population (222 million) facing water scarcity (He, et al., 2021). As per latest NFHS 5 report (2019-21), about 67.5 % of the urban households have piped water supply, tap water, public tap/ stand pipe; whereas close to 16.5 % depend upon the tube well /handpump (National Family Health Survey, 2025). The previous number of NFHS -4 (2105-16) reveal close to 69% of the urban households were under the piped water supply, tap water, public tap/ standpipe (ibid). Further, projected per capita water availability for 2025 and 2050 indicates that most Indian states will fall under water scarcity conditions (Niti Aayog, 2025).

Figure 2: Per Capita Water Availability for 2025 and 2050



Source: CWC in (Niti Aayog, 2025)

With the projected rise in urban population, addressing this challenge will become increasingly difficult—particularly in the context of climate change, which is expected to exacerbate water stress and infrastructure vulnerabilities.

Sanitation Services

Since 1971, India's urban population has tripled, leading to a sharp rise in water demand and sewage generation. However, the development of sewage treatment facilities has not kept pace with this growth. As of 2018, approximately 96.3% of urban households had access to latrine facilities within their homes (National Family Health Survey, 2025).

Sewage generation increased significantly from 7,067 million litres per day (MLD) in 1978–79 to 62,000 MLD in 2014–15 (Central Pollution Control Board , 2021). In contrast, the available treatment capacity rose only from 2,758 MLD to 23,277 MLD (ibid) during the same period, highlighting a substantial and growing gap between wastewater generation and treatment infrastructure. In 2021, sewage generation from urban centres was estimated at 72,368 million litres per day (MLD), while the total treatment capacity stood at only 36,668 MLD – just 50%. Moreover, of this capacity, only 578 sewage treatment plants (STPs) — with a

combined capacity of 12,200 MLD i.e., 33% — were found to be in compliance with the environmental standards (ibid).

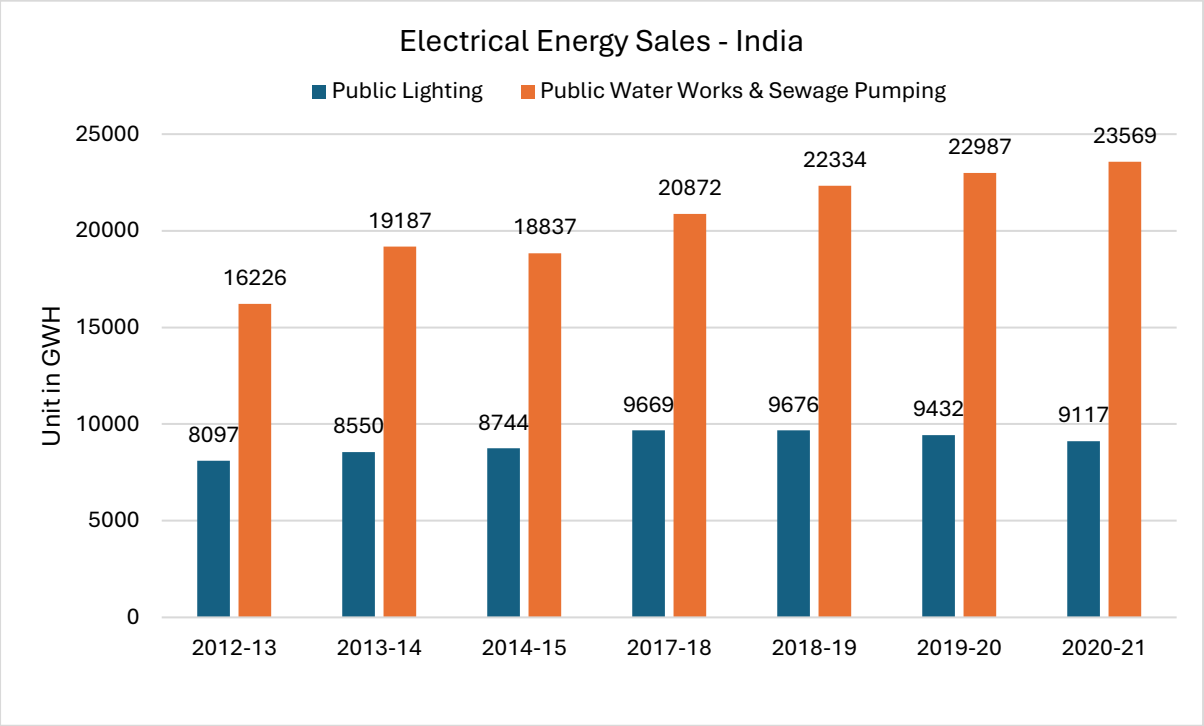
GHG Emissions from Wastewater

In 2019, India's total GHG emissions, amounted to 2,647 $MtCO_2e$. This represents a 4.56% increase compared to 2016 and a 115.42% rise since 1994. **The waste sector contributed a relatively small share to total emissions—accounting for just 2.34% of national GHG emissions** in 2019. In absolute terms, the sector emitted 73,189 $GgCO_2e$, marking a 2.72% decrease compared to 2016 (Ministry of Environment, Forest and Climate Change, 2023).

Emissions from water supply and wastewater management primarily stem from their energy-intensive operations. Additionally, non-compliance with treatment standards, the discharge of untreated wastewater, and the improper management of on-site sanitation systems further contribute to greenhouse gas (GHG) emissions. According to the (GHG platform India, 2018), the country's total emissions grew at a compound annual growth rate (CAGR) of 4.90%, rising from 1,585.51 $MtCO_2e$ in 2005 to 2,952.87 $MtCO_2e$ in 2018. The waste sector accounted for nearly 4% of total emissions, contributing 114.50 $MtCO_2e$ in 2018. Emissions from this sector grew at a CAGR of 2.02%—from 88.23 $MtCO_2e$ in 2005 to 114.50 $MtCO_2e$ in 2018. A notable spike in emissions from the waste sector was observed in 2011, primarily due to an increase in domestic wastewater emissions. Domestic wastewater accounted for the largest share—56%—of India's total waste sector emissions (114.50 $MtCO_2e$) in 2018. Emissions from domestic wastewater across both rural and urban areas grew at a compound annual growth rate (CAGR) of 2.93%, increasing from 43.82 $MtCO_2e$ in 2005 to 63.76 $MtCO_2e$ in 2018. Notably, rural areas contributed approximately 61% of these domestic wastewater emissions in 2018, highlighting the significant impact of inadequate wastewater treatment infrastructure outside urban centres.

The GHG emissions would increase further if energy consumption from public water works and sewage pumping were also included. Currently, the share of electricity sales for public water works and sewage pumping and public lighting is approximately 1.94% and 0.9%, respectively (Figure 3).

Figure 3: Electrical Energy Sales for Public Lighting and Public Water Works & Sewage Pumping – India



Source: (Central Electricity Authority, 2025)

Section C: Policy and Institutional Landscape in Water, Sanitation and Climate Change - National Level

*This section provides a concise overview of the **national-level policy and institutional landscape** at the intersection of urban water, sanitation, and climate change. It also reviews key programmes and schemes, as well as the major sources of funding for urban water and sanitation. The analysis is informed by state and **12 town-level assessment studies (conducted by IIT-Bombay)**, which ground the discussion in local realities. It also highlights key challenges.*

1. Institutional Landscape

At the national level, multiple ministries and institutions have distinct mandates related to groundwater and surface water extraction, water treatment and supply infrastructure, municipal wastewater management, and climate change policy (see table below 2). The table outlines the specific roles of key national-level institutions in climate change, urban water supply, and sanitation governance.

The Ministry of Jal Shakti oversees water extraction and development, a critical function in climate adaptation, particularly in the context of increasing water stress and variability. The recently established Bureau for Water Use Efficiency plays an important advisory role in promoting efficient water use—an essential adaptation and mitigation strategy to reduce resource stress and energy consumption. The Central Ground Water Board (CGWB) is responsible for assessing groundwater quality and quantity, and for advising relevant authorities on groundwater policies, management, and regulation.

The Ministry of Housing and Urban Affairs (MoHUA) is responsible for urban water supply and sanitation infrastructure and services, which form the backbone of urban resilience. The ministry leads key national programmes such as the Swachh Bharat Mission (SBM-Urban) and Atal Mission for Rejuvenation and Urban Transformation (AMRUT), aimed at improving service delivery, infrastructure, and urban governance. MoHUA is also responsible for setting service-level benchmarks to standardize and monitor performance across urban local bodies. Its technical arm, the Centre for Public Health and Environmental Engineering Organisation (CPHEEO), develops design standards and technical guidelines for water and sanitation infrastructure to ensure quality, safety, and sustainability.

The Ministry of Environment, Forests and Climate Change (MoEFCC) plays a dual role: it ensures water quality across sources—an important adaptation function—and leads national climate change policy formulation, guiding both mitigation and adaptation efforts in the sector. The Central Pollution Control Board (CPCB), under MoEFCC, monitors pollution and enforces environmental regulations, contributing to mitigation through improved wastewater treatment and emissions control. Municipal wastewater and faecal sludge management, comes under the purview of MoHUA, are central to reducing greenhouse gas emissions from untreated waste (mitigation), while improving public health outcomes and resilience to climate-sensitive diseases (adaptation). The National Green Tribunal (NGT) reinforces governance in these domains by ensuring compliance with environmental standards.

In the broader climate governance landscape, the Ministry of Environment, Forests and Climate Change (MoEFCC) is supported by other key ministries such as the Ministry of Power (MoP) and the Ministry of New and Renewable Energy (MNRE). Their policies—such as the Energy Conservation Act and various renewable energy initiatives—have a direct impact on reducing emissions from energy-intensive water supply and treatment systems. The Bureau of Energy Efficiency (BEE) further strengthens mitigation efforts by promoting energy-efficient technologies and operational practices in the water and sanitation sector.

The National Disaster Management Authority (NDMA) plays a critical role in climate resilience adaptation by addressing urban vulnerabilities to climate-induced disasters such as floods, cyclones, and droughts through preparedness, risk reduction, and resilience-building frameworks. The National Disaster Management Authority (NDMA) is responsible for setting national guidelines for disaster risk management, within which state governments are required to develop their respective state- and district-level disaster management plans. Within this national-level climate change and urban water and sanitation governance framework, state governments can develop their own context-specific policies and programmes. Implementation of these initiatives takes place at the district and city levels.

Table 2: Key Government Agencies in Urban Water and Sanitation and Climate Change

S. No.	Institution/Department	Main Role
1	Ministry of Housing and Urban Affairs (MoHUA)	Formulates policies, rules, laws for urban development in India. Set-up service level benchmarks (SLBs)
2	Central Public Health Engineering and Environmental Organisation	Technical wing of MoHUA serves as advisory body for WaSH Responsible for developing water and sewerage engineering manuals
3	Ministry of Jal Shakti	Responsible for development water resources, and providing quality drinking water and sanitation facilities, recently started Bureau of Water Efficiency (BWE)
4	Central Ground Water Board	works in sustainable groundwater management
5	Ministry of Environment Forest and Climate Change	Plans, promotes, coordinates, and oversees the implementation of environmental and forestry conservation programmes.
6	Central Pollution Control Board	Statutory board established to control, monitor, regulate water and air pollution in India
7	Ministry of Consumer Affairs and Food and Public Distribution	Formulates plans, policies and programs for consumer protection, welfare, and food security.
8	Bureau of Indian Standards, Ministry of Consumer Affairs, Food & Public Distribution	Formulates standards, markings, and certifications for goods to ensure quality and safety including drinking water, sanitation services standards
9	Ministry of Finance	Entrusted with formulation of budget, offering policy advice, and review of government programs. Accountable for finance, governance and financial management through funds, grants, and procurements.
10	Central Finance Commission	Recommends the distribution of tax revenues between the Union and the States and amongst the States themselves.
11	Ministry of New and Renewable Energy	Policies and schemes on renewable Energy from urban Waste, solar power

12	Ministry of Power	Bureau of Energy Efficiency (BEE), Energy Conservation Act, energy efficiency standards implementation through BEE and state designated energy agencies
13	National Disaster Management Authority	sets national guidelines for disaster risk management, which serve as the framework for state and district-level disaster management plans

2. Policy Landscape

A review of national policies related to urban water, sanitation, and climate change indicates that adaptation remains the dominant focus in India's climate discourse and policy landscape. This is also reflected in India's recent Third Communication to the UNFCCC, which emphasizes the need to address the demands of the vast population while simultaneously ensuring sustainable development (Ministry of Environment, Forest and Climate Change, 2023).

"India recognizes the fact that adaptation is imperative for its development process and has been undertaking several efforts to increasingly mainstream adaptation efforts while furthering developmental requirements" (Ministry of Environment, Forest and Climate Change, 2023, p. xxxiv)

This emphasis reflects the country's broader developmental priorities, including efforts to address systemic challenges and safeguard vulnerable populations and sectors. The prominence of adaptation was consistently reinforced through interviews with officials from the Ministry of Housing and Urban Affairs (MoHUA), urban think tanks, and organizations working closely with state governments on climate action plans. It was also echoed during stakeholder consultations with city officials in Maharashtra, Goa, and Karnataka. This policy orientation is further reflected in budgetary allocations in states such as Maharashtra, where adaptation-linked investments have received greater emphasis.

Mitigation efforts within the water and sanitation sector are largely driven by concerns around **energy self-sufficiency** and the need to reduce emissions from energy-intensive service delivery systems. While adaptation initiatives are led by ministries responsible for infrastructure and environmental management—namely, MoHUA, the Ministry of Jal Shakti, and the MoEFCC—mitigation strategies, particularly those promoting renewable energy and energy efficiency, are spearheaded by the MNRE.

The section discusses the review findings in detail.

2.1 Mitigation Focus

The country has committed itself (non-binding) to reducing the GHG emission intensity and improving the energy efficiency of its economy by 2030, along with safeguarding vulnerable sectors of the economy and segments of society (GoI, 2022). India now stands committed to reduce Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level and achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 (Government of India, 2022). India's current mitigation efforts in the water and sanitation sector are primarily driven by the goals of achieving energy self-sufficiency and reducing emissions associated with energy-intensive service delivery systems.

India launched its very first dedicated national policy on climate change in 2008, known as the National Action Plan on Climate Change (NAPCC), six years after signing the United Nations Framework Convention on Climate Change's Kyoto Protocol in 2002.Despite addressing energy efficiency in energy-intensive industries through its National Mission on Enhanced Energy Efficiency (NMEE), the plan remains silent on Water and Sanitation, infrastructure and services (Government of India, 2008) (Government of India, 2021). Nevertheless, India initiated its journey towards a low-carbon future long before the introduction of the NAPCC.

The oil shocks of the 1970s had a profound impact on the national priorities of that era. The imperative to achieve national energy self-sufficiency and reduce the energy intensity of the Indian economy, found expression in subsequent planning documents, giving rise to two interconnected approaches: the development of alternative energy sources and the promotion of energy efficiency and conservation.

For instance, the emphasis on alternative energy sources prompted the Government of India to establish the Commission for Additional Sources of Energy in 1981 and the Department of Non-conventional Energy Sources (DNES) in 1982, which later evolved into the MNRE in 1992. Simultaneously, the focus on energy efficiency and conservation resulted in the enactment of the Energy Conservation Act-2001, the Electricity Act-2003, Integrated Energy Policy-2006, Energy Conservation (Amendment) Act-2022, and the establishment of the Bureau of Energy Efficiency (BEE) under the Ministry of Power. Initially focusing on major energy-consuming sectors such as power and industries, both approaches influenced various policies, programs, schemes, and regulations. The government's initiatives in energy efficiency, initially launched in the industrial and transport sector, have gradually expanded to encompass municipal services and subsequently commercial and residential establishments.

Within the broader alternative energy approach, initial policy efforts focused primarily on industrial waste-to-energy schemes, with attention gradually expanding to include municipal solid waste. While India established its first municipal waste-to-energy (WtE) plant as early as 1987, the potential of sewage treatment systems as an alternative energy source was recognized much later. This delay is notable given the country's substantial energy recovery potential from such systems—estimated at approximately 8.6×10^5 MWh annually through anaerobic digestion. Additionally, sewage sludge offers considerable energy recovery potential, ranging from 555 to 1,068 kWh per tonne (on a dry matter basis) through incineration and 315 to 608 kWh per tonne through anaerobic digestion (Singh, Phuleria, & Chandel, 2020) , which however remain untapped.

The Ministry of New and Renewable Energy (MNRE) launched a national programme titled *'Energy from Urban, Industrial and Agricultural Wastes/Residues'*, also known as *Waste to Energy*. Introduced with a Central Financial Assistance (CFA) outlay of ₹600 crore for the period April 2021 to March 2026, the initiative provides capital subsidies and grants-in-aid to promote energy generation from diverse waste sources (Ministry of New and Renewable Energy, 2022)iv .

