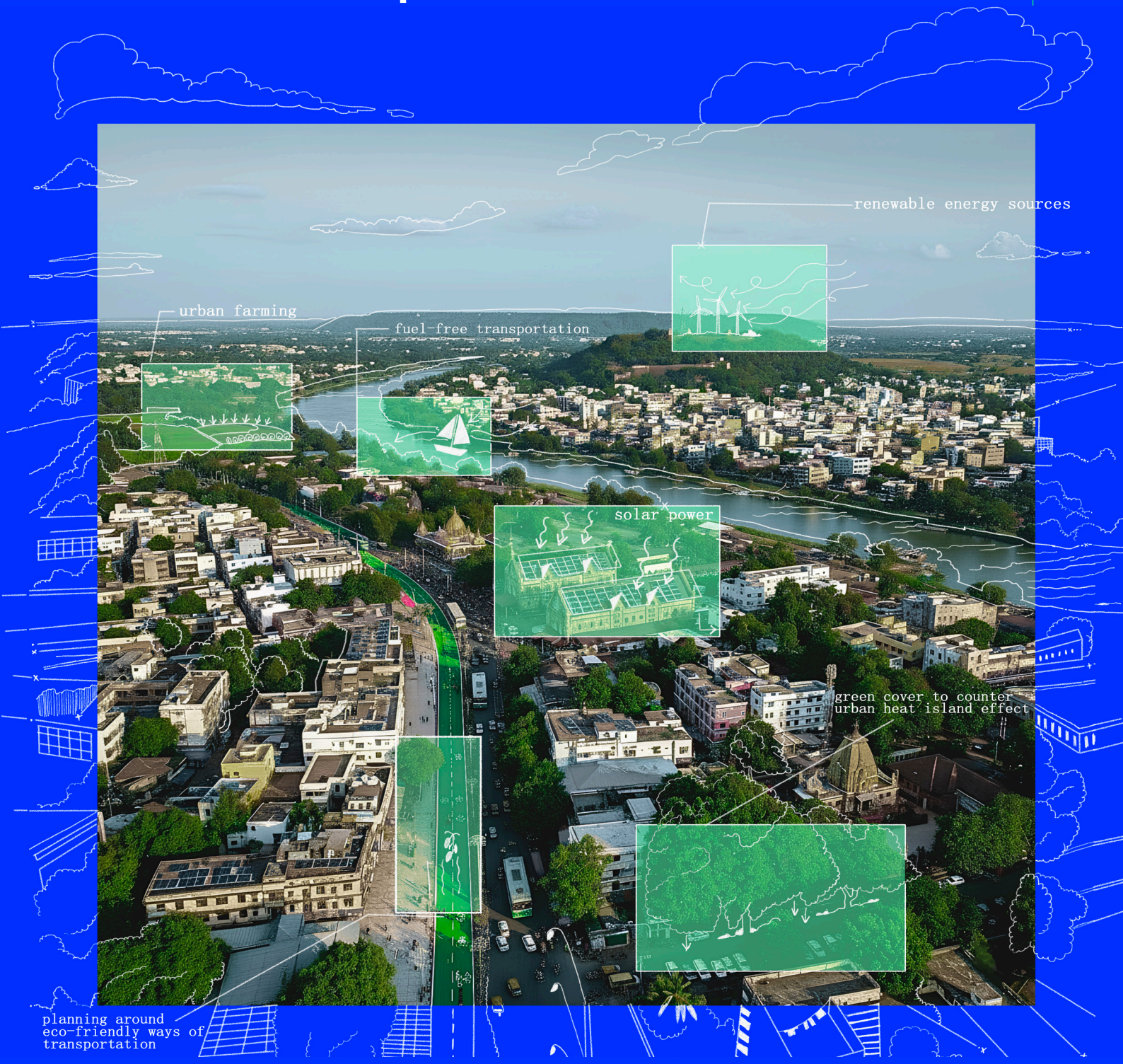
Compendium of Net Zero Solutions for Kolhapur, Maharashtra



Transitions Research

Transitions Research is a social science collective driving radical transitions at the intersection of technology, society, and sustainability. We aim to ensure these transitions are just, inclusive, and empower people while protecting the planet. Our work focuses on discovering sustainable pathways by generating anticipatory knowledge, co-creating solutions, and building capacities for societal action.

Our initiative, People's Urban Living Lab (PULL), works to co-create, test, and implement equitable climate solutions in mid-sized Indian cities. Through PULL: Net Zero, we are working to discover inclusive net zero solutions for Indian cities.

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Authors: Teenu J Thaikattil, Godwin Adams, Amita Basu, Sushant Figueiredo, Nupur Khanter

Artwork and maps: Niyatee Khinvasara, Nupur Khanter, and Hiranya Ganatra

Cover Image: From team fieldwork

Report design: Niyatee Khinvasara

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Executive Summary

India's ambitious net-zero goal hinges on large-scale low-carbon transitions in its cities. India's small and mid-sized cities, such as Kolhapur, are growing rapidly, and serve as innovation gardens for testing new ideas to avoid carbon lock-in and shape a net zero future.

People's Urban Living Lab (PULL) of Transitions Research is co-creating, testing, and implementing equitable climate solutions in India's mid-sized cities. In Kolhapur, we are supporting the city's ambitious goals of being net zero by 2050 (Global Covenant of Mayors for Climate & Energy, n.d.). We have focused on identifying solutions that are contextual and feasible for implementation. They contribute to decarbonising urban systems such as buildings, mobility and waste, but also prioritise societal goals and environmental co-benefits.

> This compendium goes beyond traditional approaches to finding solutions. All the technical remedies to achieve low-carbon goals have a social dimension in their implementation, which the compendium highlights. It explores strategies to cultivate the demand for low-carbon technologies and promote behaviour changes, and balancing equity and user needs while navigating the complexities and trade-offs of various solutions.

This compendium marks the start of Kolhapur's low-carbon journey, presenting opportunities for shaping a future that is sustainable and also inclusive.

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Introduction

About Kolhapur

Situated on the southern banks of the Panchaganga River in south Maharashtra, the ancient city of Kolhapur traces its origins back to the first century BC. Over centuries, it became a capital for various rulers, shaping its rich cultural and architectural heritage. Known as 'Dakshin Kashi' (Kashi of the South), Kolhapur's identity is deeply intertwined with the Mahalaxmi Ambabai Temple, a sacred landmark that mirrors the significance of Kashi (the ancient name of Varanasi). The city's historic core, anchored around the temple, has influenced its urban form, with settlements radiating outward in patterns that reflect its spiritual and historical significance. The city of Kolhapur is blessed with abundant water resources, including rivers, lakes, and an abundant water table, which stand in contrast to the predominantly arid environment of the surrounding district, transformed during the monsoon season brought by southwestern winds (Lad, Dige, and Jadhav, 2023).

Kolhapur has grown considerably and today its district covers an area of 7,685 sq km. The city area under the Kolhapur Municipal Corporation (KMC) is approximately 66.82 sq km (Lad, Dige, and Jadhav, 2023) with a population of 549,236 (Maharashtra Times, 2017). Kolhapur's economy is primarily driven by its thriving agriculture, textile, and manufacturing sectors, with a significant portion of the population engaged in these industries. The city is renowned for its sugar production, Kolhapuri footwear, and jaggery, which contribute to its industrial base and trade (Government of India, 2016). Furthermore, Kolhapur attracts a considerable floating population due to its cultural and religious significance, including an estimated five million domestic tourists annually, many of whom visit the famous Mahalakshmi Temple (Government of Maharashtra, 2024).

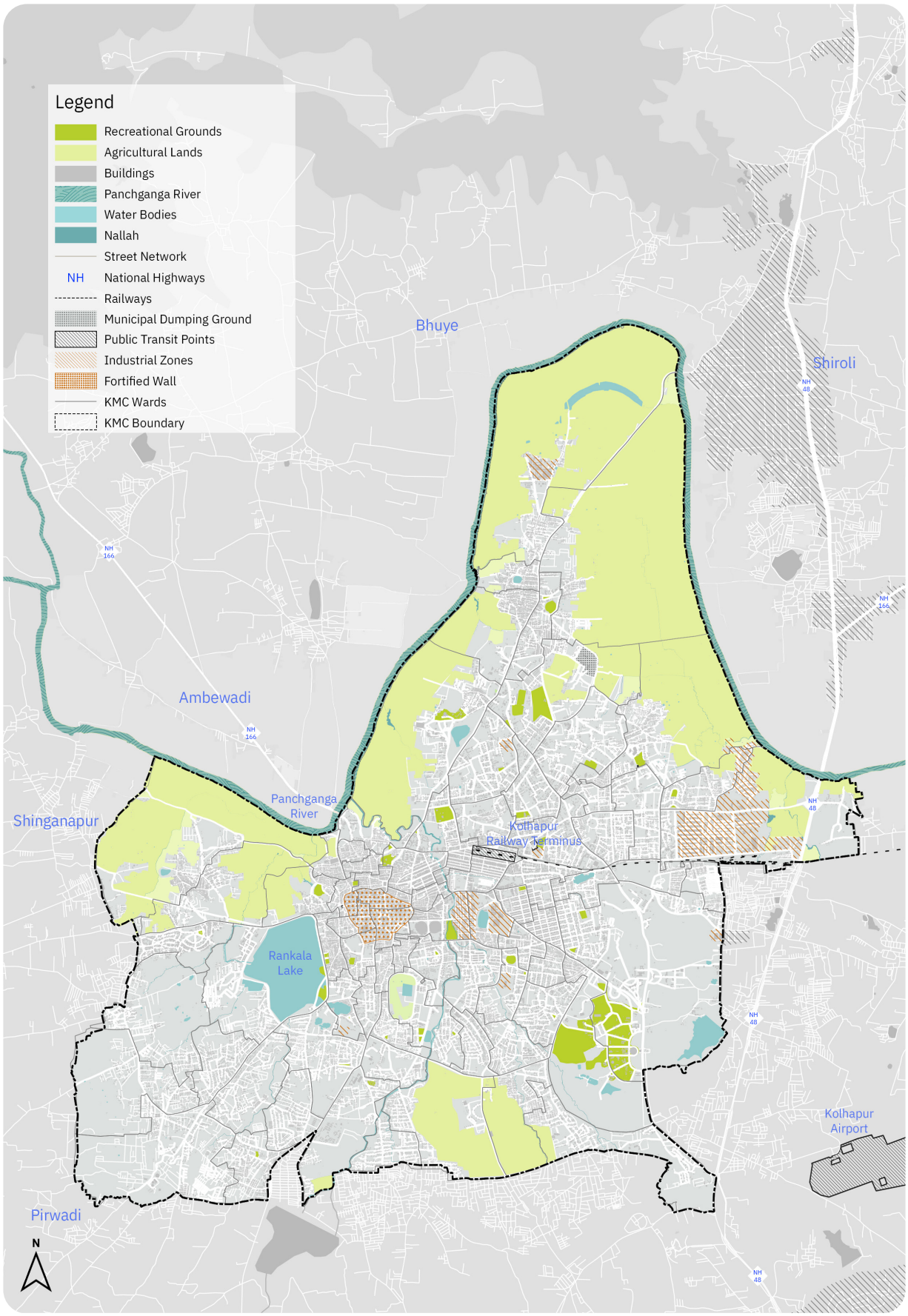

Image 1: Map 1 Kolhapur City and Region

Kolhapur's Climate Challenges and Ambition

Kolhapur city's official area, serviced by the municipal corporation, has remained unchanged at 66.82 sq km since 1971, though it has actually grown beyond those limits. Its population surged by 112 percent by 2020, leading to a significant rise in activities and emissions (Ministry of Tourism, 2020).

However, Kolhapur's urban expansion is increasingly neglecting its vital relationship with the environment, posing significant risks. As the city expands into adjacent agricultural lands and wetlands, it faces heightened vulnerability to climate-related challenges such as flooding, water scarcity, and imbalance between industrial growth and environmental conservation (Ministry of Tourism, 2020). This unchecked growth is also driving up emissions, with new developments often diverging from traditional architectural styles that were better suited to the local climate. So is the increasing dependence on private vehicles. Consequently, Kolhapur's per capita emissions have been climbing, necessitating an urgent re-evaluation of urban planning and development strategies to address climate change impacts and curb rising emissions effectively.

Previous studies have examined the factors influencing greenhouse gas emissions in Kolhapur. In 2013, research estimated the city's emissions at approximately 105,534 tons (metric) of CO_2 equivalent (CO_2e), with a per capita emission of 0.192 tons CO_2e (Deshmukh, 2017). These findings provide an early benchmark for understanding Kolhapur's contribution to climate change.

A subsequent study conducted by the Central Pollution Control Board (CPCB) identified the transportation sector as the primary source of emissions in Kolhapur. The action plan prepared by CPCB highlights that 34 percent of the city's total emissions are from transportation, including vehicular emissions and road dust (Shinde, 2021). The most recent study by the Maharashtra Pollution Control Board (MPCB) in 2022 found that the city produces about 1.99 tons of particulate matter (PM) every day. This includes PM10 and PM2.5, with vehicular emissions emerging as the leading contributor (Data Portal for Cities, n.d.). These findings show the critical need for targeted interventions in the transportation sector to mitigate greenhouse gas emissions in the city.

Net Zero Kolhapur by 2050

In 2021, Kolhapur pledged its commitment to achieve net zero by 2040 as part of the Cities Race to Zero (Global Covenant of Mayors for Climate & Energy, n.d.). In order to achieve this, the city has identified schemes for transitioning to net zero with mobility solutions, such as electric public transport and private vehicles, infrastructure solutions such as installation of solar panels, and so on. However, these efforts alone are unlikely to be sufficient, as there is an undue focus on technological solutions, without the institutional arrangements and societal shifts that must accompany these changes. The city urgently needs equitable, integrated solutions to achieve its ambition, given its rapid urban growth.

PULL Net Zero: Kolhapur

There is great potential for Kolhapur to transition to a net zero city. **The People's Urban Living Lab (PULL) Net Zero** project will co-create, test and implement equitable net zero strategies. It will identify technological solutions, while prioritising social planning for the implementation of these solutions, including focusing on addressing entrenched inequities, finding solutions for demand generation and behaviour change, and delivering on societal co-benefits that can accompany net zero transitions and must do so to achieve real, lasting transformations. This compendium is the start of Kolhapur's journey towards becoming a low-carbon city.

Compendium of Net Zero Solutions: **How to Read this Report**

This compendium of net zero solutions is an overview of sectoral, socio-technological solutions that can facilitate a transition to a net zero society in Kolhapur. These solutions have been co-created with key stakeholders and experts, based on primary and secondary research, interviews, community engagement, and case study analysis.

The chapters in the compendium cover the following sectors: mobility, waste, buildings and construction, energy generation, electricity consumption, and urban nature-based solutions. Each chapter begins by briefly setting the context, explaining the rationale for focusing on the sector. It then provides an overview of existing conditions and key challenges faced by Kolhapur in that sector, from the perspective of emissions reduction as well as the general quality of life and governance. Finally, each chapter is focused on socio-technical solutions that provide mitigation benefits while also addressing societal goals for that sector.

The chapters in the compendium cover the following sectors:

- Energy Generation
- Mobility
- Buildings and Construction
- Waste Management
- Electricity Consumption
- Nature-Based Solutions

The Social Dimensions of Net Zero Transitions

Net zero transitions necessitate a comprehensive approach that goes beyond technical and financial considerations. PULL places people, not carbon, at the core of our net zero solutions. We address deep-rooted social inequities to ensure nobody is left behind in this transition, using the following social dimensions to guide our solutioning:

Equity and Justice

Net zero pathways must ensure a fair distribution of benefits and burdens through a focus on access and inclusion in planning and design. Solutions must prioritise vulnerable groups (like the urban poor, the elderly, youth, women and other marginalised communities), in net zero transitions so as not to cement pre-existing inequalities.

Behaviour Change and Public Acceptance

Society needs to adopt new behaviours and lifestyles to address climate change. Our solutions drive demand for low carbon solutions by shifting behaviours and societal norms, and generating public buy-in for net zero interventions.

Public Participation and Trust

Actionable interventions require a strong understanding of the local context. Our work focuses on building relationships between local stakeholders, policymakers, and the public, fostering transparency through consistent outreach and communication.

Institutional Innovation

Complex institutional challenges hinder urban local bodies' ability to implement net zero strategies. We strengthen governance structures and develop coordination mechanisms across state, district, and city-level departments to enable effective implementation.

Livelihoods and Social Protections

Low-carbon transitions will disrupt local economies and livelihoods. Our solutions integrate dynamic and evolving social protection and upskilling programmes to ensure a just transition to a low-carbon future for all.

Chapter 1

Energy

Energy

Sector Overview

Maharashtra's power sector is rapidly evolving, driven by enabling policy and regulatory measures. With the largest installed power generation capacity in India at 44,143 megawatts (MW) (Agarwal, 2023), the state has implemented various initiatives to enhance access, reliability, and cost efficiency. Mahagenco, the state-owned generation utility, is India's largest public generator with 14,080 MW of installed capacity. Coal remains the primary fuel source, followed by renewables, gas, hydro, and nuclear. Nearly 50 percent of Maharashtra's total power capacity is privately owned (Mahaurja, 2019). The state ranks third in renewable energy capacity with 9,332 MW, accounting for 21 percent of its total power (Agarwal, 2023). Mahagenco is also exploring new renewable technologies, such as floating solar panels installed in water bodies and solar powered hydroponics on vacant thermal plant land.

Mahatransco, Maharashtra's state-owned transmission utility, is the largest in India, operating a 46,217 circuit kilometre (ckm) network with a transformation capacity of 1,23,846 MVA across 660 substations (Agarwal, 2023). The state has one of India's largest consumer bases, including some 42 lakh agricultural consumers (Mahaurja, 2019). Power distribution is managed by state-owned licensees Maharashtra State Electricity Distribution Company Limited (MSEDCL) and Brihanmumbai Electric Supply and Transport (BEST), along with private players Tata Power and Adani Electricity, which operate in Mumbai.

Existing Conditions and Key Challenges

Kolhapur, a cultural and historical city in southeast Maharashtra, has a population of 5,49,236 residing within its metropolitan boundary according to the 2011 census. Kolhapur city is well-developed industrially, with several industrial zones located in and around the urban area. These include foundries, sugar mills, and textile units. The city also hosts a vibrant traditional small-scale industry sector, known for the production of silver ornaments, Kolhapuri chappals, and handloom textiles.

Other notable activities include oil-seed crushing, brick and tile making, as well as leather manufacturing and tanning. Besides industries, agriculture and tourism also provide livelihoods for many residents. With ample economic opportunities along with agriculture production, Kolhapur districts' GDP in 2013-14 was ₹54.63 thousand crore, NDDP was ₹63,545 crores and per capita district domestic product was estimated to be ₹1,51,963 in 2019–20 (Directorate of Economics and Statistics, 2021).

Potential Decentralised Renewable Energy Technologies for Kolhapur Municipality

Kolhapur's municipal area presents a strong opportunity for integrating decentralised renewable energy (DRE) solutions to reduce reliance on conventional power sources and enhance urban sustainability. The following technologies are particularly suited for implementation within the municipal boundary:

Rooftop solar photovoltaic (PV)

Rooftop solar PV maximises urban renewable energy potential. While rooftop solar utilises available space on buildings with net metering incentives lowering costs, community solar offers a shared solution for areas where individual installations aren't feasible. By leveraging municipal buildings and vacant land, these projects provide clean energy access to apartment residents and businesses, enhancing energy security and sustainability.

Bioenergy from municipal organic waste and waste-to-energy (WTE) systems:

Kolhapur can harness bioenergy and waste-to-energy (WTE) systems to manage organic and municipal waste efficiently. Decentralised biogas plants at markets and housing societies can convert food and sewage waste into biogas for cooking or power generation. Meanwhile, WTE technologies such as anaerobic digestion and gasification can process segregated waste to generate electricity, reducing landfill reliance and transportation costs while promoting sustainable urban waste management.

Small-scale wind turbines for public infrastructure

While large wind farms may not be suitable within Kolhapur's dense urban landscape, small-scale vertical-axis wind turbines can be installed on municipal buildings, bus terminals, and streetlights. These turbines can supplement solar PV systems, enhancing energy resilience for public infrastructure and street lighting.

By strategically implementing these DRE technologies, Kolhapur Municipality can improve energy access, promote waste-to-energy solutions, and support its transition towards a low-carbon urban future.

Existing Policies to Address Renewable Energy Challenges

The Maharashtra State Electricity Regulatory Commission (MERC) has imposed renewable energy procurement requirements on power distribution companies. The Renewable Energy Generation Policy, 2020, (Ministry of New and Renewable Energy, n.d.) mandates that non-conventional energy must make up a specific proportion of the total energy procured by distribution companies. To meet the state's target of 25,000 MW non-conventional energy capacity by 2025 (Government of Maharashtra Department of Industry, Energy and Labour, 2020), a revised policy and target year is needed to enhance government and private sector participation, fostering investment in transmission-connected, non-transmission, and storage projects.

