Compendium of Net Zero Solutions for Panaji, Goa

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.

Acknowledgements: This publication was produced thanks to the inputs of the residents of Panaji, fishing communities, local business owners, and members of government agenciesW, who participated in our qualitative interviews and fieldwork. We would like to especially thank the Goa Energy Development Authority for their partnership and support.

Authors: Godwin Adams, Amita Basu, Ashali Bhandari, Ronika Postaria, Shantha Venugopal, and Sushant Figueiredo

Artwork and Maps: Niyatee Khinvasara, Shantha Venugopal and Hiranya Ganatra

Images: Bucketlist Bri (Cover Image), Gemini Imagen (Energy, Green Buildings, Electricity Consumption, Mobility, Waste Management), Gaurav Pikale on Unsplash (Nature-Based Solutions)

Report Design: Niyatee Khinvasara

Please Cite As: Adams, G., Basu, A., Bhandari, A., Postaria, R., Venugopal, S., and Figueiredo, S.(2025). Compendium of Net Zero Solutions for Panaji, Goa. People's Urban Living Lab

Executive Summary

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

People's Urban Living Lab (PULL) is co-creating, testing and implementing equitable climate solutions in India's mid-sized cities. In Panaji, we are supporting the city's ambitious goals of being net zero by 2050 and becoming a solar city. We have focused on identifying solutions that are contextual and feasible for implementation. They contribute to decarbonising urban systems, like buildings, mobility and waste, but also prioritise societal goals and environmental co-benefits.

> This compendium goes beyond traditional approaches to finding solutions. Along with technological solutions, it emphasises the social dimensions of implementation. It explores strategies to cultivate the demand for low-carbon technologies and promote behavioural changes, balancing equity and user needs while navigating the complexities and trade-offs of various solutions.