The MoHUA responsible for urban sanitation services, advocates for the maximum reutilization of sewage and sludge for energy "where feasible" within the framework of the National Policy on Faecal Sludge and Septage Management (FSSM) - 2017 (Minister of Housing & Urban Affairs, 2017). As per SBM-Urban data, the country has 1,054 Faecal Sludge Treatment Plants (FSTPs) with a total designed capacity of 54,829 KLD [v]. However, our fieldwork in 12 towns reveals that Faecal Sludge and Septage Treatment Plants (FSSTPs) are either absent or poorly maintained and operated, resulting in a significant missed opportunity to effectively manage septage waste.

If effectively harnessed, it has the potential to reduce dependence on non-renewable energy sources, thereby contributing to GHG emission mitigation in urban domestic wastewater management. Additionally, such harnessing can play a pivotal role in minimizing the substantial power consumption expenses, accounting for 40% - 60% of the total cost of operation and maintenance (O&M) of waterworks at the city level (Chouhan, 2019). This becomes particularly crucial for financial sustainability, given that water utilities in the country typically recover only one-third of their total O&M cost (NIUA, Urban water and Sanitation in Indian Cities. Compendium of Good Practices , 2015). A significant factor contributing to this cost is the extensive distance that fresh water must traverse before reaching city boundaries, posing a substantial challenge, especially for cities with limited surface water availability (Bandari & Sadhukhan, 2021).

Moreover, this presents an opportunity for urban local bodies to earn carbon credits. In fact, there have been recorded instances of sewage treatment systems on the verge of earning carbon credits in cities such as Chennai, Surat, and Delhi[vi]. However, as most sewage treatment plants (STPs) in India operate in an aerobic nature (Central Pollution Control Board , 2021), the potential for energy production is minimal. Additionally, even with the use of anaerobic-based treatment plants, the energy produced would only marginally meet the plant's own energy requirements, given their connection to a centralized network (NIUA, 2023). In fact, the most energy-efficient centralized sewage treatment plants can only fulfil up to 80% of their own energy requirements (Never, 2016). Highlighting the energy intensive nature of the dominant centralized wastewater management approach, the National Urban Sanitation Policy- 2008 of MoHUA calls for mixed technology options including decentralized options for a city-wide sanitation goal. While large Indian cities with lock-in infrastructure and investments in centralized systems have limited room for experimentation with technology choices, small and medium towns can leapfrog.

For larger cities, solutions aimed at enhancing energy efficiency become critical, including measures such as energy-efficient water and sewage pumps, aerators, and smart monitoring tools (Shroff, Caleb, Kolsepatil, & Mishra, Opportunities for Reduction of GHG Emissions from Domestic Wastewater Treatment In Urban Areas. A Brief Orientation for Decision Makers, 2022) (Patel, 2022).

Addressing energy efficiency in municipal services, the Bureau of Energy Efficiency (BEE) launched the Municipal Demand Side Management Programme (MuDSM)/Municipal Energy Efficiency Programme (MEEP) during the eleventh five-year plan (2007-2012). This initiative has resulted in 390 Urban Local Bodies (ULBs) out of 500 AMRUT cities (as of March 31, 2020) entering agreements with the implementation agency to implement efficient pumping solutions in water and sewage management (World Institute of Sustainable Energy, 2020). However, our analysis across 12 towns in 4 states reveals that most municipal energy efficiency programmes continue to focus primarily on public lighting—even though its energy consumption is only about half that of public water supply systems, as illustrated in Figure 2.

Additionally, the BEE introduced a manual to guide ULBs in developing energy efficiency projects and conducting energy audits. However, the concept of municipal-level energy audits has yet to gain widespread traction. Our fieldwork across 12 towns revealed that, except for two, most towns have not undertaken such audits. This reflects either a lack of will or limited institutional and technical capacity at the ULB level. To address this gap, energy and water audits should be made mandatory for all ULBs, and the preparation of Detailed Project Reports (DPRs) for new infrastructure projects should be required to include such audits as a standard component.

Besides these programs, cities can access funds for retrofitting Water and sanitation infrastructure from the Smart Cities Mission and AMRUT. However, the absence of decentralized pumping systems and outdated municipal infrastructure often renders them incompatible with new and efficient technologies. In fact, retrofitting is not feasible in the majority of cases (World Institute of Sustainable Energy, 2020).

The energy efficiency objectives have also been extended to residential establishments through the revised Energy Conservation and Sustainable Building Code (ESBC)-2017, Eco Niwas Samhita (ENS)-2018, and the Energy Conservation (Amendment) Act-2022[vii]. The Amendment Act-2022 expands the definition of energy to include renewable energy sources and introduces a system for issuing "carbon credit certificates" (by the Central government) for the reduction of carbon emissions from commercial and residential buildings. While these establish minimum requirements for the energy-efficient design and construction of buildings, they do not explicitly address wastewater treatment systems[viii]. There is a clear need for comprehensive policies and standards targeting both energy and water efficiency in municipal and domestic wastewater management.

2.2 Adaptation Focus

Given that development and growth are regarded as the primary means of adapting to and building resilience against climate change (Government of India, 2022), these aspects have consistently held top priority in India's national and international climate change policies. This commitment is evident in various initiatives, including the latest long-term low carbon Development Strategy (2022), Nationally Determined Contribution for 2022, and the National Action Plan on Climate Change (NAPCC)- 2008.

It recognizes resilient and reliable infrastructure and services in the Water and sanitation sector as critical prerequisites for successful adaptation and resilience (Government of India, 2022). In fact, “wastewater treatment is [considered] one of the priority sectors for adaptation to climate change” (Indian Institute of Management Ahmedabad ; Indian Institute of Technology Gandhinagar, 2021, p. XVI).

In the country's discourse on climate change, water and sanitation infrastructure and services are considered from both an adaptation and resilience perspective. **Within this adaptation policy framing, the emphasis is placed on interconnected issues of water use efficiency and recycling wastewater/sewage, driven by the pressing issue of freshwater scarcity, both in terms of quality and quantity**. For instance, western coastal areas of Saurashtra region in Gujarat, not only contend with issues of low to medium surface water availability but are also

vulnerable to droughts and cyclones (Mohanty & Wadhawan, 2021) (Central Water Commission, 2021).

The policy framing is visible in the National Mission on Sustainable Habitat and the National Water Mission of NAPCC, and various policies set forth by MoHUA, mandated with service provision, and to some extent, in Ministry of Jal Shakti policies like National water policy. Additionally, the commitment to this framework is observable in the water pollution abatement policies of the Ministry of Environment, Forest, and Climate Change (MoEFCC), such as the Environmental Impact Assessment (EIA) Notification under the Environment Protection Act of 1986.

The National Urban Sanitation Policy- 2008 of MoHUA advocated for the exploration of mixed technology options, nature-based alternatives, and recycling and reuse strategies while highlighting the tendency of cities and state governments to endorse a 'one-size-fits-all' capital and energy-intensive centralized wastewater management approach. The 2022 National Framework on the Safe use of Treated Wastewater, introduced by the MoHUA, acknowledges the critical role of recycling wastewater in addressing the interconnected issues of waste stress, escalating water demand across various sectors, and the imperatives of climate change mitigation and adaptation (Government of India, 2022). Service Level Benchmarks (SLBs) of MoHUA obligate cities to recycle and reuse 20% of their wastewater. Furthermore, the Government of India has initiated discussions on the utilization of treated sewage for the artificial recharge of groundwater aquifers (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, 2020) (Central Ground Water Board, 2020). The country launched environmental standards on the reuse of treated sewage for irrigation, and horticulture (Central Pollution Control Board , 2021). Additionally, legal mandates such as the 2015 directive from the National Green Tribunal (NGT) directs state governments to install decentralized treatment units and formulate action plans for the utilization of treated sewage.

The advantages of recycling wastewater are diverse, encompassing an additional water source for non-potable purposes, thereby alleviating the strain on freshwater sources. This approach results in reduced reliance on groundwater, allowing aquifers crucial time to recharge, consequently minimizing the need for water pumping and curbing greenhouse gas emissions. Moreover, recycling wastewater presents an additional revenue stream for urban local bodies. In the Indian context, the practice of utilizing partially or untreated wastewater for agricultural purposes is widespread (Amerasinghe, Bhardwaj, Scott, Jella, & Marshall, 2013). This practice has gradually extended from the agricultural sector to encompass the industrial, municipal, and, more recently, the commercial and residential sectors.

In 2021, India had 11,622 million cubic meters of treated wastewater available for reuse, equivalent to INR 630 million (Bassi, Gupta, & Chaturvedi, 2023). According to Ministry of Jal Shakti, if 80% of urban wastewater could be collected, treated, and recycled by 2030, it would result in a total volume of around 17 billion cubic meters (BCM) available to meet nearly 75% of the projected industrial demand in 2025 (Ministry of Jalshakti, 2006). Furthermore, wastewater irrigation could contribute to the avoidance of groundwater pumping, potentially leading to a reduction of about 1.75 million megawatt-hours (MWh) of electricity, corresponding to 1.5 million tonnes of CO2 equivalent (tCO2e) in greenhouse gas emissions (WSP & IWMI, 2016). Such an interconnected understanding of adaptation and mitigation is evident in Gujarat's state wastewater recycling policy. The policy advocates for the "universal coverage of Underground Drainage (UGD) with at least 40% of wastewater to be recycled" (World Resource India, 2018, p. 4). This initiative aims to reduce the billing charges for fresh water, which are impacted by factors such as long-distance transportation, gradient, and high energy cost (World Resource India, 2018).

Major cities like Surat (Gujarat) and Bengaluru (Karnataka) have implemented the utilization of treated wastewater for revenue generation (Sandesh, 2019). Moreover, this practice helps alleviate the demand for freshwater in non-potable applications. For instance, in Bengaluru, where freshwater resources are limited and transported over considerable distances, resulting in elevated water production costs and increased energy consumption, recycling treated wastewater for non-potable purposes, such as maintaining extensive public parks and urban landscapes, stands as a financially and environmentally sustainable alternative[ix] . Despite programs like Smart Cities and AMRUT promoting sewage recycling and reuse, cities and states still prioritize the augmentation and revamping of old infrastructure (International Water Association, 2018).

The mandate for recycling and reuse has been expanded to encompass large commercial and residential establishments by states such as Karnataka and Maharashtra. The overarching goal is to substitute freshwater demand for non-potable purposes and tackle sanitation challenges in areas lacking an underground sewage network, thereby indirectly establishing a link between adaptation and mitigation. However, the implementation has not only been tardy but has also demonstrated a lack of synchronization between adaptation and mitigation efforts. For instance, in 2006, the Karnataka State Pollution Control Board expanded the responsibility of managing pollution to residential and commercial properties mandating them to establish wastewater decentralized stand-alone systems, and comply with Zero Liquid Discharge (ZLD) and discharge standards of 10 mg/l Biological Oxygen Demand (Ministry of Environment, Forest and Climate Change, 2017); (Karnataka State Pollution Control Board, 2012).

The stringent compliance requirement compelled users to adopt energy-intensive systems, resulting in high energy usage and operating expenses, thereby increasing overall cost of compliance (Rana, 2021) . This also hindered the adoption of less expensive and less energy-intensive options. Moreover, the cost of producing treated wastewater exceeded the cost of purchasing fresh water, which was readily available due to the prevalence of private tanker water and the lacklustre implementation of groundwater regulations (Rana, 2021). The absence of any external or internal incentive, led to the partial functioning of many decentralized systems (Rana, 2021) . This serves as a classic example of maladaptation, where interventions (such as recycling, reuse, and pollution abatement systems) intended to facilitate adaptation inadvertently result in unintended consequences, as observed with higher GHG emissions in this case. States like Maharashtra do call for measures to reduce the costs of compliance and provide incentives to domestic wastewater treatment equipment manufacturers (The Energy Research Institute , 2014). Hence, wastewater recycling and reuse require concrete policy evidence that highlights the interlinkages between adaptation and mitigation. This information is essential to inform policy makers and decision makers and mainstream policymaking. **However, our town-level studies reveal that wastewater recycling practice is largely absent in smaller and medium towns. Many of these towns lack a sewage network capable of collecting wastewater at a centralized location, and they also do not have sewage treatment plants in place. As a result, in such contexts, most of the wastewater remains untreated and released into drains or is managed through on-site sanitation systems.**

According to Government of India, press release, programmes like AMRUT have contributed significantly to the expansion of sewerage and septage management in urban areas. In AMRUT cities, states reported approximately 1.47 crore sewerage and septage connections in 2015, covering around 31% of urban households. By 2018, an additional 18.84 lakh connections had been added, and by 2023, this number rose to 1.47 crore new or upgraded connections. As a result, a total of 2.94 crore sewerage and septage connections were established across 500 AMRUT cities. Currently, about 42% of urban households in these cities have access to sewerage or septage facilities (PIB, Government of India, 2023).

The rainwater harvesting policies provide both adaptation and mitigation co-benefits, including freshwater savings and improved energy efficiency. As decentralized systems, they are less energy-intensive compared to traditional water distribution networks – also recognised in the State Climate Change Action plan. Additionally, the costs are shared by users, reducing the financial burden on utilities. At the national level, programmes such as the Jal Shakti Abhiyan and its *Catch the Rain* campaign focus on 148 districts identified by the Central Ground Water Board (CGWB). As in previous years, the initiative includes five key interventions including Water conservation and rainwater harvesting (Government of India,

2009). As of July 2025, Madhya Pradesh topped the list with a total of 32,463 various types of water conservation structures. Karnataka ranked fourth among the top five states, with 23,341 structures, following Madhya Pradesh, Rajasthan, and Tamil Nadu. Gujarat, with 4,788 structures, stood at 10th position, while Maharashtra ranked 12th with 4,280 structures. Goa was among the bottom three states. However, when considering only rainwater harvesting structures, Karnataka ranked 8th with 1,015 such structures (status from 22-03-2025 to 28-07-2025) (Ministry of Jal Shakti, 2025). **Our study in 12 selected coastal towns shows that the RWH is not a prominent practice in smaller and medium towns (with populations under). In contrast, it is being implemented to some extent in larger urban centres like Mangaluru and Bengaluru.**

Further, climate change-wash connect has found place in public health sector, in line with the India's commitment to "Male Declaration". The Ministry of Health and Family Welfare, Government of India, launched the National Programme on Climate Change and Human Health, under which several states developed state-level climate action plans incorporating health concerns of climate resilience. The declaration calls for essential services such as water, sanitation, waste management, and electricity to remain functional during such events. Moreover, for the health sector to be truly climate-resilient, it must adopt eco-friendly technologies, water and energy-efficient practices, contributing to a "greener" health system. The plans emphasize the need for the health department to embrace sustainable practices through environmentally conscious technologies and energy-efficient solutions.

2.3 Infrastructure Resilience Focus

The key policies addressing these issues are the Climate Action Plans and Disaster Management Plans.

At the national level, the primary nodal agency for disaster management is the National Disaster Management Authority (NDMA) and Institute of Disaster Management (NIDM). The NDMA formulates policies, plans, and guidelines for disaster management to ensure timely and effective responses to disasters. Established under the Disaster Management Act of 2005, NIDM is responsible for planning, training, and research related to disaster management. It also undertakes documentation and the development of a national database on disaster management policies, prevention mechanisms, and mitigation measures.

The key policy is **National Policy on Disaster Management 2009**, which emphasizes the continuous monitoring and strengthening of critical infrastructure—such as dams, bridges, roads, power stations, irrigation canals, coastal embankments and civic utilities—in line with

global safety standards. Responsible authorities must ensure adherence to updated safety norms (National Disaster Management Authority, 2019). **The policy recognisees Urban disasters** are increasing in frequency and severity, necessitating effective disaster management plans, specialized search and rescue training, and prioritization of controlled urbanization to create safer habitats. Improvement of urban drainage systems, protecting natural drainage, and high-resolution urban infrastructure mapping for Decision Support Systems (DSS) are key priorities for State Governments and UTs. The policy mandates periodic revision of municipal regulations—including building bye-laws—to address disaster risks like earthquakes, floods, and landslides. These regulations must align with updated BIS building codes every five years, with enforcement of the National Building Code as mandatory. Special focus is placed on preventing unsafe construction in vulnerable areas, and rural regulations are also to be developed. Local bodies may receive financial incentives to aid in regulatory preparation, with inclusive stakeholder engagement and public dissemination of building codes.

The Government of India launched the Coalition for Disaster Resilient Infrastructure (CDRI) at the 2019 Climate Action Summit. This international partnership brings together national governments, UN agencies, multilateral development banks, the private sector, and academic and research institutions to promote resilience in both new and existing infrastructure systems against escalating climate risks and natural disasters. To support these efforts, the Government of India has allocated ₹480 crore (approximately USD 58 million) for the CDRI over a five-year period from 2019 to 2023–24 (Ministry of Environment, Forest and Climate Change, 2023).