To meet rising electricity demand, in 2020 the Maharashtra government was aiming to increase installed non-conventional capacity by 17,360 kW over by 2025 covering transmission, non-transmission, and storage projects (Government of Maharashtra Department of Industry, Energy and Labour, 2020). However, only 11,590.49 megawatt capacity projects have been set up so far. This is 14.5 times less than the total capacity of the state, 2 times less than the planned construction, and 1.5 times less than the total power generation (Earth Journalism Network, 2024)

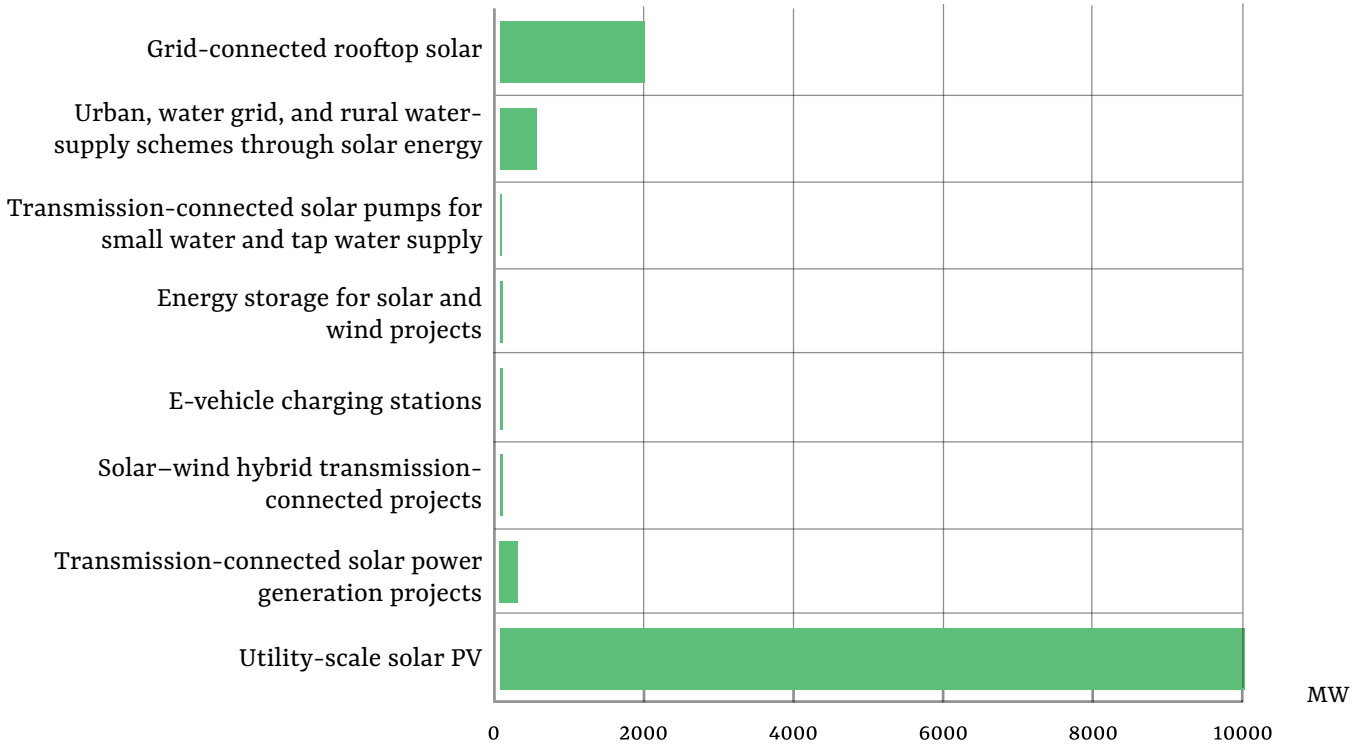

Figure 1. Solar energy projects planned by Maharashtra state

Solar Energy

The state government has estimated a potential **to install a capacity of 17,360 MW solar-powered energy through transmission-connected, non-transmission and storage projects across the state** (Thomas, 2021). These schemes are undertaken by public–private partnerships for setting up projects. Solar energy projects planned by the state include

Wind energy

The Maharashtra government aims **to install a total capacity of 2,500 MW of wind energy both onshore and offshore along the west coast** (MEDA, n.d.). The power generated by the state through wind energy will be used for private use, open access, and export to other states. The state, however, is more inclined towards projects of a hybrid nature, wind projects integrated with other non-conventional energy source projects and incorporating storage capacity.

Co-generation projects based on sugarcane chips / agricultural residues

Maharashtra accounts for about one-third of India's sugarcane production and mills, producing about 10.5 million tons of the country's sugar cane between 2022 and 2023 (Jadhav, 2023). To utilise this potential, the state plans **to set up cogeneration plants with 1,350 MW of power-generating capacity based on sugar factories and agro-industries** (Ranjan, 2021). Under this policy, the electricity generated from such projects can be used by the power distribution companies in the state to meet their renewable energy purchase obligation.

Small solid-waste-based power generation

To address the challenge of solid waste management and promote sustainable practices, the state government has announced plans to establish waste-to-energy power generation projects with a cumulative capacity of up to 200 MW. These projects will process solid waste regardless of whether it is municipal, industrial, or agricultural in origin to generate electricity, thereby reducing the volume of waste going to landfills while also contributing to the state's renewable energy goals (Phadnis, 2023). The power purchase from the urban solid waste power generation project will be done as per the power purchase agreement instead of the tender process of the power distribution company.

Kolhapur's renewable energy ambitions

The introduction of a comprehensive renewable energy (RE) policy marks a pivotal move towards sustainability and reduced dependence on fossil fuels. With a bold target of generating 14,400 MW of power from non-conventional sources, Kolhapur stands out as a prime performer and beneficiary of this policy (Phadnis, 2023). Nearly half of the state's potential wind energy sites are concentrated here in western Maharashtra, offering a substantial advantage for renewable energy development. Additionally, the presence of sugar mills in the region provides an opportunity for further energy production through cogeneration plants using bagasse, a byproduct of sugar processing. Besides, industrial waste-to-energy is one of the major initiatives put forth by MEDA (MEDA, n.d.). Kolhapur, one of the industrial hotspots in Maharashtra, aims to utilise industrial organic wastes in power generation.

By diversifying its energy sources and reducing reliance on traditional power generation methods, the district can bolster energy security and resilience against future challenges.

Renewable energy integration and challenges

Urban infrastructure must become more resilient to climate change, particularly in urban energy systems that sustain other infrastructure functionalities. Innovative business models, updated regulations, and improved distribution grid operations offer cities an opportunity to redefine their role in the national energy system. Electrifying end-use applications is key, with technologies such as heat pumps, smart-charging electric vehicles (EVs), and energy storage enabling the integration of variable renewable energy (VRE) sources, such as solar photovoltaic (PV) and wind. The greatest emissions reduction potential lies in replacing fossil fuels in buildings, transport, industry, and household cooking (piped biogas). Decentralised power systems – mini-, micro-, and nano-grids – can further support local renewable energy integration, advancing urban decarbonisation.

Integrating renewable energy in cities presents challenges, including legislative, policy, and regulatory barriers, along with financing constraints that limit investment in clean technologies. Human capacity gaps, including a shortage of technical expertise and slow implementation impact streamlined transition. Aesthetic concerns and urban planning restrictions affect system design and acceptance. Limited awareness of local renewable energy benefits and public resistance to power plants near cities, driven by misconceptions, further hinder clean energy adoption.

Solution 1

Financing Mechanisms

Equity and Justice | Livelihoods and Social Protection

Access to inclusive and affordable financing mechanisms plays a crucial role in promoting equity and justice in Kolhapur's energy transition. By designing financial models such as tiered subsidies, low-interest loans, and feed-in tariffs that specifically benefit low-income households and marginalised communities, the city can significantly boost the adoption of rooftop solar and bioenergy systems. These mechanisms not only lower upfront costs but also empower cooperative housing societies and informal settlements to participate in clean energy solutions. Additionally, targeted capacity-building programmes can equip underserved groups with skills in solar installation and maintenance, supporting both energy access and livelihood opportunities (Tyagi and Kuldeep, 2023; Barefoot College, n.d.).

Innovative financial models

Solar PV
Community solar agreements let developers install and operate PV systems while building owners buy the electricity. Utility-sponsored models allow consumers to lease or purchase solar power at reduced costs. Solar co-operatives help households negotiate better prices, with examples such as Evergreen Energy Solutions in Ohio and Namasté Solar in Colorado, in the US. Low-interest loans and 'on-bill financing' further enhance affordability.

Urban wind energy projects – green bonds
Developers can access capital through green bonds, renewable energy financing programmes, or crowdfunding platforms to fund urban wind energy projects. Green financing mechanisms provide investors with opportunities to support sustainable projects while generating financial returns, attracting capital to the renewable energy sector.

Bioenergy
A viable financing mechanism for bioenergy and waste-to-energy in Indian cities is viability gap funding (VGF) combined with feed-in tariffs (FiTs). VGF provides an upfront capital subsidy to bridge the cost–revenue gap, making bioenergy projects financially viable, while FiTs ensure a fixed purchase price for the electricity generated, guaranteeing stable revenue for project developers. This model reduces investment risks, encourages private sector participation, and supports decentralised waste management by incentivising local waste-to-energy plants.

Implementing such models in cities like Kolhapur can reduce financial barriers and drive wider participation in the clean energy transition.

Grants, subsidies and financing mechanisms

Governments can offer grants or subsidies to cover a portion of the initial capital costs of establishing decentralised bioenergy plants and rooftop solar PV. These grants can be targeted specifically at urban areas to encourage the adoption of such facilities in densely populated regions.

Subsidies for solar PV
Financial accessibility is key to expanding solar PV adoption. Maharashtra offers a 40 percent subsidy for residential rooftop solar up to 3 kW, 20 percent for 3–10 kW, and none beyond 10 kW. Expanding incentives could boost adoption, as seen in Seoul's 2019 programme, which covered over 60 percent of installation costs for small systems, increasing rooftop solar capacity from 200 MW to 1 GW in three years (Kim and Gim, 2021).

Feed-in tariffs (FiTs)
Governments can implement feed-in tariffs, which guarantee a fixed payment for electricity generated from renewable sources such as rooftop solar PV and bioenergy. This provides a stable revenue stream for bioenergy plant operators and encourages investment in these facilities.

Low-interest loans and financing programmes
Governments or financial institutions can offer low-interest loans or financing programmes specifically for urban bioenergy projects and potentially for rooftop solar PV. This can help overcome financial barriers by providing access to affordable capital for project development and construction (Kim and Gim, 2021).

Public–private partnerships (PPPs) – Collaboration models for financing and developing energy projects

Solar projects
Governments can collaborate with private entities to develop and operate renewable energy projects, leveraging private expertise and resources while sharing risks and rewards. In rooftop solar PV, PPPs enable large-scale deployment by allowing private firms to install, maintain, and operate systems on public and private buildings through power purchase agreements.

Bioenergy projects
For bioenergy and waste-to-energy, private investments improve waste management while generating renewable energy, supported by government incentives.

Wind energy projects
In wind energy, PPPs help address land acquisition challenges and support grid integration for urban and peri-urban projects. These partnerships enhance financial viability and accelerate clean energy adoption.

Urban wind energy projects – community investment funds
Community investment funds pool financial resources from local residents, businesses, and organisations to finance urban wind energy projects. Residents can invest in the fund through equity shares, bonds, or crowdfunding platforms, earning returns from project revenues or dividends. Community investment funds promote local ownership, engagement, and economic benefits, while providing capital for renewable energy development.

Solution 2

Scalability and Business Models

Behaviour Change and Public Acceptance | Livelihoods and Social Protection

Scalable and inclusive business models are essential to drive Kolhapur's clean energy transition. Models such as solar leasing, housing association procurement, and cooperative wind projects can gain traction through strong community engagement and awareness campaigns that build public trust. Encouraging joint ownership and participation fosters shared responsibility and long-term commitment. Approaches like the build, own, operate, transfer (BOOT) model for bioenergy and wind cooperatives not only ensure project scalability but also generate local employment, especially for skilled and semi-skilled workers. Supporting vocational training and offering financial incentives for local enterprises can further boost sustainable economic growth alongside clean energy adoption.

Suitable business models for harnessing solar energy

Solar leasing
New business models for rooftop solar PV implementation include solar leasing, where rooftop owners lease the system from a third party and make monthly payments based on the electricity generated. The savings from solar energy serve as revenue for the rooftop owner. In Tokyo, a roof rental scheme was introduced to boost power generation capacity to 1 GW, allowing residential and commercial buildings to rent their roofs to developers for a fixed fee (Movellan, 2015).

The renewable energy service company (RESCO) model follows a zero-investment approach, where the consumer pays only for the electricity generated, while ownership remains with the RESCO developer. Consumers benefit from lower tariffs than for grid electricity.

Solar power purchase agreements (PPAs)
Under PPAs, two sub-models exist: gross metering and net metering. In gross metering, rooftop owners earn a share of the revenue from selling electricity to the grid. In net metering, rooftop owners consume the generated electricity, reducing their electricity costs, while developers sell excess power to the grid for additional revenue.

Community programmes
Establish community solar gardens or shared solar programmes where residents can collectively invest in solar installations located outside historic buildings. This approach allows inhabitants to benefit from solar energy generation while preserving the architectural integrity of historic structures.

Involvement of housing associations in rooftop solar procurement

Joint community-owned solar PV system
Housing associations and societies within the municipality of Kolhapur can set up a joint community-owned solar PV system that would reduce energy bills and promote a sense of ownership and responsibility among the dwellers. In Denmark, a housing estate in Copenhagen, working on a model of 'tenant democracy', the tenants decided, through consensus, to install rooftop solar and solar thermal units on roofs that were already in need of renovations. The project covered ten roofs across the estate and produced 160 MWh electricity per year. This was financed by residents through additional rent payments or mortgage payments (IRENA, 2020).

Cooperative models for wind turbines

Cooperative models for urban wind energy involve local communities collectively investing in and managing wind power projects, fostering shared ownership and benefits. A notable example is Denmark's Middelgrunden wind farm near Copenhagen, comprising twenty 2 MW turbines. Initiated in 1996 and operational by 2000, the project is co-owned equally by the Middelgrunden Wind Turbine Cooperative, founded by the community, and Copenhagen Energy, the city's utility company. This partnership allows community members to invest in the cooperative, promoting local engagement and shared responsibility in renewable energy generation. Denmark's extensive use of cooperative ownership has led to over 150,000 families participating in wind turbine cooperatives, significantly contributing to the nation's renewable energy capacity (Windy Cities, n.d.).

Suitable business models for bioenergy

The build, own, operate, transfer (BOOT) model is beneficial for agro-industries such as sugar processing, cassava, palm oil, and slaughterhouses, enhancing cost savings through cogeneration plants. In Kolhapur, sugarcane factories can use bagasse for power generation, reducing grid dependence and supporting bioethanol production. Under this model, factories or external entities install, own, and operate energy systems, ensuring energy self-sufficiency, waste management, and revenue from surplus electricity and carbon credits. The Nyongara biogas plant in Kenya converts slaughterhouse waste into biogas, complying with environmental regulations while selling electricity back to slaughterhouse units (C.M. Deh-Tor, n.d.).

Local partnership model for bioenergy fosters collaboration between nonprofits or private entities and local communities to develop and manage biogas plants using locally available resources. Private or nonprofit organisations cover upfront costs, while customer payments sustain operations. Private firms benefit from subsidies and tax exemptions as tax-equity investors. Crowdfunding enhances awareness and engagement, providing low-cost electricity and clean cooking fuel. A successful example is Novato, California, where a community energy partnership launched a landfill gas plant supplying renewable electricity to over 5,000 customers (Waste Today, 2017). Such partnerships promote decentralised bioenergy solutions and community-driven sustainability.

Solution 3

Grid Integration and Energy Storage

Equity and Justice | Behaviour Change and Public Acceptance

Effective grid integration and energy storage are crucial for ensuring a stable, reliable, and resilient power supply, regardless of the energy source, in order to balance supply and demand, mitigate intermittency, and enhance the efficiency of electricity distribution in urban systems.

Enhancing grid stability

Power from renewable energy (RE) sources can be inconsistent, which may affect the stability of the electricity grid. To manage this, utility operators in cities can use computer-based simulation tools. These tools help predict changes in power supply and demand, allowing operators to take steps in advance to make the grid more flexible and stable.

Increase energy storage

To cater to the city's increasing electricity demand, it is essential to increase the energy storage capacity, to offset the intermittency of power supplied by RE technologies like solar and wind. To ensure that the supply is reliable and continuous, the transmission and distribution companies must opt for efficient storage systems such as batteries, pumped hydro, or compressed air energy storage.

Microgrid integration for variable renewable energy (VRE)

Microgrids play a crucial role in integrating urban wind energy and other VRE sources by providing localised, resilient, and self-sufficient energy systems for communities, campuses, and urban developments. These systems, equipped with energy storage technologies such as batteries or thermal storage, can balance supply and demand, ensuring reliability even in areas with weak grid infrastructure. In the United Kingdom,The wind farms, developed in collaboration with local residents, community organisations, and academic institutions, demonstrated the feasibility of micro wind energy in low-income urban areas. By leveraging microgrids and storage, cities can enhance VRE adoption, improve energy access, and encourage broader consumer participation in the clean energy transition.

Smart grid technology

As the city aims to increase its share of VRE to reduce burden on the distribution company and reduce its emissions from electricity consumption, strengthening the grid infrastructure to accommodate VRE is vital to avoid any disruptions in the transmission. Implementing smart grid infrastructure such as advanced metering infrastructure, and real-time monitoring and control systems to manage the variability of VRE generation would increase grid stability and manage supply and demand.

Renewable energy forecasting methods

To become net zero in the power sector of Kolhapur through implementation of distributed renewables within the city, it is essential to monitor and forecast the energy production by different renewables in order to ensure a reliable supply to the consumers. Given the intermittent nature of renewables, especially solar PV, forecasting methods must become an integral part of the grid upgrade.

Solution 4

Ensuring an Equitable and Just Energy Transition

Equity and Justice | Behaviour Change and Public Acceptance | Livelihoods and Social Protection

Ensuring equitable access to clean energy is key to Kolhapur's sustainable development. Marginalised communities, particularly those in low-income households and informal settlements, often face barriers to reliable and affordable electricity. Targeted renewable energy interventions such as decentralised solar, biogas, and microgrid systems not only bridge this access gap but also create meaningful livelihood opportunities. By combining inclusive financing, skill development, and supportive policies, Kolhapur can build a just energy transition that empowers vulnerable populations, enhances economic resilience, and drives community-led climate action.

Targeted renewable energy access to marginalised communities

Expanding decentralised renewable energy (DRE) access to marginalised communities is crucial for energy equity and socio-economic development. Low-income households and informal settlements often lack reliable electricity due to high costs and inadequate infrastructure. DRE solutions such as solar microgrids, biodigesters, and small-scale wind or hydro systems offer affordable and sustainable alternatives, reducing dependence on polluting fuels.

Collaborations between local governments, community organisations, and social enterprises can enhance adoption. For example, in India, the Bihar Rural Livelihoods Promotion Society (BRLPS) partnered with self-help groups (SHGs) to implement decentralised solar projects (Manocha, 2018). Similarly, informal settlements can integrate small-scale biogas systems to improve living conditions (Khalid et al., 2023). Such models empower communities socially and economically, fostering sustainable energy access.

Livelihoods and job creation

Skill development programmes for women and youth in solar, bioenergy, and grid operations Expanding renewable energy in Kolhapur offers significant job opportunities, particularly for women and youth. Rooftop solar (RTS) and decentralised PV systems can create employment in installation, maintenance, and operations. Training initiatives such as Barefoot College in Rajasthan, which equips rural women with solar engineering skills, could be adapted for Kolhapur (Barefoot College, n.d.). The municipal government, NGOs, and private firms can collaborate to establish vocational training centres, ensuring financial support for marginalised groups.

Decentralised bioenergy projects can generate jobs in operations, waste collection, and maintenance. Training informal waste workers and ensuring social protections can enhance income security, as demonstrated by Pune's SWaCH cooperative (A Comprehensive Case Study on the SWaCH Model, n.d.).

Technical training in grid modernisation, smart grids, and renewable energy integration can equip Kolhapur's youth for sustainable employment, fostering an inclusive clean energy transition while strengthening local economic resilience.

Energy affordability – targeted subsidies and tiered pricing for low-income users

Ensuring energy affordability in Kolhapur requires targeted subsidies, tiered pricing, and community-based solar models to lower costs. 'Solarize Salem' in Massachusetts reduced solar installation expenses through bulk purchasing agreements, a model that could support cooperative housing solar projects in Kolhapur (City of SalemMassachusetts, 2019). Tiered subsidies for rooftop solar PV can further benefit low-income households (Tyagi and Kuldeep, 2023).

Another case study would be in Colorado, the Coyote Ridge Community Solar Farm showcases how shared solar ownership and subscription-based models can make renewable energy more accessible by lowering financial barriers for participants. Similarly, community biogas initiatives that use organic waste for fuel offer affordable alternatives to traditional cooking methods, especially in low-income areas. These projects, supported through subsidies and skill development programmes, not only improve energy access but also generate local employment. Public–private partnerships play a key role in these efforts, helping to ensure that marginalised settlements benefit equitably from the renewable energy transition. (LIFT, n.d.)

Solution 5

Building Public Participation and Trust in Renewable Energy

Equity and Justice | Behaviour Change and Public Acceptance

Kolhapur's renewable energy transition depends on public engagement and equitable planning. Awareness campaigns and local workshops can promote adoption of rooftop solar, smart grids, and bioenergy, while behavioural changes like demand-side management can ease grid pressure. Inclusive participation by low-income households, industrial workers, and waste sector communities ensures that clean energy benefits are fairly shared.

Awareness campaigns – education on renewables' benefits and adoption strategies

Raising awareness through education and hands-on experience is key to increasing renewable energy adoption in Kolhapur. Behavioural campaigns highlighting financial and environmental benefits – such as Cape Town's Accredited Solar Water Heater Programme – can enhance public trust (C40 Cities, 2015). Community workshops, peer-to-peer networks, and pilot demonstrations can further improve acceptance, as seen with hydrogen fuel cell trials in California and Michigan (Huijts et al., 2011).

Public participation is crucial for bioenergy, waste-to-energy, and wind projects. Engaging communities in planning, transparent communication, and collaborative ownership models – like Bangalore's solid waste management initiative – can foster trust and equitable benefits (N. Hema et al., 2022). In Kolhapur, educating residents on smart grids and energy storage, similar to Bhopal's smart city initiative, can smoothen the transition to advanced infrastructure (Government of Madhya Pradesh, 2018). These strategies ensure inclusive and community-driven renewable energy adoption.

Participatory planning – engaging local stakeholders in decision-making for wind and bioenergy projects

Engaging local stakeholders in wind and bioenergy projects fosters community ownership and long-term acceptance. In Hull, Massachusetts, residents participated in planning a community-owned wind project, contributing to shared benefits and energy sustainability. Similarly, the Galena Bioenergy Project in Alaska involved local inputs in developing a biomass heating system using locally sourced woody biomass, ensuring affordability and resilience. Public consultations, participatory workshops, and transparent decision-making strengthen trust, aligning projects with local needs. These models demonstrate that integrating community voices enhances project success, supports equitable energy transitions, and builds long-term commitment to renewable energy (Menghwani, n.d.).

Behaviour change programmes and demand-side management

Behaviour change programmes play a crucial role in promoting efficient energy use and enhancing smart grid participation by influencing consumer habits and decision-making. Education campaigns and behavioural interventions raise awareness about energy conservation, encourage sustainable practices, and shift heavier electricity consumption to periods when there is maximum generation of power by variable renewable energy (VRE) sources. Demand-side management programmes ensure consumers maximise VRE potential, reducing reliance on the backup source – conventional power plants. Additionally, these programmes drive behavioural shifts toward adopting efficient appliances and lowering energy consumption. Successful initiatives, such as Opower's Home Energy Reports in the US, demonstrate how personalised feedback fosters energy savings (Manwell et al., 2006).

Chapter 2

Green Buildings

Green Buildings

Sector Overview

The building and construction sector plays a key role in accelerating the transition towards a low-carbon, resilient, and sustainable future in Kolhapur. Energy consumption and carbon emissions in the built environment are largely from the use of electricity and building materials (Bhardwaj and Tewari, 2025). The emissions associated with energy use in a building are termed operational emissions and those associated with building material production, construction of a building, renovation and repair, and demolition at the end of its life, are termed embodied emissions.

According to a study from 2013 by Data Portal for cities, the residential buildings sector in Kolhapur emitted approximately 72 tons of CO_2 equivalent, accounting for 90 percent of the emissions from the buildings sector (Data Portal for Cities, n.d.). With increasing urban growth all across Kolhapur, it is clear that more sustainable practices in existing buildings and greener construction of newer buildings is crucial to achieving Kolhapur's target of net zero by 2040.

Existing Conditions and Key Challenges

Kolhapur has experienced significant urban growth over recent decades. Between 1989 and 2019, the city's built-up area expanded remarkably, reflecting a broader trend of rapid urbanisation in India (Jarag et al., 2023).

This expansion has often been characterised by unplanned urbanisation, leading to challenges such as increased population density and pressure on civic amenities. The city's population density stood at approximately 8,400 individuals per square kilometre, surpassing both state and district averages (Moghe and Kumthekar, 2021; Ramotra and Swami, 2016).

The real estate sector in Kolhapur has faced challenges, including a slowdown due to economic factors. This has resulted in unoccupied residential complexes and unfinished projects, indicating a mismatch between supply and demand in the housing market (Joshi, 2017; Media Neliti, n.d.).

Furthermore, socio-economic surveys and stakeholder discussions have highlighted critical issues in Kolhapur's urban development, including injudicious land use, challenges arising from a lack of holistic development, and the absence of an inclusive planning approach. These insights underscore the need for strategic planning to address gaps in affordable housing and equitable urban growth. (World Resources Institute, n.d.)

Kolhapur, known for its cultural heritage and vibrant urban character, faces pressing challenges in addressing the housing needs of its informal settlements while ensuring thermal comfort and reducing emissions.

According to the Citywide Social Housing Research Project by Shelter Associates (2023), the city has a slum population of approximately 67,646 individuals living in 54 slums, with many of these settlements lacking adequate infrastructure, including proper ventilation and insulation, which are critical for thermal comfort (Shelter Associates, 2023). The excessive reliance on inefficient energy sources for heating and cooling in these settlements further exacerbates greenhouse gas emissions.

Incorporating sustainable housing designs that prioritise thermal comfort through passive cooling, natural ventilation, and energy-efficient materials is essential for improving living standards. Another study on health and hygiene in Kolhapur's slums also highlights the need for addressing indoor air pollution, a direct consequence of poor building designs and reliance on traditional fuels (Jadhav and Manglekar, 2022). Integrating energy-efficient designs with affordable housing policies, such as through the Pradhan Mantri Awas Yojana (PMAY), can create low-emission housing solutions tailored to the city's growing needs.

Overall, there is a significant demand for housing in Kolhapur, particularly for affordable options that prioritise thermal comfort. Ensuring housing solutions that are both cost-effective and designed to provide natural cooling and insulation can address the dual challenges of improving living standards and reducing energy consumption (Moghe and Kumthekar, 2021). As Kolhapur grows – or transitions – green building norms and guidelines are urgently needed to reduce emissions related to new constructions and for retrofits in and around the city. There are several challenges in achieving these, such as:

Awareness and expertise gaps

A significant gap in awareness among builders and residents regarding the benefits and methodologies of green building practices hinders their widespread adoption. This lack of knowledge limits the community's capacity to engage in sustainable construction, perpetuating traditional practices that may not align with environmental goals.

Perceived high costs

The perception that green buildings incur higher initial costs discourages many, particularly low-income groups, from pursuing sustainable construction options. Despite the potential for long-term savings on energy and maintenance, this fear of initial financial burden remains a significant barrier to adopting greener practices.

Upskilling

There is a dearth of skilled manpower to build energy-efficient buildings. There are no incentives and upskilling schemes for existing workers. Policymakers, architects, engineers, contractors, and workers lack adequate knowledge and skills for green building construction, resulting in the slow adoption of green building in India.

Unfavourable market conditions

In some cases, energy-efficient technology or materials may not be available in certain markets, or short supplies may raise prices. Consumers often lack information about the availability and benefits of energy-efficient products and services. India currently lacks testing, standardisation, and certification for efficient building materials, which discourages innovation and advances (Ibrahim, 2023).

Need for guidelines for sustainable buildings

Requiring sustainability in local building rules increases costs, which feel especially high because current construction standards are quite low. The government at the local level should incorporate efficiency considerations in construction and procurement guidelines and establish benchmarks for building energy use.

Bureaucratic hurdles

The approval process for green building compliance and the complex documentation required can deter developers from opting for green ratings.

Amidst these challenges, Kolhapur is making strides toward sustainable development, driven by a mix of municipal initiatives, institutional efforts, and community awareness.

Existing Policies for Sustainable Buildings

The Government of Maharashtra has begun to promote green and low-carbon buildings across its cities. The construction sector in Maharashtra is governed by the Maharashtra Regional and Town Planning Act, 1966, the Maharashtra Housing and Area Development Act, 1976, the Maharashtra Housing (Regulation and Development) Act, 2012, and the Maharashtra Building Bye-Laws, and its subsequent amendments.

The Maharashtra government has implemented several initiatives to promote green buildings and sustainable construction practices. The events and timeline are as follows:

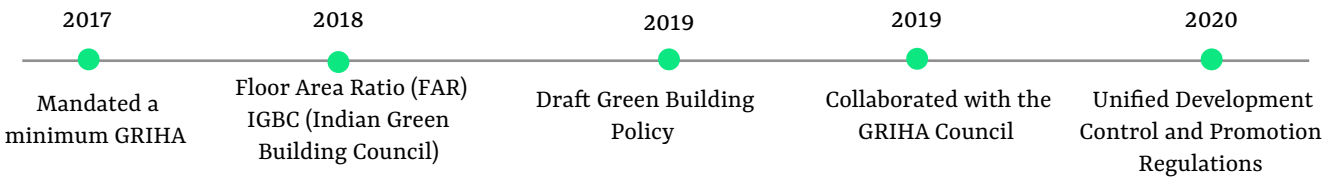

Figure 2. Timeline

2017 Mandated a minimum GRIHA (Green Rating for Integrated Habitat Assessment) three-star rating for all government, semi-government, local bodies, and public sector construction projects.

2018 Introduced additional Floor Area Ratio (FAR) incentives for buildings achieving IGBC (Indian Green Building Council) ratings: The Urban Development Department offers a bonus FAR of 3 percent for silver, 5 percent for gold, and 7 percent for platinum.

2019 Efforts to implement the Draft Green Building Policy, making it mandatory for all new commercial and residential buildings to adhere to green building norms, with incentives for developers and buyers.

2019 Collaborated with the GRIHA Council to evaluate and rate 300 existing government buildings, with plans to assess an additional 525 buildings, aiming to enhance sustainability and resource efficiency.

2020 Released the Unified Development Control and Promotion Regulations, incorporating provisions to promote green building concepts within municipal areas.

The Kolhapur Municipal Corporation (KMC) has showcased its commitment by planning a green administrative headquarters designed to conserve energy, promote renewable energy use, and enhance water efficiency. Additionally, institutions such as the Chhatrapati Shahu Institute of Business Education and Research (CSIBER) have adopted environmental audits to align their operations with sustainability goals. KMC has also enforced regulations mandating rainwater harvesting and sewage treatment for large buildings, reflecting the city's proactive approach to resource conservation.

However, traditional construction practices rooted in cultural norms continue to shape the built environment, necessitating a thoughtful integration of modern green technologies. Furthermore, Kolhapur's foundry sector creates environmental challenges, with its inefficient pollution controls that require urgent upgrades. The city is also grappling with construction and demolition waste management, calling for innovative solutions to mitigate its environmental impact. Complementing these efforts, social housing research has emphasised the need for affordable, culturally sensitive, and sustainable living solutions, setting a foundation for inclusive and green urban development. These existing conditions highlight Kolhapur's potential to serve as a model for sustainable urbanisation in mid-sized Indian cities.

Who is responsible for green buildings?

The construction and buildings sector requires the cooperation of many actors: government bodies such as Directorate of Town Planning and Valuation (DTP), Kolhapur Municipal Corporation (KMC), The Maharashtra Pollution Control Board (MPCB)vet sites, set land use and development, control regulations, and approve new buildings and retrofits. The private sector is largely involved in the planning, design, and financing of new buildings. Materials suppliers, contractors, and construction labour play a key role in transitioning to green development.

Despite the growing interest in low carbon construction, adoption of green buildings has been slow because of all these challenges. New solutions are urgently required.

Solution 1

Incentives for Green Building Constructions

Institutional Innovation | Public Participation and Trust | Behaviour Change and Public Acceptance

What is a green building?

The construction of a green building is aimed at using local resources, preserving the environment, and saving energy, water, and materials. Green building construction covers the following domains: (1) sustainable architecture and design; (2) site selection and planning; (3) water conservation; (4) energy efficiency; (5) building materials and resources; (6) indoor environmental quality; and (7) innovation and development (Indian Green Building Council, 2016).

Various government-recognised bodies such as the Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED), etc., provide a green certification based on the ability of a developer to implement various predefined conditions under each of the above categories. The rating may range from basic 'certified' to 'silver' to 'gold' to 'platinum' (for implementing the highest level of sustainability and green features). A certification allows developers to not only demonstrate a commitment towards being sustainable, but also for the building users to benefit from green features like improved comfort, productivity, and cost savings.

Awareness programmes and incentives are needed to address the higher cost of construction and knowledge gaps about the benefits of green buildings. These include

Incentives to Developers

Design phase
An incentive of special loans or expedited sanction of project may be given to developers committed to obtaining a green rating. Developers who obtain a pre-certification from any of the rating agencies get special loans at an interest rate 0.25 or 0.50 base points lower, and are able to skip the line for projects awaiting environmental or other statutory clearances, thereby saving significant amounts of time.

Construction phase
A widely used and successful incentive to green certification is increased Floor Area Ratio (FAR). Higher FAR, which is the ratio of a building's total floor area to the size of the land it is built on, means a developer is allowed a larger built-up space, which significantly compensates for the higher cost of going green. Another incentive is a reduction in infrastructure tax or any other government taxes, to be paid by the developer.

Operation phase
An incentive to improve demand for green buildings could be to reduce house-tax for homeowners with green certification. Builders might be encouraged to opt for green certification because of increased consumer demand for greener real estate.

Partnerships with green certification agencies

In collaboration with green rating agencies, training workshops on the requirements of a green certification can be held for various stakeholders, including developers, architects, civil engineers, contractors, materials and service providers, educational institutions, etc. This would help streamline processes for obtaining a green rating and increase the number of accredited firms or individuals who can provide green certification to developers.

A database for green sourcing

The lack of availability, knowledge or options of greener materials could hinder contractors looking to go green. A government-maintained rating and a repository of local, upcycled or low-carbon materials available in the market, or even better, produced in Kolhapur could help solve this problem. Such a database, which lists service providers and technologies and accredited personnel, would incentivise firms to train their staff on green rating and its requirements. Regular trade exhibitions would improve awareness and market penetration of such products.

Demonstration projects, awards, and recognitions

Showcasing projects that include green and innovative practices in their design, construction, and operation could encourage developers, architects, or contractors to opt for green certification. It would create healthy competition, drive a demand for greener materials and services, and also influence consumers to opt for more sustainable spaces. Giving awards and recognition to such projects could also nudge them towards greener practices.

Generating demand for green buildings

Green buildings need consumer demand, which involves addressing consumer preferences. Green buildings may challenge conventional aesthetic norms, particularly in India where glass skyscrapers are favoured but are not ideal for either thermal comfort or energy savings. Changing preferences requires behaviour change and normative shifts among citizens. Awareness campaigns highlighting the benefits of green buildings, aligned with people's values and aspirations, could play a crucial role.

Solution 2

Green Guidelines for all Multi-dwelling Residential and Commercial Projects

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust | Institutional Innovation

Environmental clearance (EC) was required for projects with a built-up-area (BuA) of 20,000 square metres (sq m), but a recent amendment to the law requires only those above 50,000 sq m to opt for an EC (Standard, 2019). This significantly reduces the environmental compliances for smaller developments, probably resulting in higher carbon footprints. To reduce this footprint, the following guidelines could be suggested for all new multi-dwelling or commercial developments in and around the city:

Cleaner Energy

Buildings must use cleaner sources of energy to the extent possible. While initial costs of set-up are generally higher, there are documented savings from usage. Examples include:

CNG-powered generator sets
Rather than the conventional diesel operated sets, these should be used during project construction.

Renewable energy
Every consumer of conventional energy could be mandated to generate and use 25% of power from non-conventional sources such as biogas, solar or wind energy. While constructing roof-tops appropriate provision should be made for the installation of solar panels or other renewable energy sources.

Newer technologies
Traditionally, solar is installed on the roof of a building, which is known as building-applied PV. However, more architects are learning how to integrate solar cells and modules into items such as curtain walls, roof tiles, and railings – a concept known as 'building-integrated solar PV'.

Organic, Perovskite, multi-junction and thin film panels should be explored as alternatives to the conventional silicon solar PV cells such as organic, perovskite, multi-junction and thin-film solar cells (Sinha and Mehta, 2023).

Energy-Efficient Building Envelope

A building's envelope is everything that separates its interiors from the external environment including the roof, windows, walls, floors and doors. A heat resistant envelope means cooler and more comfortable interiors.

Doors and windows
Glass should be reduced in the southern and western facades in a window–wall ratio of 40 percent, to reduce electricity consumption and load on air-conditioning (ECBC, 2024) by the Bureau of Energy Efficiency (BEE). Glass with low U-values (a metric for insulation) and solar heat gain coefficient (SHGC) as per the Energy Conservation Building Code (ECBC, 2024), such as high-quality double-glazed windows and those with a special reflective coating, should be used.

Roof
The U-value should meet at least the baseline requirement as per the ECBC by using appropriate thermal insulation material, light-coloured reflective finish, landscaped terraces and other solar-passive designs. The Solar Reflectance Index (SRI) is a measure of a material's ability to reflect solar heat. The recommended solar reflective index (SRI) value for a low-sloped roof is minimum 78 and for a steep-sloped roof is minimum 29 (LEED Rating).

Wall
Wall should meet prescriptive requirements as per ECBC for all air-conditioned spaces by using appropriate insulation. Materials such as Autoclaved Aerated Concrete blocks (AAC) blocks or fly-ash bricks could be used in masonry works to improve thermal resistance.

Energy Conservation Measures

Measures other than the use of cleaner energy, could be adopted in design, construction, and infrastructure to reduce energy consumption during operation and use of the building.

Lighting energy demand
At least 75% of the regularly occupied areas of the building should have sufficient daylighting with lux levels of 110 or above. The Lighting Power Density (LPD) for internal and external spaces should be less than or equal to the LPD requirements prescribed in ECBC. In common areas LED lights with sensors should be mandatory (Indian Green Building Council 2016).

Space cooling demand
The comfort condition to be maintained for indoor air conditioning is 26 ± 2 degrees C with relative humidity (RH) in the range of 30% to 60%. At least 50% of the regularly occupied floor area should be cross-ventilated (Indian Green Building Council 2016).

Energy-efficient appliances
Where feasible, developers or consumers should ensure that all appliances (including fans, water heaters, refrigerators, TVs, computer monitors, printers, copiers, scanners etc.) are 4-star labelled, or use any superior energy conservation technology. For Heating Ventilation and and Air Conditioning (HVAC) systems, the design coefficient of power (COP) should be greater than or equal to the prescribed COP as per ECBC. Cleaning and maintenance regimes of fixtures and equipment are required.

Parking
Traffic congestion around the property must be avoided by providing fully internalised parking. To minimise the heat island effect, no public place should be utilised for parking.

Landscaping and Green Belt Development

Landscaping around a building potentially offers many benefits beyond aesthetics.

Green perimeter
All buildings must provide a landscape bed along the periphery of the site for planting shrubs or trees to increase biodiversity and sequester carbon.

Species selection
Selection of plant species is critical with local fruit-bearing trees like kokum, mango, jamun or other native trees prioritised, based on the local geography and soil profile. The State Forest/ Agriculture Department and State Biodiversity Board could help to identify species and sites for tree plantation in case of space constraints within the site.

Reduced hardscape
Concreting or hardscaping should be reduced to a minimum, using grass pavers and paver blocks with at least 50% opening to allow for water percolation and reduction of heat island effect (Indian Green Building Council 2016).

Solution 3

Reducing Embodied Energy in Retrofitting of Old Buildings

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust | Livelihoods and Social Protection

Retrofitting of buildings refers to the process of upgrading or modifying existing structures to enhance their performance, energy efficiency, safety, or functionality. This can be done for various reasons, including compliance with new building codes, safety, improving sustainability, and adapting to changing needs. Retrofitting measures (see recommendations below) can be applied to different aspects of a building, including its structure, systems, and envelope.

Embodied energy is the energy associated with the manufacturing of a product or services, such as extracting and processing of raw materials, manufacturing of construction materials, transportation and distribution, and assembly and construction. According to the International Energy Agency, the average retrofit rate of the existing building stock is approximately 1% per year, globally, and to achieve net zero emissions by 2050, retrofit rates must jump to at least 2.5% by 2030 (International Energy Agency, 2021)

Structure (Sub and Superstructure)

For structural modifications inputs are needed from a retrofit-experienced structural engineer, who is ideally sympathetic to low-embodied carbon design.

Heavy elements should be restricted wherever possible to limit the need for additional structure or strengthening. Reduced embodied carbon targets can be achieved through low carbon concrete mix design, low carbon materials and using recycled/repurposed materials.

Envelope (Facade and Roof)

Embodied carbon of the entire retrofit solution for facade/roof systems must be considered during early design stages with carbon impacts of different options compared. For metals used, efficiency must be prioritised, and recycled content incorporated, ensuring metals can be removed and recycled at end of life. New windows could have timber frames to minimise embodied carbon impacts. Percentage of recycled content and locally sourced material should be prioritised over other materials.

Mechanical, Electrical and Plumbing (MEP)

Reducing the amount/capacity of cooling equipment would lower the embodied carbon impact of new services. To improve efficiency in new MEP systems, length of ductwork should be limited, and over-provision of the plant avoided by undertaking a detailed load assessment.

Finishes and Furniture Fixtures and Equipment (FF&E)

Products must be compared based on available data, recycled material used, and harmful chemicals like formaldehydes and VOCs avoided. Replacement cycle and specifications for longevity and end of life must be included.

Explore Reuse

Existing materials and systems should be re-used and re-purposed where possible. The lifecycle footprint of new materials must be evaluated before deciding to utilise new materials.

Miscellaneous

Material efficiency reviews must be carried out. Are all materials proposed necessary? Can some layers of the building serve a dual purpose? Future re-retrofits can be avoided by ensuring longevity of material and systems specifications, particularly in a changing climate. Unconventional and lower embodied materials or re-purposed materials should be sourced from local reclamation yards, specialised material stockists etc. In larger projects, a design team and contractor could limit over-ordering and wastage in construction, thus limiting the need for remedial works on site with higher carbon materials.

Solution 4

Greener Materials and Techniques

Equity and Justice | Behaviour Change and Public Acceptance | Livelihoods and Social Protection

Concrete is the second-most widely used substance on the planet, surpassed only by water. It is used for building residential foundations and driveways, hospitals, schools, and bridges. While a reliable and relatively affordable building material, concrete (and its production) is responsible for around 8% of global emissions (Skinner & Lalit, 2023). Project owners could avoid concrete's harmful impact by using the following materials and ensure the upskilling of contractors and masons:

Fly Ash Bricks

Coal has its pros and cons, but one of the benefits of burning coal is that it produces fly ash, a fine powder formed by mineral impurities. When mixed with water and lime, fly ash becomes similar to Portland cement, making it ideal for concrete blocks or bricks, as well as poured concrete.