State-level Disaster Management Plans and Climate Action Plans (SAPCCs) vary widely in addressing water and sanitation infrastructure resilience to climate change. Most plans overlook this critical issue, with Goa's 2023 Climate Action Plan being a notable exception—it explicitly prioritizes resilience strategies and vulnerability assessments for critical infrastructure. State Disaster Management Plans, such as those of Karnataka, Maharashtra, and Gujarat, integrate disaster risk reduction (DRR) principles into water and sanitation services, emphasizing both structural (e.g., embankments, drainage, watershed management) and non-structural measures (e.g., hazard zoning, risk mapping, early warning systems). These plans prioritize service continuity during emergencies and promote community engagement and ecosystem-based approaches. At the city level, while many existing water and wastewater infrastructures lack climate-proofing, initiatives like the Smart Cities Mission and funding from International Financial Institutions are pushing Urban Local Bodies to incorporate disaster risk and climate adaptation into infrastructure planning.

However, our study across 12 towns indicates that much of the existing water and wastewater infrastructure was developed without consideration for disaster risks or climate resilience. In most cases, these systems were not designed to withstand extreme weather events or long-term climate impacts. Only in a few instances—particularly in upcoming infrastructure projects supported by International Financial Institutions (IFIs)—did we find that Urban Local Bodies (ULBs) are now being required to incorporate disaster risk and climate change considerations into their proposals for infrastructure and service delivery.

This longstanding neglect is also being acknowledged by NIDM. It has emphasized the need to integrate disaster risk reduction into infrastructure development and to prioritize resilient infrastructure planning (National Institute of Disaster Management, 2022). Ignoring these concerns can lead to increased public expenditure and the diversion of funds from productive capital to emergency responses and frequent maintenance of vulnerable systems (Indian Institute for Human Settlements, 2023). Moreover, retrofitting conventional infrastructure is often more expensive than investing in climate-resilient systems from the outset (International Monetry Fund, 2021).

2.4 Policies Focussing on Coastal Areas

There is no dedicated national mission for coastal areas and climate change under the National Action Plan on Climate Change (NAPCC). However, the National Water Mission addresses climate change impacts on coastal regions as part of its broader mandate.

“A National Water Mission will be mounted to ensure integrated water resource management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states. The Mission will take into account the provisions of the National Water Policy and develop a framework to optimize water use by increasing water use efficiency by 20% through regulatory mechanisms with differential entitlements and pricing. It will seek to ensure that a considerable share of the water needs of urban areas are met through recycling of waste water, and ensuring that the water requirements of coastal cities with inadequate alternative sources of water are met through adoption of new and appropriate technologies such as low temperature desalination technologies that allow for the use of ocean water” (Ministry of Jal Shakti , 2021, p. 8).

Key concerns included are saltwater intrusion due to sea level rise, which significantly impacts groundwater quality and access to drinking water. Coastal regions, along with drought-prone areas, flood-prone areas, regions with deficient rainfall, and areas classified as over-exploited, critical, or semi-critical in terms of groundwater development and water quality, have been

prioritised under the mission. Strategies for these priority areas include: Improving water use efficiency by 20%, for which the Ministry has established the Bureau of Water Efficiency (BWE) ; Assessing the impacts of climate change on water resources; Maintaining a comprehensive water database in the public domain; and Publishing the Composite Water Management Index (CWMI) to track and promote effective water management practices.

In 2011, the MoEFCC established the **National Centre for Sustainable Coastal Management (NCSCM)** as an autonomous institution to support coastal protection, conservation, rehabilitation, and policy guidance. NCSCM promotes the **Integrated Coastal Zone Management (ICZM)** approach using science-based decision support systems and by facilitating collaboration among communities, government bodies, and national and international institutes. To implement this integrated approach, the Government of India launched the **Integrated Coastal Zone Management Project (ICZMP)** under the **CRZ and IPZ Notifications (2011)**.

The project has enabled key activities such as **hazard line mapping, identification of eco-sensitive areas, and delineation of sediment cells** along the entire Indian coastline, laying the groundwork for climate-resilient coastal planning and governance. For implementing the provisions of the **CRZ Notification, 2011, states have constituted State Coastal Zone Management Authority**. Its mandate includes protecting and improving the coastal environment, controlling pollution, and examining proposals for changes in CRZ classifications. The Authority is also empowered to investigate and review violations under the **Environment Protection Act** and **CRZ regulations**.

State Action Plans on Climate Change in Maharashtra, Gujarat, Goa, and Karnataka highlight both mitigation and adaptation strategies for vulnerable coastal zones. Key challenges include salinity intrusion, declining groundwater, and coastal water pollution from untreated sewage and industrial effluents. Responses include STPs, CETPs, and monitoring by SPCBs, CZMAs, and other stakeholders. Additional concerns like coastal erosion, sedimentation, and mangrove loss are addressed through erosion control, mangrove replantation, resilient housing, and integrated agri-fish culture in low-lying salinized areas.

However, a recent study highlights the **insufficient integration of climate change and disaster risk considerations in coastal governance planning** (C, Sinha, & Bisaria, 2024). The study finds that **efforts to incorporate climate adaptation and mitigation strategies into policy documents and coastal management frameworks remain weak and fragmented**. The coastal governance in India is governed by a complex web of central and state-level laws that address different sectors (e.g., fisheries, environment, urban development, environmental pollution, biodiversity conservation).

This disjointed framework leads to overlapping responsibilities, coordination failures, and limited synergy between agencies—hindering the development and implementation of integrated local-level coastal plans. Moreover, our town-level studies in 12 towns corroborate these findings, revealing limited involvement of Urban Local Bodies (ULBs) in disaster and climate change planning and governance, as well as a general lack of awareness about ongoing climate change initiatives. Further, **CRZ rules are among the most frequently violated environmental legislations in India.** Moreover, there has been ongoing dilution of policies related to ecological protection and conservation, further weakening coastal resilience. Even though, climate risks affect multiple sectors—such as housing, transport, fisheries, and tourism—yet coastal planning often occurs in silos. Although initiatives like the NAPCC, operational linkages remain weak and uncoordinated. Despite rhetorical acknowledgement of climate change, concrete measures for climate resilience—such as risk-informed land use, nature-based solutions, or infrastructure retrofitting—are scarcely embedded in coastal governance practices.

Section D: Policy and Institutional Landscape in Water, Sanitation and Climate Change - State Highlights

(Karnataka, Goa, Maharashtra, Gujarat)

*This section provides a concise overview of the state-level **policy and institutional landscape** at the intersection of urban water, sanitation, and climate change. It also reviews key programmes and schemes, as well as the major sources of funding for urban water and sanitation. The state-level analysis is informed by the **15 town-level assessment studies**, which ground the discussion in local realities. It also highlights **key challenges and outlines proposed recommendations**. Comprehensive analyses for each state are available in the respective state-specific reports.*

1. Karnataka

Karnataka is third-largest state economy in India, contributing 8.77% to the national GDP. The state covers 1,91,791 sq. km (5.83% of India's geographical area) and had a population of 61 Million in 2011 (5.05% of India's total) (Government of Karnataka, 2022). It is the ninth most populous state in the country with 38.67% of the population residing in urban areas, higher than the national average (as per Census 2011) (Government of Karnataka, 2022). It is currently rank at 8th most populace state in India (EMPRI, 2021). Increasing urbanization (by 4.68% over the last decade) in Karnataka is driving a higher demand for freshwater and sanitation services (Government of Karnataka, 2022)[x].

The state is ranked among India's top four most climate-vulnerable regions (Mohanty & Wadhawan, 2021)**.** The state is facing severe cyclones in its coastal belt (coastal line extends for approximately 320 kilometres) and compounded flood events (Mohanty & Wadhawan, 2021). Further enhancing these risks is lack of basic infrastructure and services, particularly in specific regions. **Karnataka's Human Development Index improved from 0.429 in 1990 to 0.645 in 2019, however, the state lags behind other southern states in achieving the Sustainable Development Goals (SDGs)[xi]** (Government of Karnataka, 2022)**.** For instance, in sanitation and water services, Karnataka scores 85, slightly above the national average of 83 but 15 points behind Goa, the best-performing state with a perfect score of 100. In poverty alleviation, the state scores 68, exceeding the national average of 60 but trailing Tamil Nadu, which leads with 86.

The state is also a significant contributor to national total greenhouse gas (GHG) emissions (GHG Platform India, 2018). Karnataka accounts for about 5% of India's population (as per census 2011), it contributed 4.42% of the country's GHG emissions in 2018 (GHG Platform India, 2018)[xii]. The **domestic wastewater sector,** encompassing both rural and urban areas, accounted for 53.63% of total waste sector emissions (5.37 Mt CO2e) in 2018 (GHG Platform India, 2018). Rural areas, with 62% of the state's population, contributed approximately 56% of the domestic wastewater emissions (2.88 Mt CO2e) in 2018 (GHG Platform India, 2018). **The primary drivers of emissions in this sector are the discharge of untreated wastewater and the widespread use of septic tanks** (GHG Platform India, 2018)**. The assessment, however, overlooks energy consumption in its analysis of GHG emissions from the domestic wastewater sector. Including this factor would offer a more comprehensive understanding of emissions, particularly since municipal services in Karnataka, such as public lighting and water works, account for approximately 9% of the state's total electricity consumption (~64,000 MUs), with public water works contributing around 7.1%** (Central Electricity

Authority, 2022)**. This project aims to address this gap in the analysis –** refer town assessment reports for GHG emissions from urban water and wastewater services.
The Intergovernmental Panel on Climate Change (IPCC) recognizes universal access to water, sanitation, and hygiene (WaSH)—as targeted in SDGs 6.1 and 6.2—as a critical, low-regret adaptation strategy, supported by high confidence. Moreover, ensuring universal access to WaSH not only contributes directly to SDG 11 (sustainable cities and communities) but also promotes social equity and environmental sustainability. As per the latest studies, around 78.% of the urban households in the state have Flush/pour flush connected to piped sewer system, septic tank, or pit latrine, in rural areas this percentage is 61.3% (International Institute for Population Sciences and ICF, 2021). Further, the National Family Health Survey (NFHS-5)-India (2019-20) survey shows that 96% households in Karnataka use an improved source of drinking water. Urban households (59%) are more likely than rural households (38%) to have water piped into their dwelling, yard, or plot (International Institute for Population Sciences ; ICF, 2022)[xiii]. **The lack of piped water connectivity and increasing population and urbanisation translate to over exploitation extraction of ground water.** For instance, among the 234 assessment units (taluks), 20.94% are categorized as 'Overexploited,' 4.70% as 'Critical,' 14.96% as 'Semi-critical,' and 59.40% as 'Safe' (Ground Water Directorate ; Central Ground Water Board, South Western Region, 2023). This is challenging in the context of climate change, as the state is already grappling with extreme droughts and water scarcity in certain regions.

To address the climate change related risks, the state has a Climate Change Action Plan aligned with the national climate action framework, along with several complementary policies. Recognizing the critical link between climate change and human development, Karnataka released the Human Development Index Report 2022, which outlines strategies to improve access to essential services including water and sanitation (Government of Karnataka, 2022). Additionally, the state's latest economic survey report (2023-24) highlights the alignment of its expenditures with sustainable development goals (SDGs) and climate change and efforts to achieve them (Government of Karnataka, 2024).

1.1 Finances and Programmes/Schemes

In Karnataka, the development of urban water and sanitation infrastructure is funded through a mix of **centrally sponsored schemes**—such as AMRUT, UIDSSMT, and SBM—and **state and ULB-level contributions**. For Financial Year 2024–25, Karnataka Urban Water Supply And Drainage Board (KUWSDB) proposed a budget of INR 3515.79 crore, primarily supported by central and local funds. Despite steady allocation growth since 2020, the sector remains a low priority relative to others like education and agriculture. While the state has leveraged central

government funds for urban development, its own allocations for urban infrastructure and climate initiatives have declined. ULBs depend heavily on property taxes but generate limited revenue from water and sewerage charges, with capital expenditure on sewerage and drainage comprising only 3–5% of total ULB capital spending.

The study highlights significant financial challenges in Karnataka's urban water and sanitation sector, marked by low budgetary prioritization, heavy dependence on central funding, weak local revenue mobilization, and volatile grant flows. ULBs face limited capital investment capacity and lack financial autonomy, further constraining infrastructure development.

At the ULB level, Mangalore, Karwar, and Kundapura are facing serious financial sustainability challenges. Mangalore's water revenue collection is projected to fall to 31.24% by 2024-25, while its sewerage services show a sharp decline in the Operating Ratio and a fiscal deficit of ₹2,902.28 lakh in 2021-22, compounded by rising operational costs and irregular capital expenditure. Karwar relies heavily on government grants, with water collection efficiency declining to 35% in 2017-18 and projected at 49% by 2024-25, while its sewerage sector depends almost entirely on grants, with own revenue contributing only 3%. Kundapura's cost recovery dropped to 50.48% during 2020-21, with operating ratios reaching balance points by 2022-23. Across all three towns, rising operational costs, fluctuating per capita expenditure, and inconsistent capital investments underscore the urgent need for improved revenue generation, cost control, and strategic alignment of operational and capital spending to ensure long-term financial sustainability.

To address these issues, the state must increase its own investments and reduce reliance on central transfers, while reforming ULB finances through tariff revisions, expanded tax bases, and stronger revenue collection mechanisms. Establishing stable, formula-based grant systems and prioritizing capital expenditure in underfunded sanitation sectors will be critical. In addition, learning from best practices of peer states and empowering ULBs with greater fiscal and operational authority can strengthen financial resilience and ensure sustainable service delivery.

1.2 Institutional Landscape

Urban sanitation governance in Karnataka reflects a fragmented, multi-tier system with uneven responsibilities. The multi-tier governance of WaSH in Karnataka suffers from fragmentation, unclear roles, and poor coordination among households, ULBs, and state agencies, undermining service delivery and climate resilience, exemplified by the case of Mangaluru.

Water and sanitation governance in India operates within a **multi-level, multi-stakeholder framework**. While water is a state subject and sanitation lies in the State List, the **74th Constitutional Amendment** gives Urban Local Bodies (ULBs) primary responsibility for service delivery. However, policies are framed by the **central ministries (MoHUA, CPCB, CPHEEO, BIS, MNRE, etc.)**, while **states adapt and implement** them through departments, agencies, and centrally/state-sponsored schemes such as AMRUT, SBM, and Smart Cities Mission. At state level, multiple institutions coordinate across water, sanitation, climate change, and disaster governance:

- **Urban Development Department (UDD)** oversees infrastructure schemes and urban planning, with KUIDFC financing and implementing projects.
- **Department of Water Resources** manages surface water; the **Groundwater Directorate and Authority** regulate groundwater.
- **Department of Forest, Environment and Ecology** and **KSPCB** enforce environmental laws.
- **KREDL** drives renewable energy initiatives.
- **EMPRI** leads climate change action planning and capacity building.
- **State Disaster Management Authority** integrates disaster risk reduction and climate adaptation.
- Standards are set centrally, but compliance is enforced by **State Pollution Control Boards (SPCBs)** and other state-level regulators.

The case of Mangaluru shows that At the **household level**, families manage toilets and on-site systems, often poorly regulated, creating risks of contamination and climate vulnerability. **ULBs** oversee small-scale infrastructure like community and public toilets but face challenges in equitable access, environmental compliance, and resilience, as O&M is often outsourced. For **large-scale systems**—sewerage networks and STPs—ULBs have minimal authority; state agencies (e.g., KUIDFC) and international financiers dominate planning, funding, and monitoring, sidelining local perspectives.

In **disaster and climate governance**, ULBs remain largely reactive, confined to relief service delivery, with little role in preparedness, risk assessment, or long-term recovery. This marginalization undermines the intent of the **74th Constitutional Amendment**, which aimed to empower ULBs, and weakens climate-resilient urban sanitation governance. Strengthening ULBs' **institutional capacity, financial autonomy, and strategic planning role** is critical for embedding water and sanitation systems into urban climate resilience.

1.3 Policy Landscape

This section reviews policies on climate change, urban water supply and sanitation (UWSS), energy, disaster, and environmental governance, focusing on adaptation, mitigation, and infrastructure resilience. It also draws on fieldwork in Mangaluru, Karwar, and Kundapura to evaluate how state policies are implemented locally.

Karnataka, aligned with India's Net Zero 2070 target, has established state climate action plans, nodal institutions (EMPRI, Karnataka Strategic Knowledge Centre), and sectoral policies integrating climate concerns into water, health, HDI, SDGs, and building regulations. However, the annual budget for climate actions declined by 0.13% of the overall budget between 2017–18 and 2019–20 (EMPRI, 2021). Of 103 schemes under the State Climate Action Plan, 57.3% focus on adaptation—mainly in agriculture, forestry, and fisheries—while urban water and sanitation remains underfunded (EMPRI, 2021). Mitigation measures are largely unintended and neglect UWSS needs. Adaptation focus is understandable given that no towns meet Service Level Benchmarks (SLBs) for water and sewerage, and Karnataka is among India's most drought-affected states.

Mitigation Focus

Karnataka's mitigation efforts in the urban water and sanitation sector primarily focus on energy efficiency and biological processes, with limited attention to energy generation from wastewater.