Ferrock

This is an environmentally-friendly cementitious product made up of up to 95% recycled materials. This concrete substitute consists of recycled steel dust, iron-rich ferrous rock, and silica from recycled glass. When mixed with water, it forms a compound up to 5 times stronger than concrete, more flexible, and more resistant to oxidation and corrosion (What is Ferrock in construction? 2022).

Rammed Earth

Made from layers of silt, clay, sand, and water, poured into forms and then compressed with power rams. The result is a beautiful, durable material very similar to concrete at a much lower cost.

Straw Bales

Straw bales, made from the by-product of wheat production, are used for constructing walls. The straw is compressed into dense bales by a machine, which is used for making the walls. Then, the installer coats the walls with a mud and clay mixture. The result is a smooth finish, providing a sustainable and energy-efficient building option.

By-Blocks

Recyclable and non-recyclable plastic is heated, and then compressed into cinder block-sized bricks.

Hempcrete

Made from a bio-composite of hemp shives – a waste product generated when processing hemp into fibre – and lime, sand, or pozzolans.

Engineered Wood

A construction material made from strands or veneers of wood products (typically by-products from the timber industry) and adhesives. Since each length of wood uses less tree material than a piece of traditional lumber the same size or of the same strength, engineered wood is considered more environmentally sustainable.

Prefab Construction

A proven way to reduce construction GHG emissions by using prefabricated construction materials and technology. Low-carbon building components are manufactured off site and transported to construction sites for assembly.

Solution 5

Formalisation, Training and Skilling of Professionals and Labour

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust | Institutional Innovation | Livelihoods and Social Protection

Countries around the world are facing challenges as they work to decarbonise their economies, underscoring the need for a "just transition" that puts support for vulnerable workers and communities at the heart of climate action. It is estimated that the industry will need around 45 million additional skilled workers in the next decade (Skill Development Trainings for Construction Workers is the Need of the Hour).

Without proactive policies to support the workforce throughout this transition, many current workers (84% of India's total construction workforce falls under the semi-skilled and unskilled category) could be at risk of losing their livelihoods (Lewis, 2021) (Gupta & Olickal, 2024). To ensure that new opportunities in sustainable construction benefit all workers, policymakers should focus on supporting capacity building, upskilling and reskilling and providing technical assistance:

Increasing Skilling and Training in Low-Carbon Technologies

Modern approaches such as modular construction and 3D printing have changed how we think about building technology. The building and construction industry has immense potential to create much-needed employment opportunities, social stability, competitiveness and growth. A quick way to start is by ensuring that 80% of its informal workforce becomes part of the formal economy.

Review of existing curriculums
Existing architecture, engineering and technical training curriculums must be reviewed to include Green Building Code, modern technologies, sustainable construction practices etc., for new professionals to gain new knowledge and skills. Alternatively, electives on the subject may also be offered.

Short-term training courses
Non-profit organisations and educational institutions could curate short-term training courses on topics related to digital design and quantity surveying design for sustainable construction . They could also provide training to help semi-skilled workers take up better roles in assembly and execution, e.g., specialised courses on masonry, carpentry, steel work, and plastering.

Skill development
Construction Skill Development Council of India (CSDCI), with support and promotion from National Skill Development Corporation (NSDC) plays a major role in catalysing skill development across the construction industry. These initiatives must harness inclusivity and reduce divisions such as male/female, rural/urban, and organised/unorganised employment, and traditional/contemporary workplace.

Without upskilling to gain new knowledge and building and construction skills, both people and companies in the industry will be left behind in the highly competitive construction industry.

A proactive approach and improved implementation of policies

Along with passing new legislation, decision-makers can better leverage existing policies to advance decarbonisation efforts and safeguard the interests of the construction workforce, for example:

The Building and Other Construction Workers Act was enacted in 1996 to provide social security benefits to India's construction workers. However, due to a lack of awareness and poor implementation, most building and construction workers are still to register and therefore unable to receive benefits and support from the government. A collective effort is needed to raise awareness of this Act and ensure that workers receive their rightful benefits.

Eco-Niwas Samhita
The Bureau of Energy Efficiency developed Eco-Niwas Samitha in 2018, an energy conservation residential building code to promote energy-efficient design and use of low-carbon materials and raise awareness of energy-efficient building techniques across the industry. While most states have been notified to adopt this code, implementation and adoption by construction professionals is still lagging and needs to be enforced by the state governments and urban local bodies.

A More Proactive Role by Construction Companies and Labour Contractors

Upskilling provides opportunities to expand existing capabilities. Reskilling involves training and preparation to move into a completely new role in the workplace. There are various ways to achieve this, but they all involve three steps. First, examine the existing labour demand and supply conditions; then design a training programme to fill any gaps; finally, commit the infrastructure and resources necessary to implement training at scale.

The following factors may be considered

- Focus on providing training for in-demand skill sets for specific jobs, e.g., teaching construction labourers to read plans.
- Create dedicated days for training, either at the job site or virtually, e.g., safety training and licensing.
- Partner with higher education and training institutions to provide free or discounted training for selected employees.
- Scout the industry for the most in-demand skills now and in the future. Then craft a training programme that positions your company favourably in the industry.
- Mandate and ensure that all semi-skilled and unskilled workers on a project are registered and covered under the prevailing social schemes of the government.

Solution 6

Promotion of Sustainable Affordable Housing

Equity and Justice | Public Participation and Trust | Institutional Innovation | Livelihoods and Social Protection

Through its vision 'Housing for All by 2022' the government launched the Pradhan Mantri Awas Yojana (PMAY) — Urban (PMAY-U) and Rural (PMAY-R) in 2015. It recently launched the Affordable Rental Housing Complexes scheme under PMAY-U to provide affordable housing to migrant workers and the urban poor (ARHCs). Many states have introduced their own affordable housing schemes, tailored to meet the specific needs and demands of their regions.
Integrating thermal comfort and energy efficiency strategies into the PMAY schemes provides a unique opportunity for wide-spread and quick adoption by the affordable housing sector. These strategies can be made mandatory through the PMAY schemes, thus linking them to fiscal benefits.

Case study of the Massachusetts Community Climate Bank, USA

A first-of-its-kind green bank initiative, dedicated specifically to affordable housing has been instituted in the state of Massachusetts. The Bank aims to reduce greenhouse gas emissions from the building sector by financing clean energy improvements in affordable housing. It offers affordable loans to property owners, especially for low-income and middle-income households, to support the development of greener new constructions and retrofits for energy efficiency, electrification and clean energy technologies. The bank leverages State and Federal grants from the government but also attracts private investments and philanthropy for this work (Tarun Gopalakrishnan et al., 2024).

Indian cities must also explore multi-source financing and work with states and financial institutions to develop innovative mechanisms and instruments to address climate change for vulnerable communities.

Innovative Funding

While design interventions can be integrated into projects at zero cost, material and technology interventions may result in increased construction costs. It is necessary to reduce the financial burden on developers as well as buyers. Since traditional financing may not cater to the specific needs of affordable housing projects, innovative funding options such as microfinance, impact investing, and public subsidies must be explored.

Regulatory Changes

Streamlining and simplifying regulatory processes and obtaining necessary approvals within a reasonable timeframe are crucial. Recent policy changes, such as the introduction of Real Estate Regulatory Authority (RERA) and the ARHC scheme, aim to create a conducive environment for affordable and sustainable housing development.

Multi-Stakeholder Collaborations

Collaborations with diverse stakeholders hold great potential in creating a green, affordable housing stock. Including:

Public-private partnerships (PPP) play a pivotal role in overcoming challenges by leveraging the strengths of both sectors. Collaborations between real estate developers, government bodies, and financial institutions help mobilise resources, expertise, and funding required for affordable and sustainable housing projects.

Community engagement and participation are vital for the success of such initiatives. Involving local communities from the planning stages fosters a sense of ownership and ensures that projects align with the specific needs of the target population.

Collaborative efforts with non-profit organisations and advocacy groups play a vital role in promoting awareness and education. Partnerships between the real estate industry and these organisations provide a platform for sharing knowledge, conducting research, and advocating for policies that support affordable and sustainable housing.

Financial Reforms

The government should roll out financial support programmes to absorb the extra costs of building sustainably. Increasing home loan subsidies with relaxations in GST and taxes will incentivise construction of low carbon buildings. Housing schemes under PMAY with green building certifications can be awarded extra subsidies coupled with stamp duty waiver. Strategic relaxation in Floor Space Index (FSI) norms can help reduce common infrastructure development costs. Developers can use the excess budget to provide energy-efficiency measures in their buildings.

Evaluations

Robust enforcement and high compliance rate will be essential to ensure the intended energy savings and GHG reductions through this strategy. Regular evaluation and improvements to the policy will help build trust amongst all stakeholders and inspire confidence in adopting energy-efficient strategies.

Climate Proofing Green Buildings

Increasing frequency of climate change effects such as severe droughts, devastating floods and cyclones may force millions of people to migrate from their homes. Successful affordable housing must keep people safe during such disasters. Climate-proofing of affordable housing has warranted benefits.

Chapter 3

Electricity Consumption

Electricity Consumption

Sector Overview

City overview and power sources

Kolhapur is one of the fastest-growing cities in Maharashtra and a centre for energy-intensive industries including automotive, foundries, engineering spares, sugar and jaggery, and textiles. The numerous sugar mills on the outskirts of the city account for a significant portion of the city's industrial endeavours. Kolhapur also has an active commercial hub. The city receives electricity from the state and national grids and does not produce any of its own electricity. Currently, Maharashtra pays the Centre ₹4.13/unit of electricity it receives from the Centre; the prices of electricity from private producers within the state are ₹5.46–5.47. Maharashtra's total average cost for electricity per unit is ₹4.97, about ₹0.50 higher than average state-level costs in India. Maharashtra thus has a financial incentive to moderate electricity consumption among all sectors. Consumers have been protesting rising tariffs, which creates an additional incentive for shifting towards renewable energy (RE) while also moderating overall consumption.

Rooftop solar (RTS) systems have a significant presence in Kolhapur in both residential and commercial properties, including lodges and other places of short-term accommodation. Both solar panels and solar water heaters are common on Kolhapur's rooftops. To some degree, this cuts across class strata, with both upper-income and middle-income homes boasting rooftop solar panels and/or water heaters. Many flatblocks also boast RTS. However, government buildings appear to lag, with RTS being less common on the rooftops of municipal government offices.

Many sugar mills on the city's outskirts have cogeneration plants, captive small power stations on the premises that generate electricity for local use. These plants run on the bagasse residue left over from processing sugarcane. Occasionally, though not frequently, excess electricity generated by these captive plants is exported to the main grid. Besides RTS and energy from bagasse, the city also has waste-to-energy generation plants that are, however, located outside the city boundaries. Wind power has no significant presence in or around the city.

Energy consumption in Kolhapur and Maharashtra

As of 2013, per capita power consumption in Kolhapur was approximately 277 kWh (Data Portal for Cities, 2013). Current tariffs for Kolhapur and across Maharashtra for domestic consumers are as follows, exclusive of fixed and additional charges:

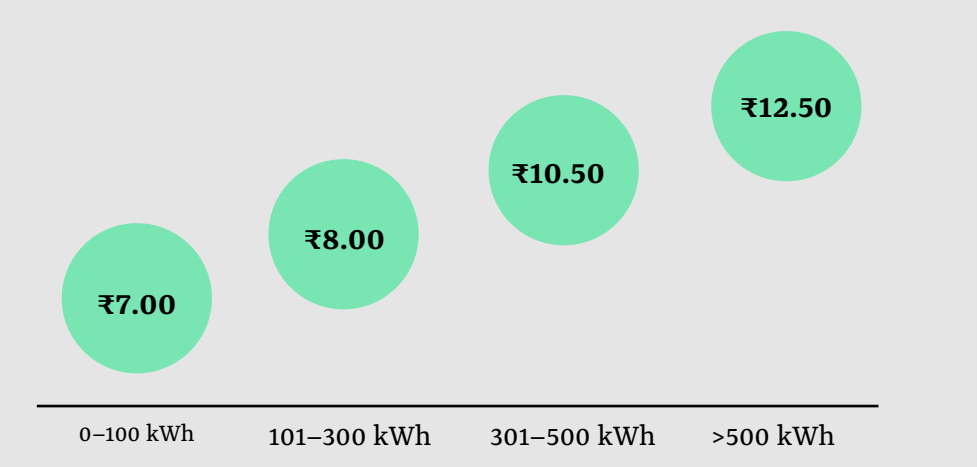

Figure 3. Current Domestic Tariffs in Kolhapur (Excluding Fixed and Additional Charges)

Electricity tariffs across India are among the lowest in the world (Goswami, 2023). Maharashtra has the highest tariffs of any Indian state or union territory. Maharashtra is also India's richest state by GDP; as of FY 2018–19, the state contributed 15 percent of India's GDP.

In 2023, Maharashtra's consumption of energy was at an all-time high of 155,158 GWh, representing a year-on-year increase of 9 percent from 2022. Since 2013, statewide electricity consumption has risen by 156 percent. The industrial sector is the thirstiest in the state, accounting for 35.4 percent of electricity consumption statewide, followed by agriculture (27.2%) and domestic (24.2%). Maharashtra is home to about 9.29 percent of India's population (approximately 132.8 million as of 2024), occupies approximately 10 percent of India's area geographically, and consumes approximately 10 percent of India's electricity.

Existing Conditions and Key Challenges

Investment in renewables

Maharashtra is currently India's third-from-top state in terms of share in solar installations as part of the state's contributions to Nationally Determined Contributions (NDCs). Hydropower is also significant statewide, contributing 13,602 MW. The state's RE policy aims to implement a large transmission system powered by solar and wind energy. In 2023, 17 percent of the state's generated energy was renewable; the state aims to increase this share to 32 percent by 2028 and 52 percent by 2030.

The Maharashtra Energy Development Agency (MEDA) aims to regulate energy conservation and promote the use of RE statewide, with a focus on solar, wind, and bioenergy. MEDA is also tasked with implementing at state level the guidelines laid down by the Bureau of Energy Efficiency (BEE). Energy efficiency and energy conservation are thus key features of MEDA's mandate. Installation of energy-efficient street lighting, financing energy efficiency in government buildings and urban local bodies (ULBs), and conducting energy audits in the government and industrial sectors have been key components of MEDA's activities in the energy-efficiency realm.

Maharashtra's Industry, Energy, and Labour Department released, in 2019, its Power Sector Vision 2030: Maharashtra planning document (Industry, Energy and Labour Department, 2019). Environmental and financial sustainability feature as key goals in this vision, via continued investments in clean energy, decentralised renewable energy (DRE), and digital technologies, to increase efficiencies and create an informed and empowered consumer base. This report notes that the state has been a frontrunner in electrification (having achieved 100 percent household electrification) and investments in clean energy and in digital technology. Key challenges noted include operational inefficiencies, high costs of delivery, and problems predicting the needs of a varying and dynamic consumer base. Further challenges are related to the successful integration of RE into the grid, especially during high wind season.

This vision document notes the key goals of decentralisation, decarbonisation, and digitisation.

Decentralisation

The vision report prioritises dissemination of RTS, especially in households, and anticipates that the share of solar energy in the state's total output will rise as costs of battery storage fall by 50 percent over the next four or five years.

Decarbonisation

The report anticipates limited investments in coal energy beyond projects currently under construction (as of 2019). (A rise in adoption of electric vehicles is also anticipated.)

Digitisation

The report anticipates growing scope for technologies, such as AI, the internet of things (IoT), and machine learning, to increase efficiency in the power production and distribution system and lower operational costs. The role of digital technology in enabling the penetration of RE is key.

Other challenges for sustainable electricity consumption, including a move towards RTS and energy efficiency, are as follows:

Low subsidies for rooftop solar

Maharashtra offers subsidies to domestic consumers of ₹30,000/kW up to 2kW only; total subsidies for systems larger than 3kW are capped at ₹78,000. Subsidies for group housing societies are also modest at ₹18,000/kW (Maharashtra State Electricity Distribution Company Limited MSEDCL, n.d.). These subsidies are quite modest and the caps are quite stringent. Given Maharashtra's high per-unit costs for energy, the policy on state-level subsidies for RTS may increase RTS adoption, ease stress on the grid, and thus help reduce average per-unit costs of energy statewide.

Low awareness

Indian consumers generally do not know about energy-efficient electrical appliances. A 2020 study found that only 25 percent of residential consumers reported awareness of energy-efficient alternatives for household devices (Agrawal et. al, 2020), or of the star labelling programme implemented by the national Bureau of Energy Efficiency (BEE). It also found an urban–rural divide, where rural respondents were only half as likely to report awareness as urban respondents. Awareness is necessary for behaviour change, so raising awareness about lower-carbon alternatives can encourage energy-efficient behaviour.

Existing Policies for Reducing Energy Consumption

National Level Programs

Bureau of Energy Efficiency (BEE)'s star labelling and other programmes

BEE's demand-side management (BEE, n.d.) in the agricultural and municipal sectors has focused on public utilities, such as street lighting and sewage treatment plants, and power consumption in public buildings. BEE could widen the scope of their demand-side management programme to include residential and industrial consumers.

Nationwide, BEE requires energy-intensive industries to conduct internal energy audits annually (BEE, n.d.). Energy savings are certified. As of 2015, BEE claimed to have achieved an emissions reduction of 31 million tons of carbon dioxide per year by implementing this programme across nine energy-intensive industries, including thermal power plants.
BEE's best-known programme is their star labelling system, which categorises household and industrial appliances such as refrigerators, LED lights, air conditioners, car tyres (domestic use), and industrial motors and pump sets (agricultural and industrial), based on their energy efficiency. They aim to educate its target audience about the financial and environmental benefits of energy-efficient devices.

Independent research finds that BEE's star labelling system has had significant impacts (Joshi et al., 2020), leading to a cumulative reduction in consumers' electricity bills ₹94,000 crore in 2021–22 alone (Times of India, 2024) – an impressive reduction in household electricity consumption. An independent assessment suggests that, between 2006 and 2020, consumer behaviour shifts linked to the star labelling system resulted in a reduction of 397 million tons of carbon dioxide emissions from refrigerators and air-conditioners alone (Joshi et al., 2020). The star labelling system is an important tool for continued emissions reductions. Reputable manufacturers are using the star rating system to market the benefits of higher-star appliances (Tathagat, 2007; Regidi, 2024).

Currently, one barrier to widespread adoption of low-carbon lifestyles is that the effects of our behaviours are often delayed, uncertain, and removed from us physically and socially. The effects of a consumer using an energy-inefficient AC in New Delhi in 2024 may or may not be felt (Dai, 2012), decades from now on, for instance, the east coast of Africa, by people very different socio-demographically from the AC user (Wright, 1990). Therefore, our motivation to make sustainable choices is low. However, if information about the effects of our actions could be concrete, that would address one set of barriers.

State Level Programs

Energy-auditing schemes

The energy-auditing schemes by Mahaurja (Maharashtra Urja Vikas Abhikaran, also known as Maharashtra Energy Development Agency or MEDA) are currently restricted to energy-intensive industries, including sugar which is produced in and around Kolhapur, under the nationwide Perform, Achieve, and Trade (PAT) scheme. The state's energy conservation goals include conducting energy audits across all sectors: street lighting and water supply, and the residential, commercial/business, industrial, and agricultural sectors. MAHAURJA's report from 2017 forecasts a saving potential of 20–30 percent of current energy use via energy efficiency measures. These include retrofitting and upgrades, to which end MAHAURJA acknowledges the need to involve banks and other financing organisations, as well as government incentives for energy-efficient practices and technologies.

The report cited above mandates all commercial consumers whose contract demand is 1,000 KVA or above to undergo energy audits through auditing companies registered with MEDA for this purpose. For industry, energy management system certification is encouraged, with the state subsiding 50 percent of the costs for this programme. For medium and small enterprises (MSEs), of which Maharashtra had five lakh in 2017, MEDA organises 'walk-through audits' and coordinates cluster development programmes to enhance energy efficiency in these businesses. MEDA also offers financial assistance of ₹3,000 per SME to undergo an energy audit.and has distributed more than 4 lakh LED bulbs free of cost to consumers (PTI, 2016). In an effort to promote LEDs and sustainable lighting in the public realm, 207,183 streetlights across Goa have been replaced with LEDs (SLNP Dashboard, n.d.), a laudable move, even though public streetlights constitute only a very small proportion of electricity consumption across Goa. LED streetlights consume about 50% of the energy of the typical existing models of streetlights.

Energy efficiency programmes

Other programmes for energy efficiency are underway for government buildings and street lightning. Financial incentives for energy efficiency include incentives for energy audits (of which 2,184 had been performed in the state as of March 2024), and additional Floor Space Index (FSI) for star-rated and green buildings. The adoption of green buildings in the state has been trending upwards.

Maharashtra performs well in the State Energy Efficiency Index (SEEI) across all states and union territories. In 2024, MEDA estimated that energy efficiency measures had resulted in total savings of 1,36,60,157 kWh of energy that year. Government buildings are frequently utilised as models to demonstrate the scope of energy efficiency measures. Statewide, 121 buildings were part of such demonstrations as of March 2024.

Energy Clubs

Maharashtra, like the rest of India, has Energy Clubs in schools to increase awareness about the need for energy efficiency and energy conservation, sensitising students to key issues that will likely be of lifelong relevance. Energy Clubs in Maharashtra are organised by MEDA. Events include competitions in painting, essay writing, and elocution as well as quizzes. Goals of this programme include inculcating a sense of responsibility for energy use and a lifelong interest in issues of energy security. 14th December is designated as Energy Conservation Day.

LED bulbs

The Bachat Lamp Yojana and the Ujala Scheme have been implemented over the last 15 years to promote LED lights across India and reduce emissions from lighting. Close to 40 crore LED lightbulbs have been distributed across the country (Ministry of Power, 2022); these schemes have reduced the price of LED bulbs from INR 300-350 to INR 70-80, increasing the affordability of this technology.

Decarbonisation plan

Maharashtra's Department of Environment and Climate Change has committed to decarbonising, and in December 2023 launched an urban decarbonisation plan for the energy and road sectors. In 2021, a total of 43 cities in Maharashtra (which together are home to 45 percent of the state's population) committed to net zero by 2040, under the UNFCCC's Cities Race to Zero campaign. Experts note that for Maharashtra's cities to achieve net zero, coordination between government departments as well as public–private partnerships will be crucial.

The C40 Knowledge Hub notes in an article that Maharashtra is the third-most urbanised state in India, after Tamil Nadu and Kerala. Energy demands from the built environment are a key source of urban carbon emissions. Reliance on fossil fuels and overall energy consumption must also be reduced. C40 also notes the need for systematic land use policies and data-driven city-level climate action plans. (C40, 2023)

Smart meters

States across the nation have been moving towards equipping domestic and commercial premises with smart meters as a means of informing consumers about their energy use and helping them regulate their consumption. This is part of a larger drive by state and national governments to upgrade meters from mechanical to digital/electronic, and to achieve full meter coverage of all consumers. The proposed smart meters would allow consumers to track their consumption without having to manually read the meters (Navhind Times, 2023). They are part of a move towards Advanced Metering Infrastructure (AMI), which allows precise and real-time recording of information about the consumption of electricity, gas, and water. Smart meters can help increase sustainable electricity consumption in several ways:

- Since smart meters transmit real-time information about grid usage, electricity providers can better adjust production and transmission in real time. For instance, in India, evening has long been peak time for electricity consumption (Tongia and Mehta, 2015). More fine-grained data about fluctuations in demand can help the electricity grid achieve better efficiency.

- Consumers get useful real-time feedback about their current usage, allowing them to reduce their consumption and thus their bills. In any domain, quick, accurate, reliable information is known to be a key requirement for behaviour change (Casal et al., 2017). Since smart meters provide accurate information with low latencies/time lags, this is a promising part of Maharashtra's plan to reach net zero. In May 2024, MSEDCL commenced installation of smart meters across Maharashtra, including in all government offices. However, by the following month, the Maharashtra government had deferred former plans to install smart meters for domestic and commercial consumers. The smart meter plans had reportedly met stiff opposition from various quarters. Feeder meters are currently being prioritised, but smart meters were expected to be back in the running post-elections, with plans to ultimately replace all

other kinds of meters statewide with smart meters. Currently, out of 2,35,64,747 smart meters sanctioned across Maharashtra, only 4,22,123 have been installed.

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Grounds cited for opposition to smart meters include the massive expense, and the prospect of raised power tariffs to recover the government's costs. Electricity workers have also been opposing smart meter installation, which was anticipated to affect 25,000 electricity workers.

Research worldwide finds that smart meters lead to modest but significant decreases in household electricity consumption.

Solution 1

Restructuring Electricity Tariffs to Incentivise Reduced Power Consumption

Equity and Justice | Institutional Innovation | Livelihoods and Social Protection

Similar to progressive taxing, which imposes progressively higher tax rates on progressively higher income brackets, increasing the per-unit tariff for the highest consumers of electricity would help redistribute the true costs of rising power consumption.

Price sensitivity (also called 'price elasticity of demand') is a measure of the change in the demand for a product as a result of a change in its price. Before restructuring electricity tariffs, it would be useful to perform a study on price sensitivity for electricity among domestic, industrial, and commercial consumers in Maharashtra. Some studies in other nations have looked at the price elasticity for electricity, specifically with respect to renewable energy, where measurements are collected on how much premium on prices for renewable electricity consumers are willing to pay (Zheng et al., 2021). Overall, however, data on end-user elasticity of demand for electricity are low; some of the available data suggest that elasticity may be low (Hari et al., 2008), which means that restructuring tariffs alone may not be enough to discourage consumption. However, restructuring would help to more fairly distribute the emissions costs of power consumption by charging higher rates for the highest-consuming brackets. (Data on income elasticity of electricity demand do exist for India, though income elasticity differs from price elasticity.)

Solution 2

Incentivising Electricity-Conserving Business Models

Behaviour Change and Public Acceptance | Public Participation and Trust

Incentivising energy efficiency in Kolhapur's sugar mills

The Centre for Science and Environment (CSE) performed an investigation into the foundry sector in Kolhapur city. Kolhapur's foundries, which primarily process iron, and powered mostly by coal and electricity, are a major source of air pollution (including PM2.5, PM10, and NOx) and carbon emissions thanks to fugitive emissions. The total energy consumption of Kolhapur's foundries is 1.39 million tons of oil equivalent/year as of 2022 . Most of the foundries are small-scale. Foundries and sugar mills are two major reasons why Kolhapur consistently fails to meet National Clean Air Programme (NCAP) standards, i.e., it is a non-attainment city. Maharashtra overall has the highest number of India's non-attainment cities. Kolhapur's foundries primarily produce castings for the automobile industry, a huge and growing industry. At the same time, the foundry industry is also growing in India overall, which makes it vital to implement energy-efficient practices in this sector.

CSE conducted energy audits of a sample of Kolhapur's foundries and identified factors that can contribute to energy efficiency in foundries. Key recommendations included installing energy-efficient foundries (e.g., replacing induction furnaces with hood-based furnaces, such as insulated gate bipolar transistor furnaces, which reduces specific energy consumption (the energy needed to melt one ton of metal) to approximately 550–720 kWh depending on the metal, down from 1,000–1,200 kWh); using lid-based furnaces in induction furnaces to reduce energy losses; using adequate charge material (including energy-efficient sand mixtures) to reduce losses of both energy and materials; installing an LED-based lighting system; and keeping the premises clear to allow efficient movement pathways for raw materials and finished goods.

Importantly, CSE also found that most of Kolhapur's foundries have had neither internal nor external energy audits performed. CSE recommends that the Maharashtra Pollution Control Board (MPCB) develop stringent guidelines for the state's foundry sector to ensure energy-efficient operations. Such guidelines, CSE believes, will help give Kohlapur's numerous foundries clarity and guidance on transitioning to a lower-emissions way of functioning that reduces overall consumption of electricity and other resources.

Clearly, Kolhapur's foundries need to be subjected to energy audits. Given MEDA's previously cited existing schemes and financial incentives subsidising energy audits for MSEs, this should be achievable. Notably, such investments also lead to cost savings for the business itself, with one case study by Small Industries Development Bank of India (SIDBI) reporting a 10 percent reduction in energy savings (equivalent to ₹6 lakh/year) and a payback period of 2.1 years by a small foundry. Measures included those similar to the ones identified by CSE, such as installing higher-efficiency furnaces and upgrading the foundry's cooling towers and water pumps.

This project was conducted as part of the MSME (micro, small, and medium enterprise) energy efficiency framework with support from the World Bank and the Global Environmental Facility. The study notes the need to facilitate additional commercial finance for improving MSMEs' energy efficiency. It also highlights the urgent need to make energy audits mandatory and incentivise energy-efficient practices in Kolhapur's foundry industry.

A comprehensive report by the BEE analyses the power demands and the potential for energy efficiency in India's foundry sector (BEE, n.d.). This report notes that foundries are a particularly energy-intensive and high-carbon sector; approximately 59 percent of energy in foundries came from electricity in FY2021-2022, and this share is expected to grow to 85 percent by 2030-31. BEE estimates a total energy savings potential from this sector (nationwide) of 18 percent from current usage.

Energy audits, subsidised (especially for MSME foundries) by BEE via MEDA, financial incentivising of investments in energy-efficiency, more stringent regulation and clearer timelines, and public–private partnerships to allow for accessible financing mechanisms, are urgently needed to reduce electricity consumption in Kolhapur's large and energy-thirsty foundry sector.

Incentivising the adoption of energy-efficient furnaces in Kolhapur's foundries

Sugar-processing plants similarly contribute significantly to Kolhapur's electricity consumption and carbon emissions. Kolhapur district's sugar mills process 50,00,000 tons of sugar annually. Sugar mills are a major employer but also a major emitter. A report by the Maharashtra Pollution Control Board (MPCB) notes the need for an emissions inventory across Kolhapur's industries, including sugar mills (ibid).

In the context of the need to improve energy efficiency in Kolhapur's sugar mills, Elion executed an energy efficiency analysis in a sugar mill in Kolhapur . This case study generated several recommendations for energy efficiency in sugar mills, including upgrading equipment, optimising processes, and training staff in efficient use of energy and other resources. Outdated machinery such as boilers were found to contribute to excess energy use. The report noted the need for prioritising upgrades based on greatest effect, and on the need for continuous improvement in energy use practices.

Other studies have noted methods for energy efficiency, such as investing in energy-efficient falling film evaporators and pans, and feeding bagasse byproducts from the mill directly into cogenerators for green power production. Lower moisture content in the bagasse was noted to improve boiler efficiency and proper combustion. Other studies recommend installing advanced variable frequency drive (VFD) systems, which leads to lower demand on the sugar mill's cooling system thanks to more efficient evacuation of heat. On-site cogeneration of electricity has also frequently been noted, and is increasingly widely practised, as a way for sugar mills to reduce their dependence on the grid. Thanks to biomaterials being produced as byproducts, India's sugar mill industry has the potential to generate 3,500 MW of electricity, thus becoming a model for industrial operations that are sustainable and energy-efficient.

Solution 3

Encouraging a Shift to Low-Carbon and Energy Efficient Cooling

Public Participation and Trust | Behaviour Change and Public Acceptance

The use of air-conditioners in Indian households and commercial enterprises will continue to grow rapidly with temperatures rising. Despite the wide availability of energy-efficient appliances, many households and businesses have not upgraded their devices. Use of air-conditioners on suboptimal settings also poses a problem. Solution 4 offers ideas on encouraging a shift to energy-efficient appliances across the board.
Other strategies for energy-efficient cooling include:

Green Architecture

Sustainable architecture can help reduce the costs of cooling a building. The Bureau of Energy Efficiency (BEE)'s Energy Conservation Building Code (ECBC) defines norms of energy performance for various building components (BEE, n.d.), taking into consideration a building's climatic region. The 2024 codes for energy-efficient design for residential and commercial buildings are available here. Incentivising or requiring adherence to BEE norms would further help reduce commercial buildings' energy consumption.

Applying these norms lowers a building's energy requirements without affecting the comfort, health, or productivity of the occupants. The ECBC encourages architectural strategies such as passive design and light integration in the commercial sector, and focuses on renewable energy and the life-cycle cost of the building.

More stringent requirements for all new residential and commercial buildings to abide by BEE codes, and financial incentives for older buildings to retroactively upgrade to greener codes (e.g., via green roofs, insulation, and other relatively low-cost efforts), could moderate the energy consumption of Kolhapur's buildings.

Using Air-Conditioners at Optimal Settings

Setting the thermostat too low, or a swing/tilt setting that fails to deliver cold air where it is most needed, can increase the power consumption of air-conditioners without concomitant increases in comfort. Manuals and remote-controls can be redesigned so that (a) optimal settings are the default, and (b) artificial intelligence is used to automatically readjust settings for energy-efficient cooling.

Land Use Change to Reduce Urban Heat Islands

The creation, upkeep, and restoration of public parks and waterbodies within Kolhapur will mitigate rising land surface temperatures, since greenery and water bodies reduce ambient temperatures. A move away from large concrete spaces (Newslaundry, 2016) (which can increase surface temperatures by up to six degrees Celsius (EPA, n.d.), towards spaces with plants, will help keep outdoor urban spaces cool. As a corollary benefit, a cooler outdoor space radiates less heat onto nearby buildings, which could lower cooling needs inside buildings. With shade-giving trees on roads and public squares, public spaces will remain relatively cool, and reduce the demand for air-conditioned spaces. Other nature-based solutions include green roofs and green walls for buildings, and low-emissions zones and green belts incorporated into city planning.

Raising Awareness About Alternatives to Air-Conditioners

Simple tactics, such as closing and opening doors and windows strategically, based on sunlight direction and time of day, and using water-based room coolers in dry climates, can reduce dependence on air conditioners.

Public Cooling Zones

Creating public-access cooling zones (also called 'cooling centres' and 'cooling shelters') where air-conditioning and hydrating, electrolyte-replenishing drinks are available, will reduce the burden of cooling in private spaces. This will also benefit particularly vulnerable populations, including the homeless, the elderly, and those who cannot afford air-conditioning. Spending even a short period of time in a cool zone can improve the human body's ability to cope with heat stress. Public cool zones including gardens, green spaces, and lakes, are an essential part of inclusive development, and, if efficiently administered, could reduce power consumption from private cooling. Subsidising companies to encourage remote work spaces, could reduce cooling-based electricity consumption in air-conditioned private vehicles and private homes.

Solution 4

Encouraging a Shift to Energy-Efficient Appliances Across Sectors

Public Participation and Trust | Behaviour Change and Public Acceptance

An independent assessment of the effectiveness of BEE's star labelling system found that a significant volume of additional emissions had dropped from the domestic sector, but uptake in the industrial sector was limited (Joshi, Sen, & Kunte, 2020). Lack of adequate financial incentives, along with a lack of awareness about energy-efficient appliances, and their various benefits, were barriers to wider adoption across sectors.
Ways to nudge consumers across all sectors towards energy-efficient appliances include:

Tariffs on Energy-Inefficient Appliances

The appliance market in India is highly price-sensitive (Tathagat, 2007). Given the higher upfront costs of energy-efficient appliances, one way to nudge consumers away from lower cost, inefficient appliances would be for the government to impose higher taxes and tariffs. For essential products such as lamps, the manufacturers of inefficient appliances would foot the costs, creating a form of product-specific carbon tax, and nudging the manufacturers towards producing more energy-efficient models. In some cases, the higher costs would be passed on to consumers, such that the product's financial cost would more accurately reflect its high environmental impact.

Ideally, most of the costs of higher tariffs and taxes on energy-inefficient appliances would be borne by
(a) the manufacturers of such products;
(b) industrial users of such products; and
(c) more affluent consumers purchasing luxury items.

Tariffs would have to be carefully designed so as not to penalise low-income households and small-scale industries.

Raising Awareness About Energy-Efficient Appliances via Concrete Information About Benefits

The financial savings from switching to energy-efficient appliances are considerable. A 5-star air conditioner produced by a major Indian manufacturer would lead to savings of approximately 3,900 units of electricity, as compared to a 3-star system by the same manufacturer, and the maximum retail price of the 5-star system is only 3 percent higher (ECBC, 2021).

Reframing key information to align with consumer priorities
Consumers tend to prioritise immediate gains over long-term benefits (Schleich et al., 2019), which give cheaper but less efficient appliances a leg-up in consumer decision-making. Indian consumers are known to be highly price-sensitive (Economic Times, 2022), and research suggests that, even for consumers in developed nations, price is cited as the most important metric in the purchase of domestic appliances (Acil Allen Consulting, 2014), while environmental impact ranks lowest. Energy-efficient appliances may thus suffer from even marginally higher upfront costs. To level the playing field,

manufacturers should consider offering a product page that clearly illustrates the financial superiority of an energy-efficient appliance, to nudge consumer choice. It should have a side-by-side comparison of energy-efficient appliances against less efficient models to highlight the savings on electricity units which could be translated to money savings, perhaps by offering embedded calculators that would allow a consumer to calculate savings based on local tariffs. The page could then show the consumer the timeline within which the energy-efficient device would prove the better investment.

Linking efficient appliances with other benefits
Manufacturers of energy-efficient appliances would benefit from focusing on their products' many desirable features, such as, in the case of air conditioners, superior durability and antimicrobial filtering. If consumers associate higher-efficiency appliances with a greater range of features, that might nudge them towards accepting their (often only marginally) higher upfront costs.

Standardising information formats for ease of product comparisons
With respect to energy savings, information about energy-efficient products should ideally be disseminated in standardised form. On amazon.in, some consumer products advertise their annual energy costs in terms of kWh, others in units. In India, these two are equivalent, but not all consumers, including those responsible for household energy bills, are aware of this. This would mean that consumers deciding between competing products (e.g., a 3-star vs. a 5-star air conditioner) would lack the information needed to make an informed decision.

Concretely linking environmental benefits with the star labelling system
Information about the environmental benefits of energy-efficient appliances could be made concrete on the basis of the star system. BEE's existing star rating system is already concrete (Tathagat, 2007), using the simple visual of stars, which have positive cultural connotations, to signify the more complex concept of electricity consumption. India's star ratings system is similar to international systems (Acil Allen Consulting, 2014), and is often accompanied by information on estimated unit consumption (though this is given sometimes on a per-day and sometimes on a per-year basis), which links to financial savings.

Concretely linking the energy savings from efficient appliances to an environmental outcome would highlight the low-carbon appeal of these devices, thus catering to the significant section of Indian consumers who claim to consider the environment in their consumer decision-making (GfK Global Consumer Life Study, 2023). Product information for energy-efficient devices could be accompanied by information related to reductions in greenhouse gas emissions. Since greenhouse gases are invisible, and the concept of 'carbon dioxide equivalent' is complex, this numerical information could be accompanied by a simple visual, for instance a clear sky, thanks to lower emissions and the lower reliance of the efficient device on coal power-plants.

Incorporating the Star Rating System into Primary and Secondary School Curricula

Children often exert pressure on their parents' consumer decision-making. Childhood is also a prime time to instil pro-environmental values. Including a unit on the star rating system and its environmental implications in the school curriculum could drive parents to choose energy-efficient appliances.

Buyback and Exchange Programmes

Consumers could be incentivised to upgrade to energy-efficient appliances through buyback programmes, perhaps subsidised by the government, where less efficient appliances are bought back by manufacturers with a cost consideration against more efficient models. Buyback programmes help reduce the costs for consumers to adopt a more energy-efficient lifestyle or business model.

Residential energy demand can be significantly reduced through “structural” investments, including upgrades to energy-efficient household appliances and retrofits to existing appliances (Kasser, 2017; Suárez-Varela et al., 2016). Education, incentives, and regulatory measures, can nudge households towards lower electricity consumption for a sustainable future.

Chapter 4

Mobility

Mobility

Sector Overview

Transportation in Kolhapur is the single largest contributor to greenhouse gas emissions. A study conducted in 2018-19, by the Central Pollution Control Board (CPCB) and the subsequent action plan published, highlights that 34 percent of the city's total emissions originate from transportation, including vehicular emissions and road dust (Central Pollution Control Board, n.d.). However, there is potential to transform this sector to help Kolhapur reach net zero by 2050.

The city centre of Kolhapur, covering an area of about 65.42 sq km, grew organically long ago, and it was based on non-motorised transport; it is not planned to accommodate large numbers of motor vehicles. However, the municipality is widening roads in newly developed areas. Traffic congestion in Kolhapur puts an overwhelming strain on its roads. The solution is to curb private vehicle ownership and promote low-carbon mobility.

Existing Conditions and Key Challenges

Kolhapur offers a variety of affordable and convenient transportation options for locals and tourists, including buses, auto-rickshaws, taxis, and trains. Local bus services are well-connected throughout the city and surrounding areas, making them popular among residents. However, some areas remain underserved as the city grows, leading to increased reliance on two-wheelers.

The lack of infrastructure for alternative transportation modes includes the following:

Pedestrian infrastructure gaps

Inadequate infrastructure for pedestrians and cyclists, including poorly maintained footpaths and lack of dedicated cycling lanes. According to KMC, there are footpaths along 100 km of the total 750 km road network in the city, indicating that 13 percent of the roads have pedestrian pathways. Many footpaths are encroached upon by vendors and parked vehicles, forcing pedestrians to walk on roads and compromising safety (Patil, 2014).

Vehicular parking

Erratic roadside parking in Kolhapur obstructs lanes and reduces usable road space, with the traffic police reporting an average of 100 fines issued daily for violations in no-parking zones (the Energy and Resources Institute, 2016).

Bus network

The Kolhapur Municipal Transport (KMT) serves the city, operating a fleet of 149 buses across 27 routes, including 32 contracted buses, ferrying approximately 125,000 passengers every day. The city provides parking facilities at Shahapuri, Kapilteerth Market, Shivaji Market, and Mahalaxmi Temple. However, the city faces transportation hurdles such as poor road conditions during monsoons, congested railway crossings, and inadequate street lighting in newly developed areas. Additionally, poorly planned bus schedules and undiversified routes lead to insufficient parking, increased on-street parking, and congestion, mainly on Bhausinghji Road, Tarabai Road, and Station Road. Moreover, luxury buses parking or halting on main roads exacerbate congestion problems.

Lack of multimodal connectivity

The use of private vehicles, especially two-wheelers, is increasing due to lack of an Integrated Mode of Public Transportation. To shift to public transport, there must be a well-connected multimodal transport system and an appreciation of the environmental benefits.

Reducing the number of private cars and encouraging the use of public transport will reduce emissions and road congestion, improve air quality and make a net zero Kolahpur possible.

Existing Policies to Address Mobility Challenges

Kolhapur has several policies to address mobility challenges, under the following categories:

Road and Parking Infrastructure Improvement Schemes

Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)

The city has allocated ₹60,434 lakh to roads and the urban transportation sector upto 2031 under the central government UIDSSMT Scheme.

Integrated Road Development Programme (IRDP)

KMC formed an Integrated Road Development Programme (IRDP) to be implemented under the build, operate, transfer (BOT) model, allowing the private sector to participate in the development of road infrastructure. The BOT model allows private firms to receive a concession from the private and public sectors to finance, design, construct and operate an infrastructure facility for a particular time before transferring it back to the government authority after the concession period ends.