Municipal services, including street lighting and public water works, account for nearly 9% of the state's electricity consumption (~64,000 MUs). Within this, public water works alone contribute 7.1%, which is significantly higher than the national average of 2% (2021–22). At the same time, Karnataka's overall share of municipal electricity use is lower than the national average of 17% (2020–21). The state's energy efficiency studies indicate a saving potential of 21% (3,210 MU) in municipal services, supported by sectoral targets set under the Energy Efficiency Policy 2022–27. These include reduction targets of 4% in the domestic sector (2,912 MU), 3% in the commercial sector (2,628 MU), 2% in industry (728 MU), 3.5% in agriculture (6,551 MU), and 6% in municipal street lighting and 3% in water works (3,210 MU). If achieved, these measures could result in savings of 744 million kWh, reduction of 610,080 tonnes of CO_2 emissions, and avoidance of 454 MW of additional power capacity.

Reflecting these efforts, Karnataka scored 86.5 out of 100 in the State Energy Efficiency Index (SEEI) 2023, ranking first in India. Municipal services alone scored 10 out of 11, improving performance by 35.9% since 2021–22. Complementing this, the Municipal Energy Efficiency Project (MEEP), under which Karnataka is one of 13 states mandated to adopt Bureau of

Energy Efficiency (BEE) 4/5 star-rated pumps, has seen the installation of efficient pump sets in 18 towns. However, field studies in Mangaluru, Karwar, and Kundapura reveal that while Detailed Project Reports (DPRs) considered lighting efficiency, they did not account for the use of energy-efficient pump standards.

On the other hand, while the **Karnataka Renewable Energy Policy 2022–27** promotes green energy, there is **no explicit integration with UWSS systems**, and no evidence was found of energy generation from sewage treatment plants (STPs) in the studied towns.

In terms of biological processes, Karnataka generates **4,458 MLD of wastewater** but has only **61% treatment capacity**. Actual compliance is even lower, with just **1,168 MLD meeting prescribed discharge standards**. In addition, the state has established **nine faecal sludge treatment plants (FSTPs) with a combined capacity of 264 KLD**, which play a role in reducing methane emissions from septic tanks. Governance frameworks such as the Karnataka State Pollution Control Board's (KSPCB) consent mechanisms and building bye-laws mandating decentralized treatment systems also support this agenda. However, field observations indicate weak post-installation monitoring, abandonment of high-cost, energy-intensive centralized systems (especially in Bengaluru), and mixed greenhouse gas (GHG) benefits from decentralized solutions.

Overall, while Karnataka demonstrates leadership in municipal energy efficiency, mitigation measures within the UWSS sector remain fragmented, with limited attention to integrating wastewater-to-energy strategies and ensuring sustained performance of treatment systems.

To address these issues, state's climate and sanitation agenda should broaden its mitigation scope by integrating emissions from faecal sludge and sewage treatment, with clear targets and incentives for methane capture, nutrient recovery, and bioenergy generation. Expanding treatment capacities in underserved towns and strengthening compliance for both centralized and decentralized systems are critical, alongside ensuring DPRs and municipal plans adopt energy- and water-efficiency standards. Linking renewable energy and sanitation policies can drive waste-to-energy pilots from sludge and co-treatment facilities, while robust data systems and stronger inter-agency coordination will be essential for tracking emissions, energy use, and compliance across the UWSS sector.

Adaptation Focus

Most climate-water-sanitation policies in Karnataka prioritize **adaptation**, reflected in the State Action Plan and budget allocations. Focus areas include: (i) water scarcity and security, (ii) equitable access to drinking water and sanitation, and (iii) human and environmental health. Adaptive measures include **rainwater harvesting, groundwater recharge, water-use**

efficiency, regulated groundwater withdrawal, and treated wastewater reuse, crucial as Karnataka is water-stressed and drought-prone (State Water Policy-2022). Key policies: Karnataka State Action Plan on Climate Change 2.0 (2021), State Action Plan for Climate Change and Human Health (2023), Karnataka State Water Policy-2022, Groundwater Acts (1999, 2011, 2012), Municipalities Model Building Byelaws 2017, KSPCB consent mechanisms, Policy for Urban Wastewater Reuse-2016, and national programs such as Jal Shakti Abhiyan – Catch the Rain (2025), Smart Cities Mission, and groundwater guidelines.

Programs addressing water and sanitation access include SBM (Urban), AMRUT, and state/national funding schemes. Policies mandate **20% recycling of treated sewage** (Urban Wastewater Reuse-2017, SLBs), though towns like Karwar, Kundapura, and Mangaluru show room for improvement. Bengaluru generates **1,440 MLD of sewage**, potentially yielding **1,153 MLD** of non-potable water; at Rs. 300/1,000 liters, this could generate **Rs. 346 crore annually** for BWSSB, with 35% of its revenue currently from treated effluent reuse. Decentralized property-level wastewater systems face high energy costs, lack of incentives, and conflicting standards between urban development and pollution control policies.

Rainwater harvesting provides freshwater savings and energy efficiency at shared user costs. Jal Shakti Abhiyan targets **148 districts** with five interventions, including water conservation and RWH. As of July 2025: Madhya Pradesh – **32,463** structures, Karnataka – **23,341** (4th), Gujarat – **4,788** (10th), Maharashtra – **4,280** (12th), Goa – bottom three. For RWH alone, Karnataka ranked **8th with 1,015 structures**. Field data show RWH is limited in smaller towns (<50,000) like Karwar and Kundapura, but partially implemented in larger towns such as Mangaluru and Bengaluru.

Overall the state faces acute **water scarcity and drought**, with policies promoting rainwater harvesting, groundwater recharge, efficiency, and wastewater recycling, though implementation—especially in smaller towns—remains limited. **Access gaps** persist despite SBM (Urban) and AMRUT, as most towns fall short of the **20% sewage recycling mandate**. **Policy incoherence** between strict pollution norms and urban development guidelines leads to costly, energy-intensive systems that are often abandoned, while the **lack of incentives** further discourages compliance. **Rainwater harvesting** is inconsistently adopted—common in Bengaluru and Mangaluru but rare in smaller coastal towns. Meanwhile, **wastewater reuse potential** is underutilized.

To address these challenges, policies must be made more coherent by aligning pollution control and urban development regulations to enable cost-effective, energy-efficient wastewater treatment solutions suitable for local contexts. Financial and technical incentives should be provided to encourage property owners to adopt and maintain decentralized wastewater systems, while wastewater recycling must be scaled up in larger cities to conserve

freshwater, reduce pollution, and generate revenue for utilities. Rainwater harvesting should be expanded, particularly in smaller towns, through awareness, technical support, and integration into urban planning. Effective implementation and monitoring are critical to ensure recycling targets are met and systems remain functional. Finally, an integrated approach that combines rainwater harvesting, groundwater recharge, and wastewater reuse is essential to address Karnataka's severe water stress sustainably.

Infrastructure Resilience Focus

The **State Climate Change Action Plan** largely overlooks the resilience of water and sanitation infrastructure, focusing instead on sectors like agriculture, forests, livestock, fisheries, biodiversity, and communities. While it references the UN 2030 Agenda and climate-sensitive technologies, it does not specifically address water and sanitation resilience. Key policies and programs addressing water and sanitation resilience include the **Karnataka State Disaster Management Plan (KSDMP) 2021-2022**, **Karnataka State Water Policy-2022**, **State Action Plan for Climate Change and Human Health (2023)**, and the **Smart Cities Mission**. These initiatives approach water and sanitation through adaptation, preparedness, and recovery priorities.

The KSDMP links climate change, disaster management, and SDGs, emphasizing **Disaster Risk Reduction (DRR)** in water management, resilient infrastructure, safe construction in flood-prone areas, and flood zoning. The State Water Policy-2022 addresses climate-resilient infrastructure and risk mapping but focuses mainly on **dam safety**, omitting municipal water and wastewater infrastructure resilience. At the city level, the **Smart Cities Mission** encourages integrating risk resilience in project planning. Field observations in **Kundapura, Mangaluru, and Karwar** show that much existing water and wastewater infrastructure was built without climate-proofing. Upcoming IFI-funded infrastructure projects now require **ULBs** to integrate disaster risk and climate considerations into planning.

To address these challenges, water and sanitation resilience should be explicitly prioritized in policy and planning, supported by comprehensive risk assessments of municipal infrastructure. Existing systems in vulnerable towns should be retrofitted and climate-proofed, while interdepartmental coordination is strengthened and dedicated funding is provided to build ULB capacity for resilience. Additionally, the widespread adoption of climate-resilient solutions should be actively promoted to ensure sustainable, adaptive, and future-ready water and sanitation services.

Policies Concerning Costal Areas

There is **no dedicated national mission for coastal areas under NAPCC**, but the **National Water Mission** addresses climate impacts, aiming to increase **water use efficiency by 20%**, promote wastewater recycling, and adopt **low-temperature desalination** for water-scarce coastal cities. Priority areas include coastal, drought- and flood-prone regions, and over-exploited or critical groundwater zones. The Mission maintains a public water database and publishes the **Composite Water Management Index (CWMI)**. **MoEF&CC** established the **NCSCM** (2011) to support coastal protection and **ICZM**, implemented via the **ICZMP** (2011), enabling hazard line mapping, eco-sensitive area identification, and sediment cell delineation. The **Karnataka State Coastal Zone Management Authority** oversees CRZ compliance, pollution control, and coastal development approvals.

The **Karnataka State Action Plan on Climate Change (2021)** highlights coastal water and sanitation challenges: **salinity intrusion, groundwater depletion, toxic algal blooms, coastal erosion, sedimentation, and mangrove degradation**. Measures include **STPs/CETPs, mangrove replantation, safe housing, integrated agri-fish culture, and erosion control**, with oversight by **SPCB, CZMA, NGOs, and fisheries bodies**.

Studies (C, Sinha, & Bisaria, 2024) and fieldwork in **Mangaluru, Karwar, and Kundapura** show weak integration of climate and disaster risk in coastal governance. Overlapping laws, frequent CRZ violations, and diluted ecological policies limit ULB involvement and coordination. Despite climate risks across sectors like housing, transport, fisheries, and tourism, coastal planning remains fragmented, with minimal use of risk-informed land use, nature-based solutions, or infrastructure retrofitting.

To address these issues, the state needs to strengthen institutional coordination and build ULB capacity. Climate resilience should be mainstreamed into land use and infrastructure planning, with stricter enforcement of CRZ and ecological protection regulations. Promoting cross-sectoral, integrated coastal management and leveraging scientific tools for hazard mapping and eco-sensitive zoning can ensure more effective, resilient, and sustainable coastal governance.

2. Goa

Goa, **one of India's smallest states,** covering an area of 3,702 square kilometers and a coastline of approximately 105 kilometres[xiv]. According to the 2011 Census, Goa has a population of 1.46 million, constituting around 0.12 percent of India's total population. **Goa exceeds the national average of 382 people per square kilometre**, with a population density

of 394 people per square kilometre, (Government of Goa, 2023). **The state excels in comparison to other states across a range of human development indicators.** The state has about INR 54000 Crore Gross State GDP - 0.34 per cent of the National GDP. **For instance, Goa has consistently ranked among the top states in terms of Human Development Index (HDI), alongside Delhi and Kerala, maintaining a spot in the top three from 1990 to 2019** (Raj, Gupta, & Shrawan, 2023). Furthermore, **Goa ranks at the top of the Social Progress Index for key basic needs indicators including water and sanitation, and shelter** (PIB, 2022). However, certain areas with high population density, significant slum populations, and a heavy reliance on the fisheries and tourism sectors are particularly vulnerable to the climate change impacts discussed in the previous section. **For example, approximately 4 percent of the state's population lives below the poverty line - a relatively low figure compared to many other states in India** (Government of Goa, 2023)**- is under risk.** Hence, **in terms of vulnerability, State Climate Change Action Plan (2023) has prioritized the Bardez, Mormugao, Tiswadi and Salcete talukas – our 3 selected towns fall under these talukas- for adaptation efforts, as these regions host the majority of the state's population (80%) and economic activities, and are at higher risk due to climate change** (Government of Goa, 2023, p. 147).

Further, the state is particularly vulnerable to sea level rise due to the impacts of climate change, and this phenomenon is already being observed. Goa is currently experiencing a rise in sea levels. For instance ; long-term data from the Mormugao station indicates that the sea level in this area has been rising at a rate of 1.45 mm per year, with 95 percent confidence, from 1969 to 2013 (Government of Goa, 2023). According to a United Nations Development Programme (UNDP) study cited in the Goa State Climate Action Plan, the state is at risk of losing a significant portion of its land, including many of its iconic beaches and vital tourist infrastructure. **A 1-meter rise in sea level could affect 7 percent of Goa's population and result in damages estimated at Rs. 8,100 crore** (Government of Goa, 2023). Additionally, **a recent study shows that between 1990 and 2018, around 26.8 km of Goa's 139.64 km coastline[xiv] (approximately 19%) has been affected by river and coastal erosion** (National Centre for Coastal Research, 2022).

The state is also responsible for 5.40 Mt CO2e net greenhouse gas (GHG) in 2018, contributing 0.18 per cent to India's GHG emissions (GHG Platform India, 2018)**. The per capita emissions of Goa were higher than India's per capita emissions, across the reference years[xv].** The major GHG-emitting sectors in the state are transportation, agriculture, waste, construction, and mining. **Energy sector was the major contributor to Goa's economy-wide emissions, throughout the reference period** (GHG Platform India, 2018). **In 2018, the domestic wastewater sector, which includes both rural and urban areas, accounted for 36 percent of total waste sector emissions (0.50 Mt CO2e), amounting to 0.30 Mt CO2e[xvi].**

Emissions from **domestic wastewater in both rural and urban areas grew at a compound annual growth rate (CAGR) of 3.42%,** increasing from 0.07 Mt CO2e in 2005 to 0.11 Mt CO2e in 2018. **Notably, approximately 65 percent of the domestic wastewater emissions in 2018 originated from the urban areas of Goa** (GHG Platform India, 2018).

The state has a Climate Change Action Plan (2023) in place that aligns with the national climate action framework, supported by **complementary sectoral policies and plans such national plan on climate change and human health, groundwater regulations and rainwater harvesting** initiatives. **Given its dependence on tourism sector, Goa also has a tourism policy (2020) that indirectly addresses environmental pollution, particularly the discharge of untreated domestic and industrial wastewater into beaches, creeks, and rivers.**

2.1 Financial Programmes and Schemes

In 2022–23, a substantial 68% of revenue receipts came from the State's own resources, while central tax transfers and grants-in-aid accounted for only 32%. This reflects a relatively strong financial position for the State, indicating greater fiscal independence and flexibility in resource allocation.

According to the State Climate Change Action Plan (SCCAP), Goa has budgeted INR **2,341.06 Crores** for 2023–2033, averaging **INR 234.106 Crores annually**. This equals **1.1%** of the state's annual budget (**INR 21,056.35 Crores, 2020–21**) and **0.26%** of GSDP (**INR 92,260.53 Crores**). Of this, **INR 15 Crores (0.64%)** is earmarked for sewage management and **INR 80.6 Crores (3.44%)** for water resources- reflecting weak prioritization. **Allocations for water and sanitation fluctuated between 2020–23: 8% (2020–21), rising to 13% (2021–22), before declining to 5% (2022–23).**

At the ULB level, the sources of revenue include own revenues (both tax and non-tax), assigned revenues, and government transfers, including Finance Commission (FC) grants. **The recent CAG report highlights a steady upward trend in the Municipal councils own revenue resources to their total revenue sources between 2016 and 2021** (Comptroller and Auditor General of India, 2024)**.** For instance, between **2016–2021**, municipal councils' own revenues formed an average of **56.14%** of total revenue, while grants averaged **39%**, with fiscal transfers contributing **20–49%** annually. However, ULBs generated only **74%** of their total expenditure, as **77%** of spending went to establishment costs (salaries/contingencies), leaving just **21%** for O&M and projects **(ibid).** This limits the ability of smaller municipalities to invest in climate-resilient water and sanitation infrastructure. Only larger cities like **Panaji and Margao** are financially self-sustaining.

Out town studies show concerns for financial sustainability in water and sanitation. The Public Works Department (PWD)- nodal agency to deliver infrastructure and service in water and sanitation, Goa faces persistent financial challenges in managing water supply and sanitation across towns like **Canacona, Mapusa, and Mormugao. In water supply, issues include fluctuating cost recovery (often dropping below 80%), inconsistent collection efficiency (ranging between 70–90%), and a heavy reliance on government grants due to low tariffs that fail to cover service costs. While occasional improvements, such as backlog settlements, temporarily boosted revenue, the long-term trend reflects weak billing systems, arrears, and consumer resistance. Sewerage and sanitation services face even greater challenges: in Canacona and Mapusa, cost recovery and collection efficiency remain at 0% due to absent or non-operational connections, making the sector entirely dependent on grants and subsidies. Although Mormugao has achieved stronger performance—80–97% cost recovery in water supply and up to 100% in sewerage—fluctuations in collection efficiency, enforcement gaps, and rising operational costs undermine sustainability.** Across towns, the absence of consistent revenue mobilization, weak tariff structures, and grant dependency constrain PWD's ability to finance infrastructure, maintain services, and build climate-resilient WASH systems. Strengthening tariffs, improving billing and collection mechanisms, and reducing external dependence are critical for long-term financial viability.

Moreover, there are no dedicated financing instruments—such as climate funds or ring-fenced budgets—for WaSH infrastructure in vulnerable areas. Finally, limited financial devolution keeps ULBs excluded from capital project planning and climate-sensitive decision-making, constraining their ability to build resilience and expand services.

Strengthening WaSH governance and resilience in Goa requires a comprehensive set of financial and institutional reforms. First, SCCAP allocations to water and sanitation must be increased to reflect their central role in adaptation, with budgetary support stabilized over multiple years to enable long-term planning. Enhanced fiscal devolution is critical to empower ULBs in planning, financing, and managing WaSH infrastructure, supported by reforms in user charges and improved property tax collection to build sustainable revenue streams. Ring-fenced budgets should be created for climate-resilient WaSH services at the ULB level, complemented by innovative instruments such as green funds and climate-linked borrowing mechanisms for urban infrastructure. ULBs also need training in financial planning, cost recovery, and service-based budgeting to improve efficiency and accountability. Further, ULB development plans must be aligned with SCCAP goals and incentivized through performance-based grants that reward measurable progress in climate resilience. Finally, leveraging central schemes such as AMRUT 2.0 and SBM 2.0 with matched state funding will strengthen financial sustainability and ensure resilient service delivery.

2.2 Institutional Landscape

Goa's **institutional architecture** for managing **urban water, sanitation, and environmental services** is characterized by **fragmentation, overlapping mandates, and weak coordination**. Key agencies like the **Public Works Department (PWD)**, **Water Resources Department (WRD)**, and the new **Department of Drinking Water (DDW)** share responsibilities without clear demarcation. Similar overlaps occur between **PWD** and the **Sewerage and Infrastructural Development Corporation of Goa Ltd. (SIDCGL)** in sanitation infrastructure planning, execution, and maintenance.

Urban Local Bodies (ULBs), despite being constitutionally responsible for water and sanitation under the **74th Constitutional Amendment Act**, are largely **marginalized** in infrastructure development. Most capital-intensive projects (e.g., STPs, trunk sewer networks) are controlled by higher-level state agencies **specifically PWD**. **The entire process—including technology selection, land acquisition, capital funding, technology implementation, and operations and maintenance (O&M)—is managed by the central government, state-level departments (such as the Public Works Department, and SIDCGL. This arrangement is unique to Goa state.** Such an arrangement undermines the spirit of decentralization envisaged under the 74th CAA and significantly restricts ULB autonomy in planning and managing infrastructure. **Being excluded from infrastructure development and planning and O&M, ULBs are not part of the tariff setting process and are unable to collect related revenues—further reducing their revenue base. This centralized approach disrupts the flow of critical information and finances, limiting ULBs' ability to make informed decisions, exercise ownership, and effectively manage sanitation infrastructure.**

As a result, the council's financial and technical capacity to effectively address the specific needs of its local population is severely compromised. Furthermore, interviews with the ULBs revealed that their role in disaster governance and planning is limited. They primarily focus on providing sanitation and water supply during the relief phase of a disaster. The **Comptroller and Auditor General (CAG)** has also flagged the **inadequate devolution** of powers to ULBs. Climate and disaster resilience planning remains mostly top-down, with ULBs playing a reactive rather than proactive role. The **absence of data-sharing systems**, unclear protocols for operation and maintenance, and lack of coordination across departments significantly **undermine climate-resilient urban sanitation planning**, especially in coastal towns.

To strengthen water and sanitation governance, it is essential to clarify and streamline mandates between PWD, WRD, DDW, and SIDCGL through formal MoUs and joint operational frameworks. A unified coordination mechanism, such as a state-level Urban Water and Sanitation Mission with interdepartmental representation, should be established to reduce

overlaps and improve accountability. In line with the 74th Constitutional Amendment Act, financial and functional powers must be devolved to ULBs, giving them greater authority over planning, budgeting, and the operation and maintenance of sanitation services. ULBs should also be integrated into climate resilience and disaster risk reduction (DRR) planning, enabling them to transition from reactive to proactive governance. Additionally, a shared information platform linking central, state, and municipal data on sanitation assets, performance, and service delivery would enhance transparency, coordination, and evidence-based decision-making.

2.3 Policy Landscape

State policies and programmes place greater emphasis on climate adaptation, with comparatively limited focus on mitigation and the resilience of water and sanitation infrastructure. This emphasis is well-founded—like most states in India, the priority must be to first strengthen adaptive capacity and enhance the resilience of communities before focusing on long-term mitigation goals.

Adaptation Focus

In Goa, most state policies at the intersection of **climate change**, **water**, and **sanitation** emphasize **adaptation**, with a stronger focus on **water resource management** than on **sewage and wastewater infrastructure**. Key policy objectives include addressing water scarcity, ensuring equitable access to drinking water and sanitation, and safeguarding environmental and public health—especially in the context of biodiversity and tourism. Despite Goa's high rainfall, the state faces serious **water quality** challenges due to high salinity, poor sewage infrastructure, and low groundwater retention. Several national and state-level policies aim to improve water use efficiency, promote rainwater harvesting, enhance groundwater recharge, and incentivize wastewater recycling. However, implementation lags behind policy intent. Although recent policies such as the **State Climate Change Action Plan 2023**, **Tourism Policy 2020**, and **State Water Policy 2022** propose measures (e.g., STP installation, decentralized recycling), **ground realities in towns like Canacona, Mormugao, and Mapusa** reveal poor infrastructure, low adoption of rainwater harvesting and decentralized sewage systems, and minimal enforcement of groundwater regulations. National programs like SBM, AMRUT, and Jal Shakti Abhiyan are present, but uptake and effectiveness remain low at the town level.

Water and sanitation policies in Goa exhibit a strong inclination toward water management, often at the expense of wastewater and sanitation infrastructure development. Key towns

such as Canacona, Mormugao, and Mapusa rely on inter-city sewage solutions and have limited sewage treatment plant (STP) coverage, highlighting poor infrastructure. Property-level wastewater treatment is neither enforced nor incentivized, leaving residents with little motivation to comply. Similarly, adoption of rainwater harvesting remains low despite subsidies, due to complex approval processes and high upfront costs. Regulatory frameworks, including groundwater extraction rules and wastewater reuse targets, exist but are rarely enforced or monitored. Coordination between departments such as Public Works and Health Engineering is weak, preventing the translation of policy targets—like wastewater reuse assessments—into action. Tourism-related pollution is acknowledged as a concern, yet enforcement of eco-regulations in high-footfall areas remains inadequate, further stressing the environment.

To strengthen water and sanitation governance within the context of climate change in Goa, the State Water Policy 2022 should be aligned with the Climate Action Plan 2023 to integrate infrastructure resilience and sewage management. Short-term targets, such as wastewater reuse assessments by departments like PWD and PHED, should be enforced with transparent reporting. STPs and sewerage networks must be expanded and upgraded, particularly in Mormugao, Canacona, and Mapusa, incorporating decentralized and nature-based solutions where appropriate. Property-level sewage treatment should be incentivized through tax rebates, faster subsidy clearance, and compliance monitoring, supported by institutionalized systems to ensure environmental adherence. Rainwater harvesting (RWH) approvals should be simplified and expedited, with greater awareness of scheme benefits. Groundwater extraction regulations, especially in tourism zones and peri-urban areas, must be enforced, and wastewater norms integrated into tourism licensing, linking infrastructure ratings to environmental compliance for hotels, resorts, and shacks. City-level water and sanitation master plans should incorporate climate risks and disaster resilience, while ULB staff receive regular training in sustainable wastewater management and climate-resilient infrastructure design. Finally, a central monitoring dashboard should track water reuse, STP coverage, and compliance of decentralized systems across towns to enable effective oversight and evidence-based decision-making.

Mitigation Focus

GHG emissions in Goa's **UWSS sector** stem from two main sources: **Indirect emissions** from **electricity consumption** for water supply, pumping, and treatment. **Direct emissions** from **biological processes**, including greywater and blackwater treatment, storage, and disposal.

While **mitigation** is a central theme in Goa's climate and energy policies, **municipal water and wastewater systems receive limited attention**. The state's mitigation priorities remain focused on **transport, buildings, industry, and solid waste**—the top contributors to

emissions. Mitigation in UWSS is largely confined to **energy efficiency improvements**, especially pump replacements. Goa has made **recent strides** in energy-efficient pump retrofitting and LED lighting, but lacks a cohesive approach to UWSS mitigation in its **Clean Energy Roadmap (2023)**. There is **almost no policy focus** on **energy generation from wastewater**, despite national and global best practices. Field visits to Canacona, Mapusa, and Mormugao confirm this absence. In terms of biological process mitigation, Goa treats **only 14%** of its urban wastewater. There are **no Faecal Sludge and Septage Treatment Plants (FSSTPs)**, and most towns rely on **private desludging operators**. While Goa's environmental laws and building regulations mandate septic design standards and decentralized wastewater systems, **actual implementation is absent**, especially in residential areas.

Water and sanitation systems in Goa are largely neglected in climate mitigation policies, which prioritize sectors such as transport and power. Only 14% of urban wastewater is treated**,** with the remainder contributing to greenhouse gas emissions and environmental degradation, while no Faecal Sludge and Septage Treatment Plants (FSSTPs) or decentralized wastewater solutions exist or are incentivized in the selected towns. Opportunities for energy recovery from wastewater, including biogas or heat recovery, remain unexploited, and enforcement of building codes mandating pollution-control designs is weak. Data on energy use and emissions from water and sewer services is limited, and municipal officials often lack technical capacity to implement mitigation technologies. **To address these gaps**, the Goa Clean Energy Roadmap (2023) should be revised to include UWSS mitigation targets, integrate UWSS into state and municipal GHG inventories, and mandate energy and water audits under the Energy Conservation Building Code framework. ULBs must be strengthened to conduct audits, evaluate DPRs, and ensure sustainable infrastructure. FSSTPs should be established where feasible, decentralized wastewater treatment promoted through financial incentives, and energy-efficient technologies—including solar-powered pumps, IoT monitoring, and SCADA systems—adopted. Cross-departmental coordination linking climate, energy, urban planning, and sanitation is essential, alongside subsidies or tax rebates for rainwater harvesting, decentralized treatment, and water reuse. Wastewater energy recovery projects can be included under carbon credit programs, and an online dashboard developed for real-time UWSS energy use and GHG monitoring to enable evidence-based mitigation and sustainable planning.

Infrastructure Resilience Focus

The **Goa SAPCC 2023** serves as the state's primary framework for climate action, explicitly highlighting the importance of strengthening the resilience of **water and sanitation infrastructure** as part of its "Habitat" agenda. Vulnerable talukas such as Bardez, Mormugao, Tiswadi, and Salcete are prioritized for climate-based vulnerability assessments and resilience

planning across critical sectors including water, sanitation, health, agriculture, and tourism. While the SAPCC calls for **climate-proofing infrastructure**, these priorities are not reflected in the **Goa State Water Policy 2022**, which lacks any mention of infrastructure resilience. The plan recommends integrating climate concerns into **land-use planning**, strengthening **city-level sanitation plans**, and updating maintenance protocols to address extreme weather and disaster events. Complementing this, the **Goa SDMP 2024** recognizes climate change as a **risk multiplier** that intensifies hydrometeorological hazards. It advocates for **mainstreaming disaster risk reduction (DRR)** across all infrastructure projects and highlights both structural (e.g., check dams, rainwater harvesting) and non-structural (e.g., hazard mapping, infrastructure audits) measures to enhance resilience. Despite strong policy intent, **ground realities in cities like Mapusa, Canacona, and Mormugao** reveal major infrastructure gaps. For instance, recently constructed sewerage systems in Mapusa were inundated during the monsoon, underscoring the absence of climate-resilient planning. Moreover, **Goa's cities are not part of the Smart Cities Mission**, limiting access to national funding and technical support for resilience-building.

Goa's water and sanitation sector faces significant climate resilience challenges due to a disconnect between policy and implementation. While the State Action Plan on Climate Change emphasizes resilience, the State Water Policy does not explicitly address infrastructure resilience. Existing water and sanitation systems are vulnerable to extreme climate events, and planning remains fragmented across land use, urban sanitation, and disaster management, with weak city-level climate-resilient sanitation strategies. Disaster risk reduction is poorly mainstreamed into infrastructure projects, exacerbating vulnerabilities. **To address these gaps,** the State Water Policy should be updated to explicitly incorporate climate resilience, and all critical infrastructure in high-risk talukas should undergo mandatory climate vulnerability assessments. Climate-resilient sanitation plans must be developed and implemented across urban local bodies, while future WaSH investments should integrate climate and disaster risk assessments. Vulnerable infrastructure should be retrofitted and upgraded, stormwater systems designed for future variability, and smart technologies like IoT sensors and GIS mapping adopted for real-time monitoring. Early warning systems, flood forecasting, and retention basins should be incorporated into urban infrastructure, alongside nature-based solutions such as mangrove restoration and dune protection. Coordination between the State Disaster Management Authority, ULBs, and sectoral departments should be strengthened, ULB officials trained to review DPRs through a climate-resilience lens, and engineering standards updated to embed resilient design. Performance-linked incentives can further encourage local governments to invest in climate-resilient public services, ensuring sustainable, adaptive urban water and sanitation systems.

Policies Concerning Coastal Areas

Coastal water and sanitation governance in India faces significant gaps, with the absence of a dedicated coastal climate mission under the NAPCC limiting national-level guidance and funding for vulnerable areas.

While India lacks a dedicated national mission for coastal climate adaptation under the NAPCC, several policies and programs address the intersection of water, sanitation, and climate change in coastal areas like Goa. These include the National Water Mission, Integrated Coastal Zone Management Plan (ICZMP), CRZ Notifications, Goa's Coastal Zone Management Plan (CZMP 2021), the Goa SAPCC (2023–33), and the draft Goa State Biodiversity Strategy & Action Plan (GSBSAP 2025). **These instruments collectively promote water efficiency, regulate tourism infrastructure, protect ecologically sensitive zones (e.g., khazan lands, mangroves, salt pans), and advocate for integrated and nature-based coastal resilience approaches. However, sanitation is weakly integrated in most frameworks, and domestic wastewater management remains under-addressed.**

The Coastal Zone Management Plan (CZMP), while regulating tourism infrastructure, lacks comprehensive provisions for sewerage connectivity and domestic wastewater management, resulting in ongoing contamination of rivers and coastal waters with untreated sewage, which poses serious health and ecological risks. Existing and planned infrastructure is often not climate-proofed against sea-level rise and extreme rainfall, and adoption of advanced treatment technologies and effluent reuse remains slow. Enforcement of CRZ and sanitation guidelines is weak, and institutional coordination across coastal, climate, water, sanitation, and biodiversity sectors is inadequate. To address these challenges, a National Coastal Climate Resilience Mission should be established to integrate water, sanitation, and climate adaptation in coastal zones, while strengthening coherence between CRZ norms, biodiversity plans, and sanitation frameworks. Climate-resilient sanitation infrastructure, including decentralized systems and improved stormwater drainage, should be expanded in coastal towns, and existing water and sewage networks, STPs, and supply systems upgraded and climate-proofed. Stricter wastewater regulation, promotion of treated wastewater reuse, and mainstreaming of nature-based solutions such as mangrove restoration, dune protection, and khazan land rehabilitation are essential. Local governance must be enhanced through biodiversity management committees and nodal officers, complemented by community-based management, integration of traditional knowledge, and improved hazard mapping and climate risk assessments to guide land-use and infrastructure planning.

3. Maharashtra

The state is listed **among the top three most climate-vulnerable states** (Mohanty & Wadhawan, 2021). Approximately 12% of the land is susceptible to floods and river erosion, while Maharashtra's 720 km long indented coastline[xvii] is vulnerable to cyclones and tsunamis (National Centre for Disease Control , 2022). Additionally, 68% of the cultivable land faces drought risks, and hilly regions are exposed to the threat of landslides and avalanches (ibid).

Maharashtra is also observing higher temperatures in coastal cities, such as Mumbai, Dapoli, and Ratnagiri (National Centre for Disease Control , 2022)**. The state, third most urbanized state in India, is also one of the major contributors towards urban domestic wastewater related methane emissions in the country** (Shroff, Caleb, Kolsepatil, & Mishra, Briefing Paper: Opportunities for Reduction of GHG emissions from Domestic Wastewater Treatment in Urban Areas, 2019) **;** (Mohanty, et al., 2020)**. The heightened vulnerabilities to disaster risks in Maharashtra can be related to expanding population, urbanization and industrialization, development within high-risk zones, environmental degradation and climate change** (National Centre for Disease Control , 2022).