Electric vehicle promotion

Maharashtra Electric Vehicle Policy, 2021

This aims to encourage the adoption of electric vehicles by setting ambitious targets such as 100,000 electric two-wheelers, 15,000 e-autos, 10,000 electric cars, 20,000 goods carriers (three- and four-wheelers), and 1,000 e-buses. To facilitate these goals, the policy outlines various standard operating procedures (SOPs) for EV consumers, including measures to reduce vehicle costs, provide early adopter discounts, and offer exemptions from road tax and registration fees.

EV charging stations by Mahadiscom

The state plans to establish up to 15,500 public and semi-public EV charging stations throughout Maharashtra to support the supply side of the policy. Also by 2023, all dedicated off-road public parking spaces must convert at least 25 percent of their total capacity to be electric vehicle (EV) ready. Future public parking spaces allocated through the bidding process must also provide free parking for all EVs.

Property tax discount

Kolhapur Municipal cooperation has announced that individuals who establish an EV charging station on their property for personal use may receive a 2percent reduction in property tax, provided the station is also accessible for commercial use. Cooperative housing societies are being offered a five percent discount to encourage the adoption of EV charging infrastructure (Sen, 2021).

Solution 1

Electric Buses (E-buses)

Equity and Justice | Public Participation and Trust | Institutional Innovation | Livelihoods and Social Protection

E-buses can solve mobility challenges such as congestion, high use of private vehicles, and restricted access to the city, while also reducing emissions. Through the PM-eBus Sewa Scheme, the Kolhapur Municipal Transport bus fleet will receive 100 electric buses (The Times News Network,2023, November 5). This would set up a low-carbon public transport system in the city, but a multipronged approach to ensure its efficacy would entail:

Strategic Route Planning and Optimisation

Kolhapur's bus routes are concentrated along a few key corridors. Route planning must consider demand and equity, ensuring that the neglected marginalised or urban poor have access to the city. Tiered pricing schemes and passes would make these buses more accessible.

Efficient Operations

Planning must include streamlining bus schedules and fleet utilisation to minimise idle time and fuel consumption, while ensuring timely service through coordinated dispatch and real-time monitoring systems.

User Convenience

Online ticketing and real-time information about bus timings and delays could make it easier to use public buses.

Bus Shelters

To improve route efficiency, buses should stop only at designated, well-maintained bus shelters, reducing unscheduled halts and streamlining schedules. Currently, poorly maintained shelters and the practice of hailing buses anywhere disrupt operations. Upgraded shelters with proper signage, seating, and weather protection can encourage passengers to use designated stops, enhancing time management and overall service reliability.

Comfort and Safety-Related Improvements

People feel that buses are uncomfortable and unsafe, especially for women. Employing female drivers and conductors could combat this fear. They could be trained and retained through supportive policies. Buses and bus shelters need adequate lighting. Priority seating for women and air conditioning could make buses attractive.

Behavioural Shifts

Owning and driving cars and 2-wheelers is linked to status. Campaigns are urgently needed to change this perception and promote public transport.

Reliable And Consistent Charging Infrastructure

Urban local bodies and the power distribution company must coordinate to provide necessary upstream electrical infrastructure for charging stations. Load management can reduce charge time and lower energy costs, and prevent EV chargers from overburdening the electrical grid, thus reducing the likelihood of blackouts (Ampcontrol, 2022). Charging stations need weather protection, like canopies and drainage. Solar power generating capabilities will reduce emissions.

Intercity E-buses

Efforts to replace intracity and intercity buses with electric buses are already underway. As Kolhapur attracts students, office workers, and pilgrim travellers from all over Maharashtra, a reduction in emissions from intercity commuting would prove beneficial. Currently, there are 12 electric bus services on the Pune-Kolhapur route (EQ Mag Pro, 2022).

E-buses must also be reliable and efficient. A well-routed system for intercity travel with enhanced customer services and ticketing, proper bus stops and comfortable and safe buses could help bring about a behavioural shift.

Charging infrastructure must be planned. Urban local bodies across cities and the power distribution company must coordinate to provide necessary upstream electrical infrastructure for charging stations. Charging infrastructure must be based on the effective charging time of the bus (which depends on the battery size and charger power of the vehicle), and the ratio of charging time to operational hours. As a city rolls out its e-bus system, a combination of opportunity charging – where buses charge briefly at stops along their routes – and depot charging can be employed. This hybrid approach maximises operational efficiency and passenger capacity but requires strategic planning to ensure adequate infrastructure and seamless integration.

Solution 2

Electric Vehicles

Behaviour Change and Public Acceptance | Public Participation and Trust | Institutional Innovation

Day by day, the increasing number of two wheelers, private cars, tourist vehicles and rented vehicles are contributing to emissions in the transport sector. Switching to electric vehicles could significantly reduce emissions (Moseman and Paltsev, 2022). The Government of Maharashtra has brought out the Maharashtra Electric Vehicle Policy, 2021, for promoting faster adoption of electric vehicles by 2025. Mahadiscom has been named as the state nodal agency for developing vehicle charging infrastructure in the state (Directorate of Economics and Statistics, Planning Department, Government of Maharashtra, 2023).

Incentives

Subsidies and financial incentives have encouraged people to switch to EVs in Goa, demonstrated by the increase from 0.2% to 9.4% in EV sales in 2022-2023 (PTI, 2023).

Charging Facilities

Kolhapur Municipal Corporation becomes the first to offer concessions in property tax for housing societies and individuals setting up electric charging stations (Express News Service,2021, December 18). The charging stations must be reliable and durable so that concerns over their functioning do not prevent people from buying EVs. There must be separate charging facilities for cars and two-wheeler vehicles, EV chargers across the city must be of standardised design; and fast chargers should be placed at commercial areas, pilgrim destinations and high-density residential areas, where people park long enough to recharge their vehicles.

Behavioural Shifts

Strategic campaigns are needed to encourage behaviour shifts among the public. When purchasing a new vehicle people should want to prioritise low-carbon mobility, thus making EVs equally or more desirable than the motor vehicles currently in demand. Charging stations should be used more during the day to leverage solar energy, instead of using fossil fuel-generated electricity at night. Users can be incentivised by making charging less expensive during the day through time-of-use pricing and by placing fast charging stations at workplaces or office parks.

Tourist Vehicles, Taxis, Rental Cars, Two-Wheelers and Pilots

Ensuring all new tourist vehicles and rentals are electric will significantly reduce emissions generated by tourist trips around the city. Furthermore, a percentage of the tourist vehicles already in use should be retrofitted to electric vehicles (PTI, 2023).

Upskilling workers

When EVs are widely adopted, the livelihoods of car mechanics, garage workers, informal workers in automobile manufacturing, auto parts dealers, and others are at risk. EVs require less maintenance and a different skill set when sent to a garage for any kind of servicing. Education (such as free courses) would upskill automotive workers to handle newer EV batteries, charging equipment, and even manufacturing.

Solution 3

Cycles

Equity and Justice | Behaviour Change and Public Acceptance

In Kolhapur, cycles are used mainly by lower-income communities. For those who can afford other modes of transportation, cycles are primarily used for recreation. The primary reasons for this are a lack of safety and infrastructure for cyclists.

Infrastructure

To enable people to cycle around Kolhapur, continuous biking lanes should be created. Bike racks for parking should be added for those who commute using cycles. If the government provides cycle lanes in city roads and promotes cycling by the citizens, it will help decongestion of traffic and air pollution issues.

Street Lighting

To make people feel safe while cycling, there must be sufficient and reliable street lighting for cycle lanes, not just vehicular carriageways.

Public Bike Sharing Systems

Adoption of public bike-sharing through public–private partnerships, leveraging smart technologies like GPS and app-based rentals for efficiency. Performance-based incentives ensure quality service, while integration with public transport promotes adoption, reducing congestion and emissions.

Last-Mile Connectivity

Providing infrastructure, such as bicycle parking at transportation hubs like bus stops, and bicycle racks on buses would enable cycling as a mode of first- and last-mile commuting.

Behaviour Change

In order to change people's behaviour, campaigns are needed to raise awareness about the new infrastructure to protect cyclists on roads, and highlight the benefits of cycling for health and environment. The city could partner with cycling clubs, schools and office parks to encourage people to cycle more. For example, a "cycle to school day" on the first Friday of every month could create a cycling culture amongst the youth. If trusted leaders of the community show their support for cycling, it could encourage others to follow suit and counteract social norm barriers. These behaviour changes have co-benefits like improving health.

Workplace Solutions

Along with priority and safe bicycle parking in the workplace, showers and changing rooms would allow cyclists to freshen up before going to work.

E-Cycles

E-cycles have the potential to mitigate emissions by replacing motorbikes, and be an affordable eco-friendly alternative to switching to an electric car. E-cycles will be easier to introduce as other biking and EV infrastructure solutions are implemented. Cycle rides in the heat can be long, tiring and uncomfortable, but e-cycles are faster and do not require strenuous exercise to operate, so are an attractive option. Furthermore, as a relatively new technology, e-cycles do not carry the social stigma that deters use.

E-cycles can be promoted through:

- **Subsidies** In Kolhapur financial incentives have persuaded consumers to buy electric cars, and can achieve a similar result for e-cycles.
- **Public E-Cycle sharing system** Introducing e-cycles as a convenient micro mobility transport option, with docking and charging stations in tourist hotspots and markets, will help reduce emissions and congestion in the city. E-cycles will also become more accessible to those who cannot or do not wish to purchase one.
- **Behaviour change campaigns** Benefits of e-cycles include emission mitigation potential, their speed, their efficient range of about 30 km, the ease of charging since e-cycles can be charged at any simple domestic socket, and the lower costs at just 10–15 paise per km compared to ₹2 per km for a petrol bike. Advertising these factors will be crucial to combat a lack of public awareness and to increase acceptance of this new technology (Shinde, 2022).
- **Partnerships with Delivery Partners** Companies like Hero Lectro Cargo are creating e-cycles designed specifically for delivery drivers on two-wheelers and have partnered with food delivery services like Zomato. Such pilots can be encouraged in Kolhapur to reduce emissions (IANS, 2021).
- **Upskilling** The introduction of a new mode of transport should generate new employment opportunities for locals. Upskilling cycle shop owners and repairmen will ensure that they do not lose livelihoods.
- **Charging infrastructure** Charging and docking stations should be easy to use, reliable and placed strategically. Since e-cycles can be charged from an ordinary charging socket, the infrastructure is simple. App integration is required to map charging/docking stations.
- **Promoting E-cycles for tourists** Run targeted advertising campaigns and work with the tourism agencies to promote e-cycle tours for eco-friendly exploration of Kolhapur's cultural and natural attractions. This would cut down the use of conventional vehicles, and mitigate a significant portion of emissions from tourism in Kohlapur.

Solution 4

Walking

Equity and Justice | Behaviour Change and Public Acceptance

The urban core of Kolhapur was originally designed for pedestrians, but the roads and pedestrian areas are overrun with motor vehicles. Out of the total 750 km of road network in the city, only 100 km have footpaths integrated, which is less than 15 percent. With faded zebra crossings and people jaywalking, there is a public perception that pedestrians are not safe (Sayed, 2023). This is increasing their reliance on private vehicles. Infrastructure improvements could make the city safer and help reduce emissions from shorter, avoidable trips.

Walk Paths

Creating quality pedestrian footpaths on both sides of the road with durable, non-slip materials will make them more accessible and increase pedestrian safety. These paths should have space according to Indian Road Congress standards, be continuous and maintained well. They would also improve last-mile connectivity in the city, encouraging use of public transportation.

Improving Pedestrian Facilities

Zebra crossings should be regularly repainted and convex mirrors placed at all blind turns so that vehicle drivers are aware of pedestrians. Improvements to walk paths and other basic pedestrian facilities will benefit those working in the informal sector – street sweepers, trash collectors, tea stall workers, etc. These groups are disproportionately composed of women who spend most of the day working on and along pavements. Improving footpaths could also attract more customers to roadside stalls.

Edge Management

Vehicles should not park along footpaths across designated crossing spaces, as this makes it unsafe for pedestrians to descend from footpaths and cross the streets safely.

Seating Infrastructure

Creating spaces for people to rest in the shade or socialise, will make walking not only feasible and safe, but desirable. This would also make the city more equitable for hawkers and other informal sector workers who use the footpaths often.

WASH Facilities

Water, Sanitation and Hygiene (WASH) facilities are often absent, ill-maintained, or hard to spot due to poor signage. Making them easy to find and use would help pedestrians in an area. These facilities often have male attendants which can make women wary. Employing female attendants could increase use among women.

Trash Collection

Construction debris and trash often make the walk paths unusable. Improved trash collection, visible waste bins, and instituting fees for littering will make the walking experience more pleasant.

Lighting

Ensuring good visibility for pedestrians in the city increases their safety and their perception of safety. Streetlights can be powered by solar energy.

Traffic Police Training

Traffic police should fine jaywalkers and ensure that road rules are followed by all vehicle drivers in order to promote safety and create a culture of walking. They need sensitivity training so that they can make women pedestrians feel comfortable and safe.

Improved Institutional Arrangements

New institutional arrangements are needed to carry out these policies and ensure the new infrastructure is maintained. Public forums with stakeholders from diverse backgrounds and different expertise can ensure that citizens' needs are met. The fragmentation across departments has to be remedied to ensure efficient coordination and implementation. PULL has created an apex committee for non-motorised transport (NMT) in Panjim; a similar one can be made in Kolhapur.

Social co-benefits

More pedestrians will lead to less traffic congestion and reduced travel times. Cleaner air impacts health, especially respiratory illnesses, while walking improves overall physical health.

Solution 5

Traffic Management and Parking Facilities

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust | Institutional Innovation | Livelihoods and Social Protection

In FY2023-24, on an average more than 200 units of new vehicles were registered each month in Kolhapur. A comprehensive policy for better traffic management and parking infrastructure would alleviate congestion and mitigate emissions in the city.

Strategically placed smart traffic signals and better public awareness on traffic rules would decrease congestion on the roads, especially around the Amba Bai temple and its nearby market area, which attract many tourists and frequently host large festivals. Vehicles parked on pavements and in undesignated areas affect pedestrians, while vehicles driving around in search of parking, increase emissions. Efficient parking management could also increase the city's revenues.

Traffic Management

Coordinated adaptive traffic signals can regulate the flow of traffic and decrease gridlocks. Traffic police must be trained frequently to direct traffic and ensure road rules are followed. Using non-motorised transport will also reduce traffic congestion.

E-Shuttles

Intracity e-shuttles with equitable fare structures would reduce the number of short trips made within the city and the strain on parking infrastructure.

Expansion of Parking Infrastructure

More parking spaces, especially at popular destinations such as markets could earn Kolhapur considerable revenues. The city's smart parking pilots and initiatives could be expanded (International Urban Cooperation, 2021). With good intracity shuttles and walking paths, parking structures at the entrances to the city could reduce traffic within the city, especially during peak tourist season.

Improved Parking Efficiency

Congestion occurs when people don't know where parking facilities are located or if there are spaces available. It gets worse during the numerous major events in Kolhapur, like the Rathotsav and Shardh Navarathra when demand surges. Kohlapur could employ a dynamic parking solution to help manage parking during these times by providing real-time information about parking availability and directing drivers to available spaces, thus reducing congestion (Raghuraman et al., 2023). The system could adjust parking fees based on demand to encourage optimal use of spaces as well.

Low Emission Zones

Cities around the world are implementing Low Emissions Zones (LEZs) as a tool to restrict private vehicle use and encourage low-carbon mobility modes. By definition, an LEZ is "a defined zone that restricts the use of polluting vehicles", constituting an area, and not a single street (Yanocha et al., 2023). The zones can help reduce city emissions driven by mobility, but require the following considerations:

Pricing strategy LEZs can be priced or unpriced zones

- In priced zones, vehicles pay to enter depending on their type/size and level of emissions. London constituted these zones with congestion charges, but initially they were politically unpopular. Zoning requires enhanced public transport connectivity regionally, transparent fee structures, and emissions testing regulations and standards to ensure that vehicles meet the stipulated criteria.
- In unpriced zones, vehicles below a minimum emission standard are banned from entering the LEZ. In Seoul and Lisbon, there are very high fines for entry. This has more political support than priced zones, but also requires high quality public transport, NMT facilities and regional connectivity.
- In both cases, revenue generated from fines or pricing strategies, can be used to invest in public transport as well as non-motorised infrastructure.

Zone selection criteria Multiple factors determine suitability and preparedness for an LEZ (or the more ambitious no-emissions zone)

- A high emissions zone will have the greatest impact.
- Safe infrastructure for walking and cycling, and affordable and well-connected public transport are required within the zone and the region to ensure that commuters coming to this zone have alternative modes of transport.
- The zone should ideally be medium- to high-density with mixed use, where distances to reach destinations are not high enough to warrant the use of private vehicles.

In Kohlapur, creating usable LEZs would be a major transitioning step to moving to net zero emissions.

Financial incentives To encourage equitable access to the zone, financial incentives can be provided for

- Public transport and NMT facilities: Discounted public transport passes and memberships to public bicycle-sharing schemes
- Purchasing sustainable mobility modes: Rebates for electric cycles and/or vehicles and subsidies/ rebates for changing particulate filters
- Benefits for scrapping old vehicles to finance new, low-carbon modes.

Solution 6

Transit Oriented Developement and Master Plan Integration

Public Participation and Trust | Institutional Innovation

The Kolhapur city Integrated Road Development Project is a significant initiative that should prioritise sustainable mobility within statutory planning frameworks to facilitate a transition towards net zero emissions. Transit Oriented Development (TOD) is integrated planning that brings together people, public spaces, commercial and residential land uses, and public transportation, to allow for walkable, connected neighbourhoods and has proven to be one of the best strategies for reducing emissions. The successful implementation of TOD requires certain steps to be taken.

Land-Use Planning Regulations

TOD requires a change in land use and zoning to encourage high-density, mixed-use development, with adequate pedestrian and, ideally, cycling infrastructure near commercial and transit hubs. Housing policy can also be amended to encourage affordable housing near transit stations, to enable better connectivity for communities.

Reforms to Development Control Regulations and Building Bye-Laws

Cities and states can amend development control regulations and building codes to promote TOD by regulating Floor Space Index and Floor Area Ratios to encourage denser development, as it enables more people to live and work near public transit, supports mixed-use neighborhoods, reduces car dependency, and makes better use of existing infrastructure. These regulations can also mandate reductions in parking requirements and allow buildings to create set-backs to create walking and cycling facilities.

Integration of Comprehensive Mobility Plans

Master planning processes in Kolhapur must incorporate recommendations from the city's CMP. Ideally, planning time frames and jurisdictions should be synergised and CMPs be updated periodically and integrated with master plan guidelines. There should be statutory requirements for the approval of large-scale developments, ensuring they comply with transport and mobility guidelines. Finally, CMPs must incorporate performance indicators and regular audits, to ensure progress towards sustainable mobility goals.

Institutional Innovations

Since there are overlapping jurisdictions and responsibilities in transportation planning, a Transportation Apex Committee or Unified Transportation Authority should be set up. It would comprise members of relevant departments and agencies, including Transportation Department, Public Works Department, Traffic Police, Public Transportation Operators, Town and Country Planning Offices, and State Urban Development Authorities, along with private sector actors. This would mainstream transportation recommendations and enable access to central transportation funds.

Urban Reform in Legislature

Urban local bodies urgently need to be empowered to implement and finance mobility recommendations in Kolhapur. That requires revisions to Schedule 12 of the 74th Amendment of the Indian Constitution and then the state Legislature needs to delineate urban mobility as a city-level subject. However, this is not a Kolhapur-specific challenge, and applies broadly to cities across the country.

Chapter 5

Waste Management

Waste Management

Sector Overview

Kolhapur, a historic and culturally significant city, has been growing in recent years. Its population just within the city's municipal limits rose by 13 percent between 2001 and 2011, to about 5.5 lakh (Chourey, P. M., 2016).

The district of Kolhapur is quite developed industrially as well, with many industrial zones in and around the city: the Maharashtra Industrial Development Corporation (MIDC) areas of Shirol and Gokul Shirgaon lie very close to the city. Kolhapur is also an important tourist destination in Maharashtra, with several temples of high religious importance, places of natural scenic beauty and culturally significant museums and other attractions. The Mahalaxmi temple situated here is a famous teripilgrim destination and has even been mentioned in ancient religious texts. Other sought-after destinations include Panhala fort and hill station, Rankala Lake, Jotiba temple and Radhanagri Wildlife sanctuary (Dajipur), among others. Shivaji University in Kolhapur city attracts the immigration of students from the nearby districts.

The above factors, combined with economic growth, increasing disposable incomes, and growing consumption, have led to a significant increase in the amount of waste generated in and around the city. This presents a dual challenge: first, the existing waste management infrastructure risks being overwhelmed, leading to reduced efficiency, with poor-quality output and segregation; second, this mismanagement could exacerbate issues such as pollution, environmental hazards, health risks, and social problems.

A few years ago, the system of waste collection was more effective, with about 1,500 workers engaged by KMC for waste collection through sweeping of roads and door-to-door collection. KMC had provided about 900 dustbins of 3.5 cubic metres capacity across the city from where refuse compactors on dedicated routes would collect this waste. Over 100 cycle rickshaws were allocated with the task of door-to-door collection of waste, especially in the congested and high-density areas. About 10–15 tons of waste, collected from the hotels and restaurants via a dedicated collection trip, were used for generating biogas by a food-processing industry, a practice no longer followed (Chourey, P. M., 2016). The current system of collection as well as disposal leaves a lot to be desired.

Existing Conditions and Key Challenges

As per available data, Kolhapur generates 220 tons of municipal solid waste (MSW) per day. Waste is collected on a daily basis by around 170 small collection vehicles covering the entire jurisdiction of KMC (Patil, 2024). Residents are required to haul the garbage bags or empty their bins directly into the collection vehicle. No door-to-door collection is undertaken. While vehicles have separate compartments for dry and wet waste, waste is largely mixed due to poor source segregation and mixing in the vehicle. Another drawback is that residences, and institutional and commercial establishments, are on the same route for a collection vehicle, leading to large volumes of dry waste mixing with unsegregated wet and dry waste from residences. The collected waste is sent to Kasaba Bawada waste management facility for sorting, treatment, and landfilling. Two other smaller sorting and waste processing facilities with a combined capacity of around 15 tons/day are also located within the city (Nerlekar. 2024). Separate trips are undertaken to cover wards, hotels, and market areas.

There are a host of challenges faced by the corporation with respect to sustainable management of waste.

Lack of segregation by residents is the primary and largest concern. Reasons for this include lack of bye-laws and proactiveness from KMC, an inefficient waste collection system, lack of awareness in the public, and general apathy about the issue.

An inefficient waste collection system is the next major problem. This includes an absence of door-to-door collection, poor route planning and scheduling, lack of motivation in waste collection staff, and a high transportation footprint. This was found to be a major inhibitor of source segregation among city residents, the reasons of which shall be elaborated later in the document.

Insufficient infrastructure to be able to treat 100 percent of the waste generated in the city. This is primarily due to the fact that waste is largely mixed, therefore requiring more space, time, and infrastructure for segregation and sorting. The city has a wet-waste management capacity of around 85 tons/day, including 55 tons in a windrow composting facility (which does bulk composting) and around 30 tons in biomethanation plants (Patil, 2024). In addition, the mixed-waste sorting shed has a capacity of around 100 tons/day. Most of these function at a much lower capacity due to poorly segregated waste. There are no separate material recovery facilities (MRF) for segregation, sorting, processing, and storage of dry waste.

Poor efficiency and resource recovery at the waste treatment facilities are the consequence of the above issues. While the major reason is again mixing of waste, another noteworthy factor is the type of contracts with service providers at the waste treatment facility. The terms of agreement do not encourage resource recovery as they do not provide for adequate labour; nor do they give the facility operator ownership of recyclables or specify a minimum number of categories to be sorted and recovered, all resulting in low- to mid-value recyclables being discarded as refuse-derived fuel (RDF). This results in less than 5 percent of recyclables by weight being recovered from the dry waste stream.

The absence of local bye-laws means there is a lack of clear guidelines on segregation, waste reduction strategies, management of waste by bulk waste generators (BWGs), a clear system of accountability and a mechanism for penalising and/or incentivising residents.

The informal sector plays a huge role in the waste recycling process, creating serious challenges in maintaining financial viability of operations. Independent waste collectors cherry-pick high-value recyclables, such as rigid plastics, metal, and cardboard, and sell the collected waste to waste aggregators along the route. In addition, there are a number of informal workers at the Kasaba Bawada dumping ground who further pick put high-value recyclables, not removed during collection, from the dumped waste before it is sent for further processing or landfilling. They have also been known to threaten the formal service providers employed at the site, posing a major security concern to them.

Rampant open dumping of mixed waste at the Kasaba Bawada dumpsite over the last two decades has led to a severe space crunch for disposal of waste collected from the city. The increasing amount of waste being collected daily also makes rehabilitation or biomining of this dumpsite challenging in the absence of alternative land parcels for constructing of a sanitary landfill. Groundwater samples collected near the dumping site were found to be highly polluted and unfit for any kind of domestic use.

Lack of quantifiable data: The absence of a functional weigh bridge, the scavenging by informal sector workers, and open dumping, together means an absence of data quantifying incoming waste as well as the proportion and types of recyclables. This makes it difficult to identify inefficiencies, monitor compliance, ensure economic sustainability, plan waste-sorting and processing infrastructure, and attract private participation.

Existing Policies And Efforts To Address Waste Management Challenges

Given the above challenges, efforts were made to improve treatment infrastructure, improve resource recovery, and bring about an improved behaviour change among residents. Some of these included:

Infrastructure Initiatives

Setting up of sanitary landfills at abandoned stone quarries

To reduce the pressure of open dumping at the existing landfill, back in 2015 the KMC identified two abandoned quarries – one of 1.5 ha and the other of 7.5 ha at Takala and neighbouring Top village, respectively. Although construction of the Takala site was almost completed, it never received waste due to various reasons. One was the high water table due to its proximity to the lake, and the other was objections from activists and locals. There were similar agitations against the Top project by villagers, resulting in the project hitting a roadblock. This site was expected to manage RDF for a period of up to 30 years (Chourey, P. M., 2016).

Waste-to-energy plant at Kasaba Bawada

A plant based on the mass-combustion technology was proposed to utilise the calorific value of waste to generate electricity and thus further reduce open dumping (Chourey, P. M., 2016). However, due to lack of funds and other constraints, it did not see the light of day.

Waste-sorting and treatment

The KMC supports an NGO, Avani Sanstha, largely for sorting dry waste and composting wet waste at a few wards in the corporation. A sorting and treatment facility was set up at Ward 7 where KMC vehicles deposit waste, which is sorted and managed by the Avani workers. These women were trained in waste sorting and composting to enable them to receive fair wages through sale of recyclables and compost. The RDF and non-recyclables are transferred from the facility to the Kasaba Bawada for landfilling or further processing

In order to manage the growing amounts of waste and the challenges listed above, the city must continue to be proactive and pioneer innovative waste management that could improve existing municipal solid waste regulations and policies, mobilise individual as well as collective action, and incentivise segregation at source.

Solution 1

Improved Segregation at Source

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust

As per KMC, the city generates around 220 tons of waste per day. This is bound to increase in the coming years owing to increasing population and flourishing tourism in the city. Segregation is critical for effective utilisation of existing waste-sorting and -treatment infrastructure as well as for improving health and hygiene of workers, maintaining environmental safeguards, improving resource recovery, and the financial viability of operations. More importantly, it results in reduced dependency on open dumping, which is a huge concern in Kolhapur. To effectively address these issues, there is a need for:

Stringent bye-laws

A set of local waste-management bye-laws are important, as they form the basis for setting and implementing waste-management goals at city level. Segregation must be mandated and enforced, along with penalties to defaulters and incentives to those following the norms. A clear set of guidelines must be provided to various categories of waste generators to ensure uniformity in number and types of categories segregated, infrastructure required, fees levied, encourage in-situ waste treatment to the best extent possible and integration of informal sector players into the planning process.

Awareness and IEC campaigns

An effective way to begin the process of awareness creation and bring about positive behaviour change is through information, education, and communication (IEC) campaigns in schools and colleges. Campaigns, competitions, and workshops on how to reduce waste generation, make compost, and live more sustainable lifestyles should be periodically conducted at educational institutions. Social welfare organisations, like Lions Club or Rotary Club and NGOs, must also be roped in to improve awareness among citizens. Other options include IEC material, street plays, clean-up drives, etc.

Improving waste collection

One glaring finding from the interaction with residents was a direct linkage between segregation and waste collection. Residents were reluctant to segregate at source, since there is often waste mixing during the collection process; also many respondents are unable to hand over waste to the collection vehicle. Streamlining the collection process can therefore encourage residents to segregate their waste, when they trust that it will result in improved resource recycling rates and less open dumping.

Run segregation pilots

In addition to improving waste-management practices and recycling rates, waste pilots can help raise awareness, inform policy, and explore newer methods of waste management. These may include training of residents' welfare associations (RWAs) in segregation and setting up of an in-situ waste-sorting system where recyclables may be sold to authorised partners, providing a financial incentive to the society. Effective in-house wet-waste-management practices could lead to long-term savings in waste-collection fees to be paid by the generator.

Incentivising improved waste management

Campaigns such as waste bartering, setting up of waste-procurement points, exchange offers, etc., could incentivise citizens to better manage waste generated by them. Brands selling single-use plastic should also be encouraged to offer incentives to consumers to collect wrappers and plastic packaging generated by their products.

Solution 2

A More Robust Waste-Collection System

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust | Institutional Innovation | Livelihoods and Social Protection

As stated above, a robust waste-collection mechanism can result in improved segregation practices by residents. It can also help prevent littering, save resources, and ensure optimal resource recovery from the collected waste. The various issues and challenges faced by the residents of the city, which have been listed earlier, can be solved by considering the following

Streamlined waste collection

Adherence to fixed timings for covering a certain locality or ward permits residents to be ready with the waste.

Minimising of vehicle rotation and route changes as far as possible, so the collecton staff become familiar with the neighbourhoods on their beat.

Exploring the option of a multi-pronged system with door-to-door collectors collecting waste using handcarts/large bins and storing it at a convenient location on the street for collection by KMC vehicles.

Allocation of a back-up vehicle along the route, if feasible, in case the vehicle fills up prior to completion of the entire route (e.g., on collection days after holidays or during festivals).

Have a separate route covering office areas, educational institutions, hospitals and commercial complexes, given the higher proportion of dry waste there.

Have the option of dry- and wet-waste collection on both sides of the vehicle to avoid mixing (each of the two existing compartments to be divided into two).

Given the larger quantum of wet-waste generation and its smaller storage times, dry waste collection may be planned once or twice a week with wet waste collected daily to improve segregation and quality of waste.

Orientation for vehicle operators and waste pickers on the need for improved practices while obtaining inputs for a more efficient collection system.

Revisiting existing contracts with collection agencies

Waste-collection contracts signed with collection agencies must mandate separate storage of wet and dry waste, with a standard operating procedure (SOP) in case of a vehicle getting full before completing the area or its breaking down, and include penalties for non-conformance with the guidelines. Waste collectors or safai sathis may also be asked to instruct and guide citizens with segregation and undertake random checks of bags or bins, with incentives provided for workers reaching the desired standards of segregation along the route. Coupons, recognition and bonuses, etc., may be considered as incentives.

Improved use of technology

Interventions based on information communication and technology (ICT) can be used to improve the day-to-day operations at all levels across the MSW value chain. Appropriate technological interventions such as real-time tracking of vehicles through GPS equipment, Radio Frequency Identification (RFID) to assess the extent of collection, QR codes to analyse the extent of segregation, door-to-door collection coverage, sensor bins at high-footfall tourist locations, etc., can be initiated and developed in a phased manner throughout the city. The automation of the entire process by installing edge devices and setting up a command-and-control centre for collection and management of data, alerts for deviations and non-performance, real-time monitoring, grievance redressal, etc., could also be explored.

Integration of informal sector players

Various tried and tested models exist in the country, where existing networks and infrastructure of informal sector players may be leveraged to include them in waste collection. This can result in cost savings to KMC, generate income opportunities, and divert waste from landfills. Door-to-door waste collection with or without ownership of waste, and even provision of land or sheds for basic sorting and treatment of waste collected, may be explored. However, to improve accountability and traceability of waste, guidelines must be established for registration and/or formalisation of the informal sector. Sensitisation on safe disposal of non-recyclable and hazardous substances must also be provided.

Solution 3

Reducing Waste Quantums

Behaviour Change and Public Acceptance | Institutional Innovation | Livelihoods and Social Protection

A look at the Kasaba Bawada waste dumpsite at Kolhapur is a startling reminder of the urgent need to encourage waste reduction in the city. In spite of completing phase one of the reclamation, tons of new mixed waste are dumped in the area every day, only compounding the problem. The situation in the monsoon months is further compounded with flowing streams of leachate noticed along the entrance to the facility. With existing waste-sorting and -treatment infrastructure running well above capacity, waste-reduction strategies must be prioritised and implemented with urgency. These include

Policy measures for waste reduction

Phasing out of certain kinds of packaging materials, including small PET bottles, milk pouches, consumable sachets, etc., may be considered. A more proactive approach is required to create awareness of better waste-management, improve existing guidelines, identify suitable alternatives, and ensure strict implementation of prevalent rules and guidelines.

Waste-reduction campaigns

The impetus in waste management in the city is currently centred around regular collection and dumping of waste. Little attention has been paid to reducing the quantum of waste and understanding types of waste in terms of recyclability, value, ease of handling, or disposal processes. Campaigns could help raise awareness and bring about behaviour change among residents through more sustainable consumer choices. Incentives could be designed for residents who treat their own wet waste, and avenues for sale of resultant compost explored. Training, workshops, and demonstrations could be conducted at resident welfare associations (RWAs) and bulk waste generators (BWGs) to demonstrate waste reduction and available on-site treatment technologies.

In-situ waste management by BWGs

The need for model municipal solid waste (management and handling) bye-laws was highlighted as part of solution 1 to improve segregation. Such bye-laws could also aid in reduction of waste volumes by mandating that BWGs manage and treat their waste. Organic waste converters (OWCs), small biogas plants, or any other form of composting may be mandated at such locations to reduce the burden and resultant emissions from centralised windrow composting systems and the footprint from collection and transportation of this waste. Authorised agencies may also be employed for management and disposal of their dry waste.

Composting at household level

Kolhapur is a high-density city with a significant number of multidwelling units where individual composting may pose a challenge. The ‘khamba composter’, a terracotta-stack home compost bin, could be used in individual residences and flats to deal with small quantums of waste. Small canteens and restaurants could set up biogas plants and use the resultant gas for cooking. Residents could be incentivised through awareness and training, discounted rates for khambas or other suitable units, ward-level competitions, recognition of best practices, and so on.

Promotion of Greener Alternatives

There are various alternatives to conventional plastic cutlery and packaging. Mandating the use of such green products by street vendors, food hawkers, institutions, and businesses within the city, promoting entrepreneurs making green products, incentivising their use, and improving availability are crucial to wider use and acceptance of biodegradable products.

Solution 4

Improved Waste Treatment Infrastructure

Equity and Justice | Behaviour Change and Public Acceptance | Public Participation and Trust

Proper waste-management infrastructure is crucial in preventing environmental pollution, ensuring worker health and safety, and maximising resource recovery. Waste management infrastructure includes all the systems and facilities involved in collecting, transporting, processing, and disposing of waste. These include storage bins, material recovery facilities, composting facilities, sanitary landfills, etc. The currently available infrastructure at the Kasaba Bawada waste-dumping site is inadequate to deal with the all of the waste brought into the facility daily. Presence of unsegregated waste only compounds the problem and reduces efficiency of these systems. Means of improving waste management infrastructure include

CSR funds for infrastructure set up and operations

Corporate social responsibility (CSR) has proven to be a very effective tool for setting up of waste-collection and -treatment infrastructure, as well as creating awareness. Waste-management organisations that have existing CSR partners for setting up and operating waste-management infrastructure could be sought and appraised of the situation in the city. Material recovery facilities (MRFs) for dry waste and biomethanation plants for wet waste may be constructed with the help of such funds.

Strategically located community bins

While the use of community bins was prevalent in Kolhapur, they were removed primarily due to the areas becoming eyesores. However, a lot of these areas continue to be dumping grounds with no bins anymore. Suitably designed bins could be reintroduced as part of the improved waste collection plan along with requisite guidelines to prevent littering and creation of black spots. These could be specially significant for low-density areas or those having standalone houses or bungalows where waste collection times may coincide with work timings making waste handover a challenge.

Waste-sorting and -transfer stations

With a vast majority of the city dependent on the Kasaba Bawada dumping ground for disposal of MSW, setting up of a few smaller sorting stations will reduce the pressure on the existing infrastructure and reduce the carbon footprint of waste transportation. This can be undertaken by identifying available public land areas and creating clusters of two or more wards from where dry waste may be collected, sorted, baled and stored for further management. One such facility exists at Ward 7, operated by the NGO Avani Sanstha, which is also given ownership of waste. A similar model could also be set up for informal workers to divert larger waste volumes away from landfills.

Setting up of waste buy-back centres

Such centres encourage segregation by residents by offering a per-kg value for various kinds of dry waste including tetra packs, multilayered plastic (MLP) and other low-value categories. Procured waste is further sorted, baled, and sent to recyclers for further processing. The municipal corporation can provide assistance through awareness creation, providing small plots of land, and sorting and storage infrastructure.

Construction of a sanitary landfill

This is a landfill where municipal solid waste is carefully deposited and compacted in designated locations. These are engineered sites with measures in place to minimise the impact on the environment and public health by limited exposure to air, capturing and treatment of leachate, collection and flaring of landfill gas and improving aesthetics of the area by capping, when full utilised. Currently, open dumping is practised with no such safeguards followed, resulting in serious environmental and health risks.

Solution 5

Optimising Resource Recovery and Financial Viability

Equity and Justice | Behaviour Change and Public Acceptance | Institutional Innovation | Livelihoods and Social Protection

Reducing the financial strain on KMC by ensuring the financial viability of operations is very critical for sustainability of waste management systems. This includes collection of appropriate fees from generators, optimising route planning to reduce collection costs and improve segregation – thereby ensuring sorting and recycling of larger proportions of waste including low-value types; optimising of manpower costs throughout the process; availing of the best rates from sale of recyclables; and revisiting operation contracts with various service providers for improved efficiency, among others. While the need for improved source segregation, a more robust waste collection plan, and improved infrastructure provision have already been discussed earlier, other measures include

Integration of informal sector players

The waste dumping ground at Kasaba Bawada is home to a number of informal workers who pick out high value recyclables from the waste as soon as it is dumped. They have been known to even threaten and clash with KMC service providers on the ownership of waste. Creating an ecosystem where such workers are registered, formalised, and trained, while maintaining the necessary health and safety measures, could substantially increase resource recovery from the dumped waste. The above measures can be provided in return for sorting a larger number of waste fractions, including MLP. The collected waste could either be directly procured by KMC at pre-determined rates or these workers could also be directly connected to waste aggregators or recyclers to be able to avail the best rates for the material.

Extended producer responsibility (EPR) for low-value plastics and MLP

EPR as a concept could be a gamechanger for waste management, but loopholes in its implementation, added to which is a pro-recycler regulation, do not allow the desired impact on stray and low/negative-value plastics. EPR enables additional funding, from manufacturers and producers of plastics, for waste management. These funds could help to set up improved collection systems, pay for increased workforce for waste sorting, improve waste-processing infrastructure, positively influence consumer actions, and help finance clean-up drives to reduce generation and improve channelisation of stray plastic into formal waste management systems. Service providers working with plastic manufacturers to help meet their EPR targets must be prioritised when selecting vendors to operate existing facilities.

Revisiting of contract terms with service providers

It was found that contracts of service providers deployed at the waste-processing sheds at Kasaba Bawada did not incentivise them to improve resource recovery from the incoming waste. In case of the shed sorting mixed waste, the ownership of the waste continued to be with the corporation, with the service provider merely required to coordinate the worker roles and incoming and outgoing waste. Allowing ownership of waste would incentivise improved sorting and segregation, which means lower dependence on landfills

Strategic tie-ups with recyclers and co-processors

Availing of the best possible rates for the sorted recyclables is crucial for improving the financial viability of operations. While the choice of recycler/ aggregator may vary based on the extent of sorting, need for transportation, minimum quantum, space available for storage, and rate provided, an assessment of all the options to determine the most financially viable is important. Similarly, for disposal of refuse-derived fuel (RDF), the most cost-effective systems can be selected by negotiating with the co-processor or making arrangements to deliver RDF in a more usable form.

Chapter 6

Nature-Based Solutions

Nature-Based Solutions

Sector Overview

Kolhapur, a city surrounded by the Western Ghats, is characterised by a diverse landscape that includes hills, rivers, and agricultural land. Its proximity to the Western Ghats contributes to a rich ecological environment, supporting various flora and fauna sustained by the Panchganga River, which plays a vital role in the local ecosystem and agriculture. However, the expansion of urban areas has encroached upon natural habitats, resulting in ecological degradation and challenges to sustainable development. Rapid urbanisation has led to the conversion of agricultural land and natural habitats into residential and industrial zones, disrupting local ecosystems and biodiversity. This transformation has resulted in heightened air and water pollution levels, which adversely affect both human health and the environment.

Increased pressure on land resources due to urban sprawl, tree cutting, and encroachment, emphasises the need for sustainable management practices to mitigate negative effects on the environment. The city's dwindling ecosystems play an important role in addressing climate change: they buffer the city from the impact of extreme events, such as floods, cyclones, and heat waves, while also sequestering carbon emissions, contributing to net zero goals. In recent years, the framing of nature-based solutionshas contributed to a larger discourse on ecosystem restoration for climate change adaptation and mitigation. Nature-based solutions (NbS) are actions to protect, sustainably manage, and restore natural or modified ecosystems, which address societal challenges (e.g., climate change, food and water security, or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits (IUCN, 2020). However, the role of nature in cities like Kolhapur, goes beyond climate change; it supports livelihoods, ensures food security, and serves as spaces for culture and recreation. NbS must be designed on sound ecological principles to ensure larger ecosystem health.

To ensure the effectiveness of NbS, it is crucial to analyse the broader implications and potential trade-offs of these solutions by taking into account local environmental conditions, social dynamics, and economic factors.