The Intergovernmental Panel on Climate Change (IPCC) recognizes universal access to water, sanitation, and hygiene (WaSH)—as targeted in SDGs 6.1 and 6.2—as a critical, low-regret adaptation strategy, supported by high confidence. Ensuring universal access to WaSH not only contributes directly to SDG 11 (sustainable cities and communities) but also promotes social equity and environmental sustainability.

The state is experiencing a severe water crisis, with a record deployment of water tankers, late monsoons, and deficient rainfall depleting groundwater in **279 talukas** and leaving less than **10% live storage** in **13 major reservoirs** (CEPT, 2024). Data for **2021–2022** show that towns of all sizes fail to meet the **SLBs of 100% water supply and sewerage connections**, with the exception of individual toilets—though at least **3 towns** still lack full toilet coverage (Government of Maharashtra, 2022, p. 47)**.** Smaller towns show the lowest access, highlighting the need to prioritize WaSH infrastructure, while variations in service coverage also result in differing direct and indirect emissions across towns of different sizes.

The poor sewage management leads to GHG emissions. The GHG emissions from domestic wastewater sector of Maharashtra contributed 54% of the state's total emissions in the waste sector (11.77 MtCO2) in 2018. The total GHG emissions from domestic wastewater treatment and discharge for urban Maharashtra in 2018 were estimated to be 30,47,989 tCO2, equating to 0.051 tCO2 per capita—slightly lower than the national average of 0.053 tCO2) (GHG platform India). **The state is also one of the five states—along with Uttar Pradesh, Tamil**

Nadu, West Bengal, and Gujarat—that collectively contributed to approximately 47% of the total CH_4 emissions from urban domestic wastewater in 2018. This is largely due to lower sewerage network connections leading to a reliance on OSS systems which are significant source of CH_4 emissions in these states (Shroff, Caleb, Kolsepatil, & Mishra, Briefing Paper: Opportunities for Reduction of GHG emissions from Domestic Wastewater Treatment in Urban Areas, 2019). Therefore, the promotion of FSSTPs (fecal sludge and septage treatment plants) is highly significant. The state is a frontrunner in managing fecal sludge, with 179 operational FSTPs and 60 more in development.

To address these challenges, the state has established a Climate Cell to facilitate the integration of climate change considerations across various sectors. However, there is an urgent need to update the State Action Plan on Climate Change to reflect current realities, as the last version was released a decade ago in 2014. Nevertheless, Maharashtra has introduced several policies and programmes that directly or indirectly contribute to adaptation and mitigation efforts in the water and sanitation sector.

3.1 Financial and Programmes/Schemes

Maharashtra's urban water and sanitation financing relies on a mix of **centrally sponsored schemes (AMRUT, SBM-U/2.0)**, state budgets, Finance Commission grants, and ULB revenues. The AMRUT mission in Maharashtra covers 44 cities and 76% of the urban population, with sanctioned grants of ₹7,759 crore (Government of Maharashtra, 2022a). Of this, ₹4,313 crore was allocated for 38 water supply projects across 34 cities, of which 14 projects worth ₹931 crore in 13 cities had been completed by January 2022, while ₹3,267 crore was approved for 30 sewerage projects, with 3 projects worth ₹150 crore completed. In addition, 128 Green Space (Amrutvan) projects worth ₹179 crore were sanctioned, of which 122 projects worth ₹171 crore were commissioned. However, priority under AMRUT has leaned towards water supply over sewerage in terms of projects, per-project allocations, and expenditure (Government of Maharashtra, 2022a).

Under SBM-U, all cities in Maharashtra were declared ODF on 1 October 2017 (Centre for Policy Research, 2019), but by March 2018, only 35% of the allocated funds had been released, pointing to challenges in utilization (Centre for Policy Research, 2019) . Budget allocations across sectors increased between 2019–2024, though urban development, water supply, and sanitation remained among the bottom five, just above housing. Despite this, CAGR analysis shows sharp growth, with urban development, water, and sanitation among the top three sectors (33% and 57% respectively), suggesting a gradual shift in priorities (Government of Maharashtra, 2022a).

The Maharashtra Suvarna Jayanti Nagarotthan Maha Abhiyan (MSJNMA) and Vasishpurna Scheme, aimed at smaller towns, recorded a 27.3% rise in allocations between 2016–2020 (Centre for Water and Sanitation, 2019). By January 2022, 224 projects worth ₹12,801 crore were approved under MSJNMA, of which 64 projects worth ₹3,856 crore were completed (Government of Maharashtra, 2022a). Sewerage projects, though fewer in number, had higher per-project allocations and better performance on completion and expenditure than water supply.

Finance Commission grants to the state increased by 218% between 2015–2020 (Centre for Water and Sanitation, 2019), but only 16–20% of state transfers were devolved to ULBs, limiting their effective functioning. At the same time, ULBs' own-source revenue steadily declined between 2015–2020 (Government of Maharashtra, 2022a), increasing their dependence on state and central grants and eroding autonomy. To support ULBs, the state introduced incentive funds, allowing ODF cities to use SBM Incentive Funds and 50% of 14th Finance Commission grants to achieve ODF+ and ODF++ status. The total eligibility under SBM Incentive Funds was ₹408 crore, with a state share of ₹1,675 crore allocated for 2015–2020 (Centre for Water and Sanitation, 2019).

Wastewater management in smaller towns suffers from poor cost recovery and weak collection of user charges, despite capital inflows from central and state schemes. The reliance on uniform, centralized systems—flagged as financially unsustainable in the **National Urban Sanitation Policy (2008)**—worsens the challenge. A sharp disparity exists between **municipal corporations**, which generate **86%** of revenues internally, and smaller **municipalities**, which generate only **51%** (Centre for Water and Sanitation, 2019).

At the ULB level, our studies reveal persistent financial distress in Ratnagiri, Vengurla and Alibag. Between 2009–10 and 2022–23, Ratnagiri, Vengurla, and Alibag Municipal Councils struggled with severe financial instability in managing water supply and sanitation services. RMC's cost recovery in water supply fell to 36.71% by 2023–24, with collection efficiency dropping from 92.44% to 35.84%, and fiscal deficits peaking at ₹53.19 crore in 2022–23, while sewerage services depended almost entirely on over ₹150 crore in grants. VMC relied on grants for over 98% of its water supply financing, saw cost recovery plummet to 1.76% by 2022–23, and accumulated a fiscal deficit of ₹74.25 crore, with nearly zero collection efficiency in sanitation for a decade. AMC, though benefiting from central grants, faced a declining cost recovery ratio (46.88%), deficits from bulk water purchases, and dependence on fluctuating external funds. Across all three towns, low local revenue generation, weak billing and enforcement, and rising operational costs have deepened fiscal deficits, making

financial reforms in tariff revision, revenue collection, cost control, and strategic funding alignment urgent for long-term sustainability.

Parallel to the regional trends, CDD India assessment of Malvan, Guhagar, and Dahanu reveals deep-seated disparities between operational coverage and financial viability. **Malvan Municipal Council** presents a stark dichotomy; while it achieves a robust 97.45% cost recovery and 97% collection efficiency in water supply, this financial health is isolated, as both sanitation and Solid Waste Management (SWM) sectors operate with 0% cost recovery and collection efficiency, signalling total dependence on external subsidies. **Guhagar Nagar Panchayat** exhibits a similar fiscal vulnerability despite operational excellence; while achieving 100% success in SWM handling, the system recovers only 6% of its costs, and the water sector struggles with 50% cost recovery and 0% metering, severely limiting revenue mobilization. **Dahanu Municipal Council** faces broader financial distress, where SWM cost recovery is a mere 17% and water supply recovery stands at 43.50%, exacerbated by a low collection efficiency of 63% in waste management. Across all three towns, the disconnect is profound: despite high reported toilet coverage (100%), centralized sewage infrastructure is virtually non-existent (0% network coverage in Guhagar and Dahanu), resulting in a complete absence of sanitation revenue. This systemic inability to monetize services, coupled with discontinuous water supply (averaging 1–2 hours daily), underscores a critical need for structural tariff reforms and infrastructure investment to reverse the growing reliance on government grants.

To strengthen the sustainability of water and sanitation services, the state must rebalance sectoral priorities by enhancing allocations for sanitation alongside water supply, while ensuring timely and adequate devolution of Finance Commission grants to safeguard ULB autonomy. Dedicated urban WaSH funds, combined with capacity-building support, can further enable effective planning and delivery. At the ULB level, reforms are needed to improve financial health through periodic tariff revisions, stronger revenue mobilization, better billing and collection systems, and adoption of digital platforms. Exploring alternative financing mechanisms such as municipal bonds, and pooled financing can help bridge capital investment gaps, while cost-control measures, energy-efficient technologies, and preventive maintenance can reduce operational burdens. Integrated service planning that links water supply with sanitation, reuse, and waste management should be prioritized, alongside performance-based grants and transparent data systems to monitor revenues, expenditures, and outcomes. Together, these measures can help build resilient, financially viable, and inclusive water and sanitation systems in Maharashtra's towns and cities.

3.2 Institutional Landscape

In Maharashtra, overlapping mandates across state agencies lead to duplication, inefficiencies, and accountability gaps in water, sanitation, energy, climate, and disaster management. The Water Resources Department (WRD) and Maharashtra Jal Pradhikaran (MJP) both manage rural water infrastructure, creating duplication in watershed development and groundwater recharge. The Public Works Department (PWD) continues to build pipelines and sewerage systems, even though Urban Local Bodies (ULBs) handle service delivery, causing ambiguity in maintenance. In energy, the Maharashtra Energy Development Agency (MEDA) promotes renewable energy but depends on WRD and MSEDCL for implementation, delaying projects such as rooftop solar. Climate governance is similarly fragmented, with SCCC, MPCB, the Environment and Climate Change Department, and CZMA working in silos. Disaster management is led by MSDMA but relies heavily on WRD and UDD, especially in flood control and emergency water supply.

Urban water and sanitation governance faces further systemic challenges. Overlapping roles among WRD, MJP, PWD, and UDD weaken accountability. Within ULBs, responsibilities are misaligned: they handle operations and maintenance but are excluded from planning, design, and investment decisions, undermining performance and resilience. Their limited role in long-term climate preparedness compounds vulnerabilities. Financial fragility—marked by low cost recovery, operational deficits, and dependence on external grants—constrains sustainability. Sanitation infrastructure is poorly integrated with climate and disaster frameworks, while unregulated household on-site sanitation (OSS) in flood-prone areas increases health and environmental risks. ULBs also remain peripheral to disaster governance, engaged mainly in post-disaster relief rather than proactive risk reduction.

Strengthening governance requires clarifying mandates across WRD, MJP, UDD, and others to reduce duplication and improve accountability. ULBs must be empowered in planning, design, and capital investment, alongside strengthened finances through better cost recovery and diversified revenues. Policy integration of water and sanitation with climate risk and disaster preparedness is essential. Regulatory oversight of household OSS, with local mechanisms and technical support, is needed to safeguard public health and ensure resilience.

3.3 Policy Landscape

It is clear that while state policies primarily focus on adaptation, they also indirectly support broader mitigation goals in water and sanitation services. **This is reflected in the budget allocations for 2023-24, where 5% is dedicated to adaptation compared to just 2% each for mitigation and resilience efforts.** This prioritization is understandable—similar to many other Indian states—since none of the towns currently meet the Service Level Benchmarks (SLBs) for water supply and sewerage connections. Therefore, the immediate focus must be on strengthening adaptive capacity and enhancing community resilience before advancing long-term mitigation objectives.

Adaptation Focus

The State Action Plan on Climate Change is outdated, having been last updated in 2014, and requires a revision to reflect current priorities and emerging climate challenges. Maharashtra's climate and WaSH policies mainly focus on adaptation, emphasizing climate-resilient development through strategies like rainwater harvesting, groundwater recharge, water-use efficiency, wastewater recycling, and groundwater regulation. The State Water Policy (2019) and Integrated State Water Plan (2018) reinforce these priorities, but wastewater reuse remains low nationally and locally, with Vengurla leading in decentralized treatment and monitoring. Groundwater management under the 2009 Act is effectively enforced in Ratnagiri and Vengurla, including mandatory extraction permits. Rainwater harvesting, offering both adaptation and mitigation benefits, is underused except in Vengurla, where 60–70% of municipal buildings have systems supported by state incentives. The Maharashtra Water Resources Regulatory Authority promotes efficient water use, though key initiatives are still in draft. Water and energy audits, encouraged by state policies, are mainly practiced in Vengurla, enabling targeted improvements. Health sector plans focus on maintaining essential WaSH services during climate events and adopting eco-friendly, energy-efficient technologies.

In the WaSH sector, many towns face low wastewater recycling rates and inadequate sewage treatment infrastructure, while rainwater harvesting adoption is restricted to a few proactive municipalities. Draft regulatory frameworks and economic instruments for water reuse and efficiency are not yet fully operational, and implementation of water and energy audits is uneven, with weak integration of health and WaSH climate resilience planning. Service Level Benchmarks for water supply and sanitation infrastructure remain incompletely achieved. To address these gaps, mitigation-focused initiatives should be strengthened and expanded alongside existing adaptation efforts. Sewage treatment infrastructure must be accelerated, and wastewater recycling improved across towns, while widespread adoption of rainwater harvesting should be promoted through incentives and regulatory mandates. Regulatory frameworks such as water entitlement transfers and wastewater reuse certificates should be

finalized and implemented to encourage efficient water use. Water and energy audits need to be scaled up across urban local bodies, and health-sector climate resilience integrated with WaSH planning to ensure uninterrupted essential services during climate events. Enhanced budgetary allocations and policy support are essential to complement adaptation measures and achieve service-level goals.

Mitigation Focus

Maharashtra's WaSH sector has made notable strides in climate change mitigation through leadership in faecal sludge management—with 179 operational and 60 upcoming treatment plants—and the promotion of non-networked sanitation systems that reduce operational emissions. The state also plans to install 425 energy-efficient water pumps in AMRUT cities under the Municipal Energy Efficiency Programme (MEEP), supported by key policy instruments like the Septage Management Guidelines (2016) and the Integrated State Water Plan (2018). **However, major challenges persist, including limited integration of climate and WaSH policies, slow progress in implementing energy-efficient technologies—with only 12 of 44 AMRUT cities advancing in pump installations—and a heavy reliance on centrally driven programmes with minimal local innovation. Additionally, MEEP's focus has largely been on street lighting rather than water pump efficiency.** At the local level, encouraging efforts are visible, exemplified by Vengurla Municipal Council's energy and water audits and its proactive promotion of renewable energy. The council has equipped all municipal buildings with rooftop solar systems and introduced property tax incentives for households adopting rooftop solar panels and rainwater harvesting, reflecting a strong commitment to reducing carbon footprints.

Recommendations include strengthening policy integration across climate and WaSH sectors, accelerating energy efficiency project implementation beyond street lighting, encouraging localized innovation and planning, and scaling up renewable energy and water-saving initiatives at the municipal and household levels to enhance climate resilience. Further, strengthen and expand mitigation-focused initiatives within WaSH, alongside existing adaptation efforts.

Infrastructure Resilience Focus

Maharashtra's State Climate Change Action Plan and Disaster Management Plan 2023 recognize the vulnerability of water and sanitation (WaSH) infrastructure to climate impacts such as floods, droughts, sea-level rise, and landslides. Both plans emphasize enhancing physical resilience through climate-informed design, improved drainage, flood mitigation, ecosystem restoration (e.g., mangroves, wetlands, Miyawaki forests), and decentralized community management. Structural measures include embankments, retention basins, check

dams, watershed recharge, and infrastructure retrofitting, while non-structural strategies involve hazard zoning, early warning systems, GIS risk mapping, and policy integration with resilient building codes. Innovative data-driven water management using IoT and climate forecasting supports proactive risk response, particularly in cities under the Maharashtra Resilient Cities Development Programme. The Smart Cities Mission promotes integrating disaster resilience in urban projects. However, field studies in Vengurla, Ratnagiri, and Alibag reveal that much existing and planned WaSH infrastructure lacks disaster and climate-proofing considerations.

Existing water and sanitation infrastructure in Maharashtra often lacks climate resilience and disaster risk integration, and new infrastructure plans rarely incorporate climate or disaster risk assessments. Coordination across multiple governance levels and sectors is complex, limiting effective implementation, while vulnerability remains high in flood-prone, drought-affected, coastal, and hilly areas due to inadequate protective measures. Urban local bodies (ULBs) have a limited role in disaster risk and climate planning. To address these gaps, climate-resilient design and planning should be integrated into all water and sanitation projects, including stormwater systems designed for future variability, and infrastructure should incorporate flood forecasting, early warning systems, and retention basins. Land-use and building codes must be enforced based on hazard assessments, and coordination strengthened among the State Disaster Management Authority, ULBs, and relevant departments. Climate-resilient design standards should be embedded into engineering manuals, with targeted training provided to ULBs for reviewing Detailed Project Reports (DPRs). Climate projections and risk assessments must guide both new and existing WaSH infrastructure, prioritizing retrofitting and upgrades of vulnerable systems. Advanced data-driven tools, such as IoT sensors and GIS mapping, should be institutionalized to enable proactive risk monitoring and adaptive management of urban water systems.