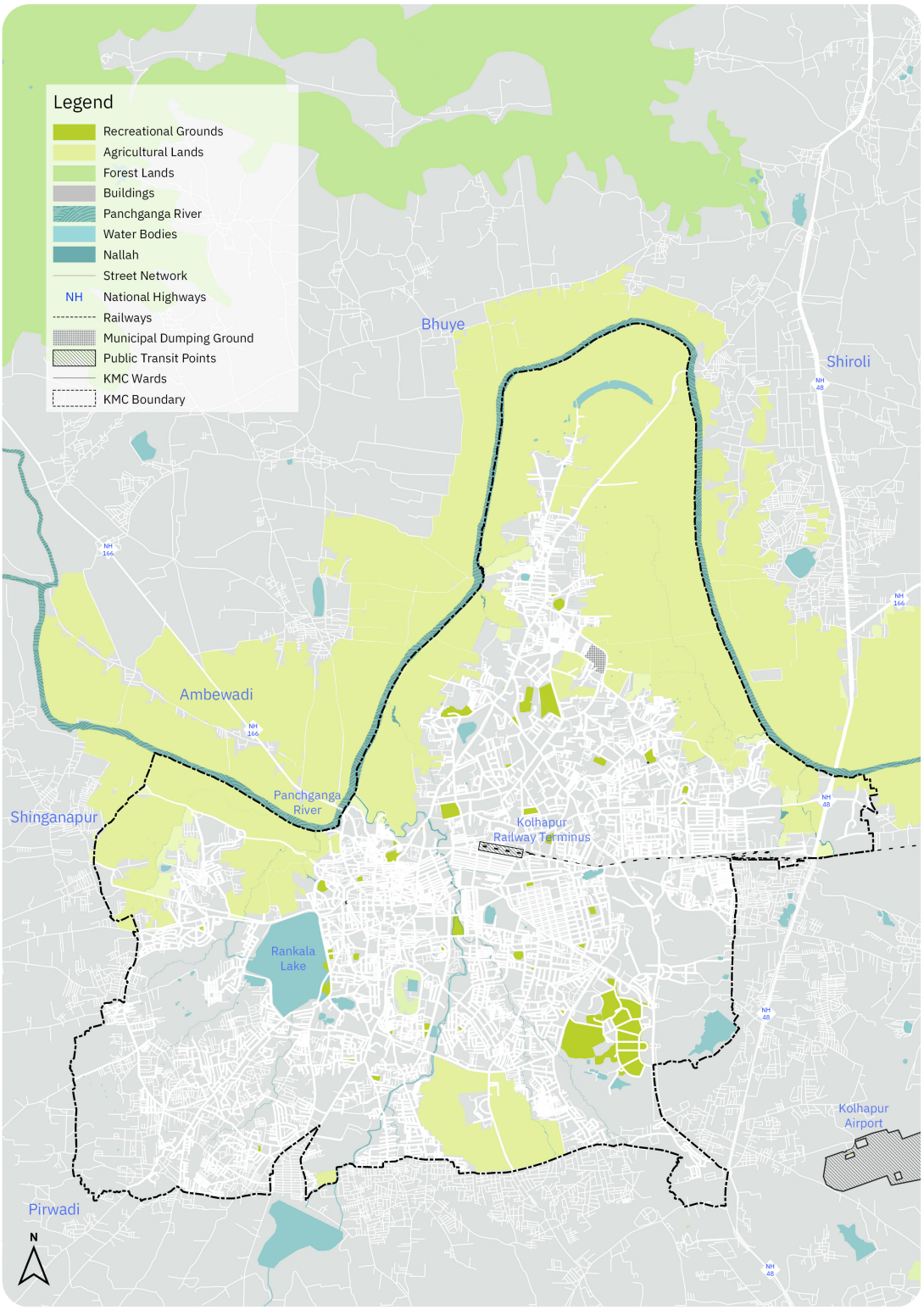

Image 2: Map of existing ecological assets in Kolhapur, Maharashtra (2025)

Existing Conditions and Key Challenges

Kolhapur city has seen exponential growth in population over the past few decades, causing a strain on the natural resources of the region, particularly land and water (Environmental Status Report of Kolhapur city 2015-16). As per Census of India 2011, the population of Kolhapur municipal limits was about 5,49,283 and is projected to increase by 16 percent between 2011 and 2031. Kolhapur's expansion is proposed to absorb over 42 nearby villages as the population grows, although agricultural villages on the city's outskirts oppose urban integration, fearing adverse effects on land use and traditional practices. In the process of urbanisation, nature in the city is being encroached upon, limiting its ability to serve as a buffer to climate risks.

The City Development Plan has overlooked the unique ecological characteristics of the region, failing to protect natural terrains disrupted by unchecked urbanisation, creating challenges in the city, such as

Air pollution

Rapid industrial growth and vehicular emissions have led to deteriorating air quality in Kolhapur. High levels of NOx (oxides of Nitrogen) and PM10 (particulate matter) pose significant health risks to residents, contributing to respiratory diseases and other health issues (Desai and Samant, 2016).
Urban localised flooding: The expansion of urban areas has obstructed natural drainage systems, increasing the risk of urban flooding during heavy rainfall. The inadequate drainage network is unable to cope with the growing population and associated infrastructure demands, exacerbating flood risks (Environmental Status Report of Kolhapur City 2015-16).

Urban localised flooding

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Water resource management

The city faces challenges in managing its water resources due to the release of untreated sewage and industrial waste, leading to pollution of surface water bodies and waterlogging, especially due to Jayanti Nala. This not only affects water quality but also poses risks to public health and biodiversity.

Land use changes

Urban sprawl has resulted in significant land use changes, including the conversion of agricultural land into residential and commercial areas. This threatens local biodiversity, while also impacting traditional agricultural practices, leading to socio-economic challenges for local communities. The agricultural and water bodies in Kolhapur city decreased by 50 percent between 1977 and 2000, while residential areas doubled, indicating many agricultural lands were converted to non-agricultural plots (Environmental Status Report of Kolhapur City 2015-16).

Key Issues

The urban landscape of Kolhapur is characterised by limited green spaces. Urban wilderness areas, gardens, and parks are essential for improving air quality and providing ecological balance. However, many of these green spaces are under threat from encroachment, neglect, and insufficient maintenance. The perception of local residents regarding these urban wilderness habitats is critical; studies indicate that people are aware of their importance, and concerned over their degradation due to urban sprawl and lack of conservation efforts (Desai and Samant, 2016).

The relationship between the community and their environment highlights the need for a balanced approach to urban planning that incorporates sustainable practices. Engaging the community in environmental stewardship can foster a sense of ownership over local green spaces and encourage sustainable practices that benefit both people and the environment (Desai and Samant, 2016).

In addressing air pollution and carbon emissions in Kolhapur, it is essential to recognise the interconnectedness of social, economic, and environmental factors. The integration of green spaces into urban planning is crucial for enhancing the quality of life and promoting public health.

While Rankala Lake in Kolhapur has been cleaned and restored under the National Lake Conservation Programme, Jayanti Nala remains a point of concern for the city. Kolhapur city has five major nalas (drainage channels) – Dudhali, Jayanti, Bapat Camp, Line Bazar and Veet Bhati. The total length of these nalas is estimated to be about 94 km and all these drain into Panchganga River (TERI, 2016). Jayanti Nala is a prominent drainage channel that plays a significant role in Kolhapur city's water management system, starting from Kalamba Lake, extending 9 km before merging with Gomati Nala at Hutatma Park to form a substantial nala basin. However, its current state shows severe environmental degradation. Identified as the largest contributor to the pollution of the Panchganga River, the nala collects various forms of waste, including garbage, grey water, and black water from across the city. This untreated discharge significantly impacts water quality, aquatic ecosystems, and public health. During the rainy season, garbage accumulation blocks waterways, exacerbating flooding and increasing health risks to communities in the surrounding areas. Additionally, industrial discharges from factories, and waste generated by households and religious practices along the nala further compound its pollution. Despite the efforts of local governance initiatives aimed at cleaning Jayanti Nala, the results have been limited due to a lack of sustainable interventions. Jayanti Nala's current condition poses both environmental and social challenges. Its status as a major pollutant of the Panchganga River not only threatens biodiversity but also diminishes the cultural and economic value of the river.

While local governance initiatives such as cleaning drives have shown potential, their effectiveness is diminished by several hindrances to proper implementation. Limited community involvement is one of the primary obstacles. Many of the initiatives lack robust participation from local residents, industries, and religious groups. Without collective ownership of the problem, these efforts fail to address the root causes of pollution.
Additionally, the city lacks adequate infrastructure to prevent garbage from entering the nala. Current initiatives also tend to focus on short-term solutions, prioritising surface-level cleaning rather than implementing long-term, nature-based strategies.

Despite its agricultural prominence, Kolhapur faces several problems that significantly impact both productivity and sustainability. One of the primary concerns is climate variability and flooding, which have become more frequent in recent years. Excessive rainfall and recurrent flooding have led to crop destruction and soil degradation, which not only diminish agricultural yields but also contribute to the mental health struggles of farmers, exacerbating their socio-economic vulnerabilities (Jain, 2022). Additionally, soil degradation is another major issue, primarily due to the overuse of chemical fertilisers and pesticides, which has led to a decline in soil fertility and its capacity to sequester carbon. This degradation poses a substantial threat to long-term agricultural productivity and environmental health.

Another pressing challenge is water resource management. Although Kolhapur has a significant net irrigated area, the over-extraction of groundwater combined with inefficient irrigation practices has raised concerns about water scarcity and sustainability. Ensuring both the quality and availability of water for agriculture remains a crucial issue. The financial stability of farmers is also threatened by economic pressures, including fluctuating market prices for key crops such as soyabean, cotton, and milk. These market fluctuations often lead farmers to rely more heavily on chemical inputs in an attempt to boost short-term yields. Furthermore, the predominance of certain cash crops, particularly sugarcane, has resulted in monoculture practices. This lack of crop diversification depletes soil nutrients, increases vulnerability to pests and diseases, and diminishes the agricultural system's resilience to climate change.

Existing Policies

The city of Kolhapur must utilise existing laws and implement sound environmental management practices to preserve the abundant biodiversity in the state. These are existing policies to restore urban nature:

The Maharashtra State Adaptation Action Plan on Climate 2021

The Maharashtra State Adaptation Action Plan on Climate 2021 has identified sector-specific issues and suggested adaptation strategies, including:

- Enhance quality of forest cover and improve ecosystem services, modify the current tree policy to retain mature trees, especially around the origin of rivers, which can help reduce soil erosion and downstream sedimentation.
- Recharge underground aquifers through artificial recharge methods (such as percolation tank, recharge well) in scientifically demarcated zones, by declaring green belt areas in urban areas, and by using paving materials that allow infiltration in urban areas.
- Capacity-building and training of the local communities across the state, especially youth, regarding urban agriculture as an alternative source of livelihood, with a training centre to be developed at Kolhapur.

The Kolhapur District Environmental Plan 2019

The Kolhapur District Environmental Plan 2019 prepared by the Maharashtra environment department and the Maharashtra Pollution Control Board. It identifies several gaps and action points and makes suggestions how to address them:

- To tackle poor air quality management, with PM10 in ambient air being a prime concern, the plan suggests development of green barriers. It also recommends establishing at least one Ambient Air Monitoring Station in every urban local body (ULB).
- To tackle excessive noise generation during events and festivals, the plan proposes noise mapping and adoption of physical and natural attenuation methods.
- Limited efforts in rejuvenating water bodies and addressing solid waste dumping have resulted in ineffective water management. Following a critical analysis of water quality, remediation measures should be initiated.

Kolhapur Environmental Status Report 2015-2016

Kolhapur Environmental Status Report 2015-2016 outlines the diverse biodiversity of Kolhapur and emphasises the importance of green spaces and sustainable landscapes. Key recommendations from the report include:

- Increasing tree cover in urban areas as a nature-based solution to combat climate change, through the creation of planned urban forests that enhance carbon sequestration and reduce air pollution.
- Adopting sustainable landscape management practices that integrate native plant species to enhance biodiversity. This includes establishing green corridors and parks that provide habitats for wildlife, thereby promoting ecological health.
- Organising workshops and awareness campaigns to educate residents about the benefits of trees and biodiversity, fostering a sense of ownership and responsibility toward local environmental issues.
- Developing a robust policy framework to support urban forestry, biodiversity conservation, and sustainable land use planning. This includes recommending the establishment of a biodiversity monitoring committee to oversee these initiatives and ensure adherence to environmental standards.

National Clean Air Programme (NCAP)

Under the National Clean Air Programme (NCAP), Kolhapur is recognised as a non-attainment city due to poor air quality. The action plan includes:

Industrial emission controls

Specific measures targeting emissions from the foundry sector, which is a significant contributor to local air pollution.

The city must prioritise the restoration of ecological assets by implementing nature-based solutions to build resilience to climate risks and work towards mitigation targets.

Solution 1

Restoration of Jayanti Nala

Behaviour Change and Public Acceptance | Public Participation and Trust | Livelihoods and Social Protection

Restoration of Jayanti Nala will require coordination between municipal and state government bodies, planning and regulatory authorities, research institutions, civil society groups, local communities, private sector innovators, and enablers like philanthropic organisations, to implement restoration activities such as:

Adoption of blue-green filtering infrastructure

The development of bioengineered swales along the nala is a critical solution. Constructed bioswales and blue-green infrastructure can treat grey and black water naturally by leveraging the filtration capacity of aquatic plants and microorganisms. Filtration landscapes should incorporate plants that sequester carbon and also reduce water pollution. These landscapes should be designed to accommodate seasonal fluctuations in water levels, ensuring year-round functionality.

Co-designing and collaborative decision-making

A comprehensive public awareness and participation campaign must be launched to encourage community inputs into the redesign. By linking local traditions with environmental stewardship, residents can be encouraged to adopt practices like segregating waste and reducing plastic use. Education programmes in schools can create long-term behavioural shifts, ensuring sustained community involvement in restoration efforts.

Native vegetation along the nala

Planting native vegetation and fast-growing tree species along the nala's banks can create green corridors that act as carbon sinks. Planner should select plant species with high carbon absorption rates and the ability to stabilize soil and reduce erosion. This green buffer can also act as a physical barrier to prevent garbage from entering the waterway, thereby reducing emissions from waste decomposition.

Cultural integration

An essential step is the integration of spaces for cultural festivals along the nala, which can serve as designated areas for religious practices and festivals. By creating structured, well-managed zones, such as ghat-like platforms with facilities for waste collection and eco-sensitive rituals, this approach helps prevent the ad hoc disposal of offerings and plastic waste directly into the water. The festivals could be celebrated using biodegradable materials, which are then collected and processed into compost to support green spaces along the nala.

The restoration of Jayanti Nala through these nature-based solutions provides multifaceted benefits. Green buffers and wetlands contribute to carbon sequestration, helping mitigate climate change while improving water quality. These interventions also enhance biodiversity by restoring the ecological health of the nala and its surroundings. Cleaner waterways support aquatic life and improve the overall resilience of ecosystems.

Through cultural integration, such as the development of ghats and educational initiatives, the solutions ensure that the nala's restoration resonates with the community's social and spiritual values. This fosters a sense of ownership among local stakeholders, enhancing the sustainability of the interventions. By addressing both ecological and social dimensions, the proposed approach transforms Jayanti Nala into a model for nature-based urban waterway restoration that effectively reduces emissions and strengthens community resilience.

Solution 2

Urban Green Infrastructure

Equity and Justice | Public Participation and Trust | Institutional Innovation

Kolhapur is blessed with diverse biodiversity due to the presence of several habitats in and around the city. Around 125 species of avifauna, 27 species of mammals, 22 species of reptiles, 30 species of fishes, 35 species of butterflies and 144 species of trees and shrubs were reported within and around the city (Desai, 2016). Urban areas can support a variety of species if managed properly, which contributes to ecological balance and enhances the quality of life for residents. Kolhapur Municipal Corporation has formed the Tree Authority in order to conserve and maintain the tree cover within the city.
To effectively reduce carbon emissions in Kolhapur using its 53 gardens, a comprehensive strategy focused on restoration activities for carbon sequestration is essential. This strategy should prioritise community involvement and education to ensure long-term sustainability.

The carbon sequestration potential of native tree species was 508.74 tons whereas exotic species was 191.24 tons, which shows the high potential of native trees for carbon sequestration. The ratio of native to non-native species in the population is 1:2.16 – clearly, this is an argument to increase planting of native species (Vasagadekar, et al., 2023).

Restoration activities

Large-scale tree planting initiatives, launched in collaboration with local NGOs and government bodies, can significantly contribute to urban greening, particularly by prioritising native species that thrive in the local climate and soil conditions, thereby maximising carbon sequestration potential. Enhancing biodiversity within existing gardens by introducing diverse plant species can further support local wildlife while improving carbon storage capabilities. Additionally, improving soil health through practices like composting household organic waste can enrich garden soils, enabling them to sequester more carbon and support robust plant growth. Together, these strategies can create resilient and sustainable urban ecosystems.

Community engagement and education

Integrating environmental education into school curricula is a vital step in nurturing a sense of responsibility towards nature among young citizens. Schools can further contribute by adopting nearby gardens for maintenance as part of their community service programmes, fostering hands-on learning and environmental stewardship. Additionally, establishing volunteer programmes that engage local residents in activities such as tree planting, garden maintenance, and clean-up drives can strengthen community involvement and promote collective action for urban greening. These initiatives not only enhance the city's green spaces but also cultivate a culture of environmental responsibility across generations.

Urban wilderness conservation

Protecting urban wilderness areas in Kolhapur is essential to preserving biodiversity and mitigating development pressures. Identifying key areas in need of protection and engaging the community through awareness programmes can highlight their ecological importance and foster local conservation efforts. Developing green corridors that connect gardens across the city can further enhance wildlife movement and boost carbon sequestration potential.

Additionally, equitable access to green spaces must be prioritised, as studies show that people from lower-income and lower-educational backgrounds are more reliant on these areas for daily activities, with men using them more frequently than women. Urban planning should address these disparities to ensure green spaces are inviting and accessible to all groups, fostering inclusivity and well-being.

The urban wilderness areas provide natural resources, somewhat reduce the ever-increasing impacts of pollutants, by acting as pollutant sinks like for carbon sequestration and help in recycling of organic substances. There is a dire need to create thick groves and block plantations of local species of large evergreen trees for ecological functions of pollution control and carbon sequestration, provide habitats for fauna, and to function as lungs of the city by generating oxygen.

Policy advocacy

Advocating for supportive policies at the municipal level is crucial in order to promote urban greening initiatives, such as giving incentives to homeowners to maintain gardens or plant trees on their properties. Collaborative governance can further enhance these efforts by fostering partnerships between local government bodies, NGOs, and community groups, creating a unified and coordinated approach to reducing carbon emissions through green initiatives.

By implementing this comprehensive strategy focused on restoration activities within Kolhapur's 53 gardens, the city can significantly enhance its capacity for carbon sequestration while simultaneously improving air quality and fostering community engagement with nature (Desai and Samant, 2016). This people-focused approach will not only address environmental concerns but also promote social cohesion among residents committed to sustainable living practices.

Solution 3

Urban Nature in Green Buildings

Behaviour Change and Public Acceptance | Public Participation and Trust

With increasing urbanisation in mid-sized cities like Kolhapur, novel ideas for nature-based solutions in architecture and urban design are being implemented globally, along with integration of traditional knowledge into green buildings. A few nature-oriented solutions for green buildings are:

Vertical Gardens

The creation of vertical gardens on the surfaces of buildings, sidewalks, bridges, and flyovers requires water-efficient irrigation systems to manage moisture and minimise plant loss. Replicating successful models implemented in cities of India and Colombia (Yeung, 2024), vertical gardens in Kolhapur would serve many purposes – cooling, trapping air pollutants, and beautifying the city further.

Green roofs

Green roofs atop residential and commercial buildings commonly require waterproof membranes – structural layers for anti-rooting, drainage, and insulation. These urban gardens have cultural and aesthetic value, provide thermal insulation, reduce artificial cooling and energy consumption, regulate air quality, and provide food security.

Learn more about green building solutions in Chapter 2 on Buildings.

Solution 4

Agricultural Landscapes

Livelihoods and Social Protection | Public Participation and Trust | Institutional Innovation

The district's total geographical area is approximately 1.74 million hectares, with a net cropped area of about 1.26 million hectares. Major crops grown in Kolhapur are rice, jowar, sugarcane, and soybean. (Meena et al., 2017)

Addressing these challenges requires a comprehensive strategy that integrates agro-ecological principles to enhance carbon sequestration, improve soil health, and promote sustainable agriculture.

Agroforestry implementation

Integrating trees into agricultural landscapes can significantly enhance carbon storage. Studies in Kolhapur's urban green spaces have demonstrated the carbon sequestration potential of trees, with a recorded storage potential of 688.77 tons of carbon dioxide. Applying similar principles in rural agricultural areas through agroforestry can improve biodiversity, provide shade, reduce soil erosion, and sequester carbon.

Community engagement and education

Empowering local communities through education and capacity-building initiatives is crucial for the successful implementation of agroecological practices. Sharing knowledge about sustainable farming techniques, the benefits of carbon sequestration and its long-term economic advantages can motivate farmers to adopt these practices.

Soil quality restoration

Adopting organic farming practices, such as the use of biochar, compost, and cover cropping, can restore soil health and enhance its carbon sequestration capacity. Biochar, in particular, has been recognised for its ability to sequester carbon in soils for extended periods, improving soil fertility and water retention.

Crop diversification and rotation

Encouraging farmers to adopt crop diversification and rotation practices can improve soil health, reduce pest infestations, and enhance carbon storage in soils. Introducing legumes and other nitrogen-fixing plants can naturally enrich soil fertility, reducing dependence on chemical fertilisers.

Policy support and incentives

Policy support and incentives: Government policies that provide financial incentives, technical support, and market access for sustainably produced agricultural products can encourage the adoption of carbon-friendly farming practices. Establishing carbon credit systems and supporting organic certification processes can further motivate farmers to engage in carbon sequestration activities.

By implementing these strategies, Kolhapur can transform its agricultural landscape into a resilient, sustainable, and carbon-sequestering system. Such an approach not only mitigates the impacts of climate change but also enhances the livelihoods of farmers, ensuring food security and environmental health for future generations.

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Contact
hello@transitionsresearch.com

Transitions Research