Policies Concerning Coastal Areas

Despite the vulnerability of Maharashtra's coastal regions to climate change impacts—such as sea-level rise, saltwater intrusion, cyclones, and flooding—there is no dedicated national mission under the National Action Plan on Climate Change (NAPCC) focused on coastal adaptation. Institutions like the National Centre for Sustainable Coastal Management (NCSCM) and frameworks like the Integrated Coastal Zone Management Plan (ICZMP) have improved hazard mapping and coastal planning, but coordination and enforcement remain fragmented. In Maharashtra, the State Adaptation Action Plan (MSAAPC) acknowledges coastal vulnerabilities and promotes climate-resilient water and sanitation systems, groundwater protection, and integrated water resource management.

Many water and sanitation systems are not designed to withstand extreme weather or saline intrusion, and adoption of alternative water technologies such as desalination, rainwater harvesting, and wastewater reuse remains low, particularly in smaller coastal towns. To address these challenges, a National Mission for Coastal Climate Adaptation and Resilience should be established to focus on water, sanitation, and ecosystem resilience. Enforcement of Coastal Zone Regulations must be strengthened, integrating CRZ and climate adaptation plans into town-level planning. Saltwater intrusion mitigation measures, including Bandharas, groundwater recharge, and regulation of coastal extraction, should be expanded, alongside ecosystem-based adaptation such as mangrove restoration and wetland protection. Town-level efforts, such as those by the Vengurla Municipal Council, demonstrate localized best practices—including mangrove protection, solid waste management, and traditional rainwater harvesting (Bandharas)—to mitigate saltwater intrusion and enhance resilience. Alternative water solutions and decentralized wastewater recycling must be scaled up, and local institutional capacity—especially of ULBs—enhanced through training, funding access, and decentralized planning mandates. Cross-agency coordination among the Maharashtra Maritime Board, ULBs, and the Coastal Zone Management Authority should be fostered, and local best practices, such as those implemented in Vengurla, replicated across other coastal towns through knowledge sharing and financial incentives.

4. Gujarat

Gujarat ranks among the top 10 in terms of population, accounting for 4.99% of the national total. Approximately 43% of its population (60 Million population as per Census 2011) lives in urban areas. Although Gujarat comprises only around 5% of the country's population, it contributed 8.27% to the national GDP in 2023 (Directorate of Economics & Statistics, 2024). **With a 1,600 km-long coastline[iii]—the longest in India—and approximately 9.9 million people residing across 40 coastal talukas, the state is especially vulnerable to climate-related hazards such as sea-level rise, cyclones, storm surges, strong winds, heavy rainfall, and salinity ingress** (Government of Gujarat, 2021)**;** (Gujarat State Disaster Management Authority, 2024)**. In addition to rising sea levels, the state faces significant climate change risks, including extreme temperatures and erratic precipitation patterns. By 2050, 19 of Gujarat's 26 districts are projected to become climate hotspots, with temperatures expected to rise by 2–2.5°C** (Government of Gujarat, 2021)**. These impacts affect agriculture (employs 50% of the workforce, contributes 9.5% to the Gross State Domestic Product), key economic sectors**, **infrastructure, and population groups** (Government of Gujarat, 2021).

To effectively adapt to the looming risks of climate change and build resilience, the state must ensure the delivery of basic services. **Notably, it performs well across several key**

development indicators. For example, for instance, the state ranks ninth in per capita net GDP for the year 2022–23, trailing behind Goa (2nd) and Karnataka (7th) (RBI, 2024, pp. 65-68). In **terms of Sustainable Development Goals (SDGs), it ranks 6th nationally—tied with Andhra Pradesh and Telangana—with a composite score of 74 out of 100 for 2023–24** (NITI Aayog, 2024)**. It performs particularly well on SDG 6 (Clean Water and Sanitation), scoring 98 out of 100 and securing the 3rd rank. For SDG 11 (Sustainable Cities and Communities), the state scores 94, placing it among the top two states in the country** (NITI Aayog, 2024)**.**

However, the state shows only moderate performance in terms of installed sewage treatment capacity as a percentage of sewage generated in urban areas (NITI Aayog, 2024)**. This stands at 67.38%, which is better than Goa (59.09%) and Karnataka (60.83%), but significantly lower than Maharashtra, which exceeds 100% (107.82%)** (NITI Aayog, 2024). This impacts not only water pollution, environmental degradation, and public health, but also contributes to greenhouse gas (GHG) emissions. For instance, the domestic wastewater sector, encompassing both rural and urban areas, accounted for 3.42 Mt CO2e i.e., 34% of total waste sector (10.11 Mt CO2e) GHG emissions in 2018 (GHG Platform India, 2018). **The study, however, overlooks energy consumption in its analysis of GHG emissions from the domestic wastewater sector. Including this factor would offer a more comprehensive understanding of emissions.**

The state has implemented numerous initiatives to address climate change risks. **Gujarat is the only state in India to have established a dedicated climate change department over a decade ago, recognizing climate change as a critical concern for both the state's natural ecosystems and human-made systems** (Government of Gujarat, 2021). The state has developed a Climate Change Action Plan aligned with the national climate action framework, complemented by several supporting policies. **The plan, recognizing the interconnectedness between adaptation and resilience, as well as adaptation and mitigation, proposes a set of integrated strategies and measures. Acknowledging the crucial link between climate change and human health, Gujarat has also crafted a specific climate action plan focused on human health.** Additionally, the state has adopted various mitigation policies, including renewable energy, solar energy, and water management policies.

4.1 Financial Programmes and Schemes

Established in 2009, Gujarat's Department of Climate Change was the first dedicated climate department in India. Since 2015, its primary programmes have focused on renewable energy and ecology/environment. In 2020–21, the department received only **0.44% of the total state budget** (Government of Gujarat, 2021). Between 2023 and 2026, the department's focus shifted predominantly to solar energy programmes, with corresponding budget

allocations (refer (Government of Gujarat, 2021, pp. 216-218). Additionally, several adaptation and mitigation schemes are implemented through other departments. **Among selected states, Maharashtra spends the most on natural calamity relief, followed by Karnataka and Gujarat, while Goa allocates the least** (RBI, 2024)**.**

Gujarat's urban development, water, and sanitation sector is supported through **SJMMSVY, AMRUT, and SBM-U**. **SJMMSVY** (2009–2024) had a total outlay of **₹47,402.25 crore**, with **128 STPs completed** across 120 municipalities and **116 underground drainage projects** worth **₹2,525 crore** approved (Directorate of Economics and Statistics, 2025). Under **AMRUT 2.0**, **922 projects** worth **₹17,717 crore** were sanctioned, including **430 water supply projects** (**₹7,566 crore**) and **171 sewerage projects** (**₹9,380 crore**), targeted for completion by September 2026. **SBM-U** delivered **5,60,046 household toilets**, achieving ODF status across 157 municipalities and 8 municipal corporations, with **142 ULBs certified ODF++**. **Despite a** 10% CAGR **in allocations between 2020–21 and 2022–23, the water and sanitation sector remains underfunded compared to top sectors like education, energy, transport, and health** (ibid).

At the ULB level, between 2019 and 2024, **Gujarat's municipal corporations derived nearly 50% of their revenue from own tax sources**, **significantly higher than Maharashtra and Karnataka, indicating relatively stronger financial health and greater revenue autonomy. Similarly, the state has a relatively high share of** water and sewerage/drainage taxes **in its own revenue compared to southern states**, **reflecting effective tax recovery and contributing to ULBs' financial sustainability** (Department of Economic and Policy Research, 2024)**. Further,** between 2019 and 2024, **capital expenditure on sewerage and drainage by Gujarat's municipal corporations** consistently accounted for **3–4% of total capital spending**. Overall expenditure nearly **doubled** over five years, despite a dip in 2022–23, indicating a **100% increase** in sector investment(ibid).

To strengthen Gujarat's urban water and sanitation sector, overall budget allocations should be increased, with a particular focus on expanding and modernizing sewerage infrastructure using climate-resilient and decentralized solutions. Climate adaptation and resilience measures must be integrated into urban sanitation planning, linking ULB projects with broader state climate initiatives. Cost recovery and revenue collection should be improved through revised tariffs, efficient billing systems, and arrears management, while ULBs' financial management capacities need strengthening to control operational costs and optimize maintenance, energy use, and staffing. Multiple funding sources, including state and central schemes and innovative financing mechanisms, should be leveraged, alongside robust monitoring systems to ensure accountability, performance tracking, and long-term sustainability of water and sanitation services.

4.2 Institutional Landscape

Gujarat's institutional framework for water, sanitation, energy, and climate resilience is highly fragmented, with multiple departments and agencies—such as the Urban Development Department, GWSSB, GUDC, GUDM, GIDB, and GEDA—sharing overlapping responsibilities across planning, financing, implementation, and regulation. This overlap has led to inefficiencies and duplication in infrastructure development, particularly in urban water, sewerage, climate resilience, and disaster management. Urban Local Bodies (ULBs) have limited financial and institutional autonomy, relying heavily on state agencies and central schemes for large infrastructure projects like sewage treatment plants. ULBs also have limited operational capacity for disaster preparedness and weak regulatory enforcement of household sanitation. Key recommendations include clarifying institutional mandates to reduce overlaps, strengthening ULB financial, technical, and human resource capacities, and decentralizing infrastructure planning to give ULBs greater control over project design and technology choices. Integrated planning through joint task forces, improved regulatory oversight of household sanitation, and building local disaster resilience with dedicated teams and early warning systems are also crucial for effective and sustainable service delivery.

4.3 Policy Landscape

State policies and programs prioritize climate adaptation over mitigation, focusing on strengthening community resilience and adaptive capacity before addressing long-term mitigation goals.

Adaptation Focus

Gujarat's climate change and water-sanitation policies primarily focus on adaptation strategies addressing water scarcity, equitable access to drinking water and sanitation, and human/environmental health. Key recommended measures include diversifying water sources, promoting rainwater harvesting, groundwater recharge, efficient water use, groundwater regulation, treated wastewater recycling, and protection against saltwater intrusion. Despite robust policy frameworks—such as the State Climate Action Plan, national groundwater extraction guidelines, and state-level wastewater reuse policies—several **challenges** limit effective implementation and outcomes:

Gujarat faces severe water stress, groundwater depletion, and saltwater intrusion, compounded by declining mangrove cover. Implementation gaps, weak regulatory

compliance, limited wastewater treatment and reuse, low adoption of rainwater harvesting, and constraints in residential and commercial settings undermine water and sanitation management, especially in smaller towns – as witnessed in our town assessments.
Key recommendations include strengthening program implementation and monitoring, enforcing groundwater regulations, and scaling up wastewater and sludge recycling. Support for small and medium towns in adopting decentralized solutions, promoting rainwater harvesting through incentives, restoring mangroves, and fostering multi-sectoral coordination are also critical for enhancing water security and climate resilience.

Mitigation Focus

Gujarat's Urban Water Supply and Sanitation (UWSS) sector contributes to greenhouse gas (GHG) emissions through both direct (biological processes) and indirect (electricity consumption) sources. Since 2019, the state has made notable strides in promoting renewable energy (solar and wind) and energy efficiency through schemes like UJALA and PAT. **However, in the UWSS sector, mitigation efforts are narrowly focused on reducing electricity use—primarily in street lighting—while opportunities to generate energy from wastewater (e.g., biogas at STPs) remain underexplored.**

Town studies show water and sanitation services (UWSS) face significant gaps in GHG accounting, energy efficiency, and wastewater management. Official data underestimates emissions by excluding energy use from pumping, while opportunities for energy recovery from sewage and faecal sludge remain largely untapped. Inefficiencies in treatment infrastructure, weak enforcement of decentralized systems, and a focus on street lighting over water systems exacerbate emissions.

Key recommendations include institutionalizing GHG monitoring and reporting, expanding energy efficiency programs to cover water and wastewater utilities, and enabling energy generation from STPs and FSSTPs. Strengthening decentralized wastewater solutions, fast-tracking sewerage and sludge infrastructure, improving interdepartmental coordination, and building ULB capacity for low-carbon, climate-resilient UWSS are also critical for effective mitigation and sustainable urban service delivery

Infrastructure Resilience Focus

Gujarat's coastal areas are highly vulnerable to extreme climate events such as floods, cyclones, and heavy rainfall, which severely disrupt water supply, sewerage, and sanitation systems, posing significant public health risks. Coastal towns face compounded threats from both riverine and coastal flooding, including seawater backflow that degrades water quality and reduces infrastructure longevity. Extreme weather often causes power outages,

disrupting water treatment and sewage operations; however, backup power systems are inconsistently implemented, with many Sewage Treatment Plants (STPs) having backups while water treatment plants often lack them. **Although the State Climate Change Action Plan and the Disaster Risk Mitigation and Management Plan emphasize climate-proofing infrastructure, many facilities remain vulnerable in practice. For instance, the sewage treatment plant in Devbhumi Dwarka was flooded and rendered non-operational after the 2024 floods, and seawater intrusion in coastal cities like Valsad continues to cause corrosion and service disruptions.**

Water and sanitation infrastructure should integrate climate-resilient design and planning, incorporating flood forecasting, early warning systems, and stormwater management to handle future climate variability. Strengthening enforcement of hazard-informed land-use and building codes, upgrading vulnerable infrastructure, and embedding climate standards into engineering practices are essential. Effective coordination among disaster management authorities, ULBs, and relevant departments, combined with targeted training and the use of advanced data-driven tools, can enhance risk monitoring and adaptive management of WaSH systems.

Policies Concerning Coastal Areas

Gujarat's coastal regions are highly vulnerable to climate change impacts such as sea-level rise, saltwater intrusion, cyclones, coastal flooding, and extreme weather events. Despite this, there is **no dedicated national mission for coastal climate change adaptation**, and existing measures under the **National Water Mission** only partially address the unique challenges faced by coastal cities. These include degradation of groundwater due to salinity, lack of freshwater alternatives, and poor wastewater management. Although Gujarat has developed coastal zone management plans (CZMP) and state-level climate and disaster management plans **addressing vulnerabilities such as sea level rise, erosion, and extreme weather, enforcement and integration of these policies remain complex.** Challenges persist in managing saline intrusion, protecting sensitive ecosystems like mangroves, and ensuring sustainable water resource use in the face of over-extraction and pollution. Despite multiple schemes—such as the Salinity Ingress Prevention Scheme, Kalpasar Project, and Atal Bhujal Yojana—focused on groundwater regulation and saltwater intrusion mitigation, the scale of vulnerability and coordination across agencies continues to pose risks to water and sanitation infrastructure and coastal livelihoods.

While existing plans like the Coastal Zone Management Plan (CZMP), State Action Plan on Climate Change (SAPCC), and the State Disaster Management Plan (SDMP) acknowledge these risks, their enforcement and integration remain fragmented. To strengthen resilience,

the state should develop a coastal-specific climate adaptation strategy that builds on but goes beyond the National Water Mission. This includes enhancing groundwater management in salinity-prone areas through scaled-up implementation of the Salinity Ingress Prevention Scheme, the Kalpasar Project, and Atal Bhujal Yojana, alongside promoting rainwater harvesting, desalinization, and wastewater reuse as alternative freshwater sources. Wastewater and faecal sludge management systems in coastal towns must be upgraded to prevent pollution and groundwater degradation. Protecting and restoring coastal ecosystems like mangroves and wetlands is equally critical, as they act as natural buffers against sea-level rise and storm surges. All water and sanitation infrastructure should undergo climate and disaster risk assessments, especially in low-lying zones. In parallel, building the capacity of Urban Local Bodies (ULBs) and other local institutions on resilient planning and disaster preparedness is essential. **Finally, establishing a cross-sectoral coastal resilience coordination mechanism would ensure alignment among various state departments, local governments, and stakeholders, enabling effective planning, financing, and implementation of adaptation measures across Gujarat's vulnerable coastal belt.**

Section E: Discussions and Conclusion

Early urban climate concerns in India primarily centred on vulnerability to climate stresses and disaster risks (Dubash, 2019). This led to a focus on adaptation measures, which were comparatively easier to mobilize given that their benefits are more immediate and locally visible, unlike the more diffuse and long-term gains associated with GHG mitigation (Sharma & Tomar, 2010). The findings from this policy review affirm this trend. India's national climate change, water, and sanitation policy landscape continues to prioritize adaptation as the principal strategy—a focus that is understandable given that large sections of the population still lack access to safe drinking water and adequate sanitation services. This is also reflected in state level policies and financial allocations.

While the current emphasis on adaptation aligns with India's developmental priorities, greater attention must be directed toward strengthening mitigation efforts in the water and sanitation sector. Although the sector contributes only a small share to national GHG emissions, its potential to support climate mitigation—particularly through energy efficiency—remains significant. Most ULBs face high electricity costs, making energy-efficient solutions not only environmentally relevant but also crucial for financial sustainability. Yet, energy efficiency initiatives remain limited. The only dedicated national programme—the Municipal Energy Efficiency Programme (MEEP)—primarily targets public lighting, even though water supply and sewage pumping systems account for nearly twice the energy consumption. To address this gap, mitigation must be mainstreamed into urban water and sanitation infrastructure and services by integrating energy and water efficiency targets into municipal planning and Detailed Project Reports (DPRs), and by mandating regular energy and water audits for ULBs. Furthermore, there is a pressing need for a dedicated national-level programme to assess and monitor GHG emissions—both biological and non-biological—from the urban water and sewage sector across different classes of town. Currently, the country lacks comprehensive assessments of GHG emissions from municipal water and sewage services, which limits the capacity of ULBs and state water utilities and policymakers to plan effectively and implement targeted mitigation strategies.

India's climate change policies prioritize development and resilience, recognizing water and sanitation infrastructure as essential components of climate adaptation. Wastewater recycling, rainwater harvesting, ground water recharge, regulations are highlighted as critical measures that deliver both adaptation and mitigation co-benefits, such as reducing pressure on freshwater resources, lowering energy consumption, and cutting greenhouse gas emissions. Despite this policy framework, implementation remains weak, particularly in small

and medium towns, as observed in our study of 12 towns across Karnataka, Goa, Maharashtra and Gujarat. Despite subsidies, rainwater harvesting and groundwater recharge efforts are not gaining traction, and groundwater regulation is frequently ignored. Additionally, the lack of adequate sewage networks and STPs results in widespread discharge of untreated wastewater. While programs like AMRUT have expanded sewerage and septage connections, the continued focus on centralized infrastructure often overshadows more climate-responsive, decentralized solutions. Rainwater harvesting should be promoted at all urban scales, focusing on affordable, decentralized models, as uptake remains low in smaller and medium towns despite national campaigns like Catch the Rain and financial incentives. Additionally, integrating climate-resilient and energy-efficient water, sanitation, and hygiene infrastructure into health systems under the National Programme on Climate Change and Human Health is crucial. Finally, establishing robust town-level data systems to monitor wastewater reuse, RWH adoption, and energy consumption will enable better assessment of co-benefits and inform adaptive policymaking.

Key concerns in India's disaster and climate resilience policies include the widespread neglect of climate-proofing and disaster risk considerations in existing water and wastewater infrastructure, particularly in urban areas. While national frameworks like the National Policy on Disaster Management (2009) emphasize strengthening critical infrastructure and updating building codes to mitigate disaster risks, many state-level plans insufficiently address water and sanitation infrastructure resilience. ULBs often lack the capacity or mandate to integrate climate adaptation into infrastructure projects, though recent funding from International Financial Institutions and initiatives like the Smart Cities Mission are beginning to encourage this shift. The failure to incorporate disaster risk reduction early leads to higher public expenditure due to emergency repairs and frequent maintenance, with retrofitting existing infrastructure being costlier than upfront resilient investments.

To effectively enhance climate resilience and disaster risk reduction, it is essential to mainstream these principles into all water and sanitation infrastructure planning and development, particularly at the ULB level. Building codes and municipal regulations should be regularly updated and strictly enforced to incorporate the latest disaster safety standards. Capacity-building initiatives, comprehensive training programs, and community engagement must be strengthened to improve preparedness and promote resilient urban planning. Additionally, ecosystem-based and non-structural mitigation measures—such as hazard zoning, early warning systems, and watershed management—should be actively promoted. Prioritizing upfront investments in resilient infrastructure can significantly reduce long-term costs and vulnerabilities. Effective coordination between national agencies like the NDMA and NIDM and state and local bodies is crucial to ensure coherent policy implementation aligned with disaster risk reduction goals. Furthermore, leveraging international partnerships, such

as the Coalition for Disaster Resilient Infrastructure (CDRI), can help mobilize vital resources and expertise to support resilient infrastructure development.

India lacks a dedicated national mission specifically addressing coastal areas and climate change within the National Action Plan on Climate Change (NAPCC). However, the National Water Mission broadly covers climate impacts on coastal regions, emphasizing integrated water resource management, improving water use efficiency by 20%, promoting wastewater recycling, and adopting technologies like low-temperature desalination for coastal cities. Key challenges faced by coastal zones include saltwater intrusion from sea level rise affecting groundwater quality, untreated sewage and industrial pollution, coastal erosion, sedimentation, mangrove loss, and declining groundwater availability. State Action Plans in Maharashtra, Gujarat, Goa, and Karnataka focus on mitigation and adaptation strategies such as STPs, common effluent treatment plants (CETPs), erosion control, mangrove replantation, and resilient housing. Despite these initiatives, recent studies reveal weak and fragmented integration of climate change and disaster risk considerations in coastal governance. Overlapping central and state-level laws create coordination failures and limit synergy between agencies, hindering the development of integrated local coastal plans. ULBs show limited involvement in climate and disaster planning, coupled with low awareness of climate initiatives.

The CRZ rules are among India's most frequently violated environmental laws, and ongoing policy dilution weakens ecological protection and coastal resilience. Coastal planning remains siloed across sectors like housing, fisheries, and tourism, with minimal incorporation of risk-informed land use, nature-based solutions, or infrastructure retrofitting. Although climate change is acknowledged rhetorically, practical and coordinated measures for resilience remain scarce. To address climate challenges in India's coastal regions, a dedicated national mission on coastal climate adaptation and mitigation is essential. Key priorities include strengthening coordination between central and state agencies for integrated coastal management, enhancing the role of Urban Local Bodies in climate and disaster governance, and enforcing CRZ and ecological protection laws. Promoting cross-sectoral planning with risk-informed land use, nature-based solutions, and resilient infrastructure is vital for sustainable development. Raising local awareness and supporting on-ground implementation of climate strategies will further strengthen community engagement and coastal resilience.

A key insight from the study is the significant institutional fragmentation in India's climate, water, and sanitation governance. While ministries and state-level organizations have defined mandates and many states have established climate cells to support integration, overlapping or disconnected responsibilities, the absence of dedicated budgets for climate action, the lack of climate cells at the town level, and the marginalization of ULBs in disaster planning have

collectively weakened the alignment of adaptation and mitigation goals within water and sanitation policies and programmes. These institutional gaps are mirrored in the weak implementation observed across state and town-level studies. This fragmented approach has also generated contradictory outcomes. For example, adaptation projects focused on wastewater recycling and reuse are often constrained by stringent environmental regulations, such as the Pollution Control Board's Zero Liquid Discharge (ZLD) norms - requiring 10 mg/L BOD and now tightened to 3 mg/L in Karnataka- for decentralized systems. These high standards result in energy-intensive and costly technologies that impose significant financial and operational burdens, frequently leading to system abandonment. Achieving true ZLD is especially difficult in urban settings, complicating implementation and undermining both environmental goals and energy-saving efforts. This situation poses challenges for effective GHG emission mitigation. Additionally, weak enforcement of groundwater regulations further discourages the adoption of recycling and reuse practices. The lack of a cohesive strategy that seamlessly integrates both adaptation and mitigation efforts, applying a systems approach to the Water and sanitation -Climate Change nexus, has led to missed opportunities. These include untapped prospects such as carbon credits and nature-based solutions.

In conclusion, India's climate policy and institutional landscape is extensive, with a multitude of policies, programmes, schemes, and regulations addressing various aspects of adaptation and mitigation in the urban water and sanitation sector. However, significant gaps remain in ensuring resilience of critical infrastructure and services, particularly in coastal areas. At the state level, functioning broadly aligns with the national policy and legal framework on climate change, water and sanitation, while also incorporating state-specific priorities, such as Goa's tourism policy. To address these challenges, India must move beyond fragmented, adaptation-centric measures toward a cohesive, systems-based framework that integrates adaptation, mitigation, resilience, and sustainability. Strengthening the case for mitigation in water and sanitation also requires more empirical studies, including town-level inventories of GHG emissions. This shift demands stronger inter-agency coordination, the establishment of dedicated climate cells, assured climate budgets at state and local levels, and greater support for decentralized innovation. At the heart of this transformation are cities and urban centres, widely recognized as pivotal sites for climate action. This highlights the need to empower urban local bodies and citizens—by strengthening institutional and financial capacities, ensuring meaningful participation in climate and disaster governance, and supporting locally driven solutions. Only through such an approach can India achieve long-term climate resilience for its urban infrastructure and coastal ecosystems.

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Annexure-I: Town Selection Criteria and Selected Towns

IIT-Bombay

The town selection followed a two-step process. First, a set of criteria was developed through a comprehensive literature review (outlined in Table below). These criteria were designed to ensure diversity among the case study towns in terms of WaSH infrastructure and services, geography, demographics, and climate vulnerability, administrative status, enabling a more representative and contextually grounded analysis.

- **Current understanding of climate risks:** The selection process considered the known climate risks each town faces, as these are critical for assessing the vulnerability of WaSH infrastructure to climate-related hazards.

- **Variation in infrastructure and urban characteristics:** Towns were selected to reflect diversity in water and sanitation infrastructure and service levels, population size, climatic conditions, and economic activities—factors that influence exposure and adaptive capacity and GHG emissions.

- **Socio-economic profile:** Differences in socio-economic conditions lead to varied water consumption and sanitation practices. These factors are crucial for understanding a town's climate resilience and estimating greenhouse gas (GHG) emissions in the WaSH sector.

- **Administrative status:** The administrative status of a town significantly influences its capacity for climate change planning and response, especially in critical sectors like water and sanitation. Towns with higher administrative status—such as municipal corporations or class-I and beyond—tend to have greater autonomy, better institutional structures, and access to financial and technical resources. They are more likely to have dedicated departments, skilled personnel, and the ability to integrate climate considerations into urban development plans.

  These towns also benefit from larger budgets, greater revenue-generating powers, and enhanced eligibility for national and international funding schemes focused on climate adaptation and mitigation. In contrast, smaller towns or panchayats often rely heavily on state or district-level agencies, leading to delays in planning and

implementation. Moreover, higher status towns typically have better data systems and monitoring capabilities, which are essential for assessing climate risks and emissions. Their greater political visibility further enhances their chances of being included in pilot projects or targeted policy interventions. Thus, a town's administrative status directly shapes its ability to design and implement effective, context-specific climate-resilient infrastructure and services.

Table 3: Town Selection Criteria

Key Parameters	Selection criteria		
Administrative status	Municipal Corporation	Municipal Council (A and B)	Nagar Panchayat (C and D)
City Size based on population	Class-I to Class IV		
Socio-economic profile	Capturing variability in socio-economic profile of the town population		
Climate Change Exposure and vulnerability	Low Risk/vulnerable	Medium Risk/vulnerable	High Risk/vulnerable
Sanitation Infrastructure Services Status	Only On-site Sanitation	OSS + % networked system	OSS+ % networked + Non-networked (NBS/ Conventional/ FSSTP)
Economic Contributions /Profile	Industrial, agricultural, tourism, service sectors		
State government and ULB support	Past and current partnerships, collaborations		

The above process generated a preliminary list of towns, from which the final selection was made in consultation with the States' Swachh Bharat Mission (Urban) Director.

CDD India

From a list of 26 towns, excluding Mumbai and suburbs due to high density and space constraints as well as their already extensive attention compared to overlooked smaller coastal cities, a rapid assessment was conducted of 9 towns. Basis 1) population size, 2) proximity to coastline, 3) other demographic details, 4) economic status, 5) environmental

conditions, 5) climate vulnerability, and 6) on-site evaluation of WaSH conditions & climate impact, three towns were selected for study in Maharashtra.

Table 4: Selected Towns

State	Town	Population (2011)	Class
Maharashtra	Alibag	20,743	Class-III
	Ratnagiri	76,229	Class-II
	Vengurla	12,392	Class-IV
	Dahanu	5,0287	Tier-II*
	Malvan	1,8648	Tier-IV*
	Guhagar	7,299	Tier-V*
Karnataka	Mangaluru MC	4,99,487	Class-I
	Kundapura TMC	30,444	Class-III
	Karwar CMC	77,139	Class-II
Goa	Canacona	12,434	Class-IV
	Mormugao	94,393	Class-II
	Mapusa	39,989	Class-III
Gujarat	Devbhumi Dwaraka	38,873	Class-III
	Mandvi	51,376	Class-II
	Valsad	1,70,060	Class-I

*Population based categorization

Endnotes

[i] Global Climate Risk Index 2021. Who suffers Most from Extreme Weather Events? Weather-related Loss Events in 2019 and 2000 to 2019 https://www.germanwatch.org/en/19777

[ii] This indicates strong scientific agreement that the proposed solutions are beneficial, effective, and represent sound investments, even under conditions of uncertainty.

[iii] The coastline length of Gujarat referenced in this report is based on sources reviewed and compiled by Ashank Desai Centre for Policy Studies, IIT-Bombay. During report finalization, the official coastline length of Gujarat was revised to 2340.62 km as per the Press Information Bureau (PIB), Government of India, Delhi vide press release dated 04 December 2025, (Release ID: 2198800). https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=2198800&reg=3&lang=1

[iv] The funds can be availed by company or a partner of the Consortium, JV/ SPV, Local Bodies / Municipal Corporations, Govt. or Private Sector Companies/ firms, Central Public Sector Undertaking (CPSU), Joint Sector Companies, Trusts, NGO, Societies, Cooperatives, Entrepreneurs, Partnership firms, Limited Liability Partnerships, Energy Service Companies.

[v] Swachh Bharat Mission-Urban. Mission Progress https://sbmurban.org/swachh-bharat-mission-progess . July 2025

[vi] Surat Municipal Corporation (SMC) is implementing 9 waste-to-energy sewage treatment plants with a capacity of more than 800 MLD. SMC set-up sewage gas (methane) based power plants with a total capacity of 4.75 MW.

[vii] The Amendment Act -2022, also changed definition of energy to “any form of energy derived from fossil fuels or non-fossil sources or renewable sources” and renamed the Energy Conservation Building Code to Energy Conservation and Sustainable Building Code.

[viii] The codes talk about energy efficiency of water heating, chilling, heating, ventilating, and air-conditioning, systems, interior and exterior lighting, and electrical power and motors, and renewable energy systems.

[ix] Extraction of Cauvery water from 100 km. and at a 500 meter elevation, and water distribution through a network of more than 8,746 km (interview with BWSSB, Chief Wastewater Engineer, 2023)

[x] Safe = ≤ 70% ground water extraction; > 70% ground water extraction and 90% ground water extraction; > 90% ground water extraction and 100% ground water extraction; >100% ground water extraction (Ground Water Directorate ; Central Ground Water Board, South Western Region, 2023).

[xi] SDG - 1 (End Poverty), 2 (Zero Hunger), 3 (Good Health and Well Being), 4 (Quality Education), 5 (Gender Equality), 6 (Clean Water and Sanitation), and 7 (Clean and Affordable Energy). SDG - 16 (Peace, Justice and Strong Institutions).

[xii] The energy sector was the major contributor (80%) to state’s net GHG emissions (130.65 Mt CO2e) in 2018. Energy sector considers fuel combusted for captive electricity generation (auto-producers) and direct fuel combustion (industrial energy). The waste sector (including solid waste and domestic wastewater) contribution to the net GHG emissions declined from 5% in 2005 to 3% in 2018. However, in absolute terms, emissions from the waste sector increased from 4.11 Mt CO2e in 2005 to 5.37 Mt CO2e in 2018 (GHG Platform India, 2018).

[xiii] Nearly 36% of households in Karnataka live in *Kutcha* houses and almost all (99%) households have electricity (International Institute for Population Sciences ; ICF, 2022)

[xiv] The coastline length of Goa referenced in this report is based on sources reviewed and compiled by Ashank Desai Centre for Policy Studies, IIT-Bombay. During report finalization, the official coastline length of Gujarat was revised to 193.95 km as per the Press Information Bureau (PIB), Government of India, Delhi vide press release dated 04 December 2025, (Release ID: 2198800). https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=2198800&reg=3&lang=1

[xv] Emissions from the state of Goa increased at an estimated CAGR of 5.05 percent from 2.85 Mt CO2e in 2005 to 5.40 Mt CO2e in 2018.

[xvi] GHG emissions from waste sector (including solid waste and domestic wastewater) increased at a CAGR of 1.22 percent from 0.25 Mt CO2e in 2005 to 0.30 Mt CO2e in 2018 (GHG Platform India, 2018).

[xvii] The coastline length of Maharashtra referenced in this report is based on sources reviewed and compiled by Ashank Desai Centre for Policy Studies, IIT-Bombay. During report finalization, the official coastline length of Maharashtra was revised to 877.97 km as per the Press Information Bureau (PIB), Government of India, Delhi vide press release dated 04 December 2025, (Release ID: 2198800). https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=2198800&reg=3&lang=1

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