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

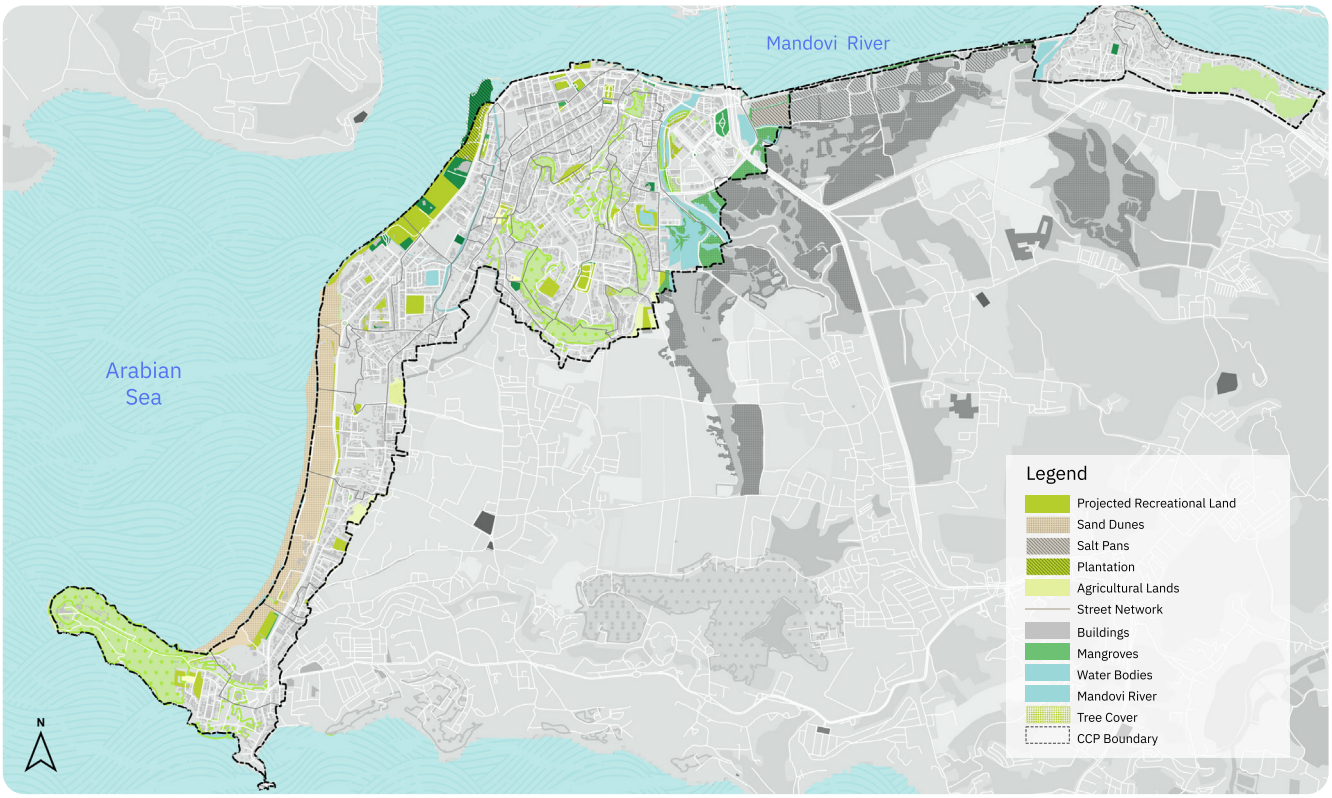
Table of Contents

Introduction

About Panaji

Nestled on the riverine island of Tiswadi, at the mouth of the Mandovi river, Panaji became the capital city of India's smallest state, Goa, less than 200 years ago. Through reclamation and engineering, wetlands and marshland were transformed into a modern city. The city was built keeping in mind its unique water ecology (Lobo & Bhandari, 2021). Urban planning created an intricate network of drains and soak spaces, managed the city's tidal creeks, and prioritised water flows to ensure the inhabitants could live safely with water.

Panaji has grown considerably and today its metropolitan area covers 53.7 square kilometres [see Map 1] (Directorate of Census Operations: Goa, 2011). The City Corporation of Panaji (CCP) governs an area of around eight square kilometres with a population of 40,019 (Office of the Registrar General & Census Commissioner, India, 2011). The city's economy is largely driven by Goa's thriving tourism (PTI, 2024) and services industry, with 98% of the population engaged in the tertiary sector (Imagine Panaji Smart City Development Ltd (IPSCDL), n.d.). This also drives a large floating population, especially in the winter season, with about 600,000 domestic and 88,000 international tourists visiting and spending time in the city annually (Imagine Panaji Smart City Development Ltd (IPSCDL), n.d.).



Map 1: Panaji City and Region

Panaji's Climate Challenges and Ambition

With the expected urban growth across Goa, Panaji will continue to grow (National Commission on Population, Ministry of Health and Family Welfare, 2020). However, the city's urban expansion is ignoring its relationship with water – at its peril. As the city continues to grow south and eastwards into the Khazan agricultural lands and wetlands, it is exacerbating its risk to emerging climate impacts like urban floods and cyclones (Lobo, Bhandari, & Kuppu, 2022). This new growth is also contributing to rising emissions, with new buildings moving away from vernacular styles which were adaptive to local climates, and a growing population purchasing more private vehicles. Panaji's per capita emissions are now three times higher than the national average (PTI, 2016). The city urgently needs a new paradigm for planning and urban development, to mitigate the city's risk from the effects of climate change and its rising emissions.

Previous studies explored the determinants of greenhouse gas emissions in Panaji. In 2013-2014 a study (PTI, 2016) stated that the city's emissions were 144,599 tonnes of CO_2e (carbon dioxide equivalent). Of this, the transport sector was the largest sectoral driver of emissions, at 38.3%, commercial and institutional buildings at 30.6%, and residential buildings at 25.1%. The waste sector was the smallest at 5.5%.

Net Zero Panaji by 2050

In 2020, Panaji pledged its commitment to achieving net zero by 2050 as part of the Cities Race to Zero (Climate Ambition Alliance: Net Zero 2050 - Climate Initiatives Platform, n.d.). In order to achieve this, the city has developed a Solar City masterplan (Tnn, 2023) and identified mobility solutions, such as the provision of electric public transport (Team Herald, 2023). 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: Panaji

There is great potential for Panaji to transition to a net-zero city. Transitions Research's **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.

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 Panaji. 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 with a brief context setting, explaining the rationale for focusing on the sector. It then provides an overview of existing conditions and key challenges faced by Panaji 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 centres 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

Energy consumption, especially in the form of electricity, is a dominant driver of emissions in Panaji as it powers the local economy and even supports mobility. Most of Panaji's energy is produced outside the city; urban bodies, including the corporation and the smart city, do not manage energy production. This chapter highlights the challenges in the energy sector in Goa, with implications for Panaji, and solutions that are applicable for both.

In FY 2018-19 the annual per capita consumption of power in Goa increased to 1,181 kWh – double the national average. Between FY 2019-FY 2021 Panaji's demand during peak hours increased by 73.49%, and 123.79% during off-peak hours. The city's expansion in population, economic activities, and sectoral demands, will affect its future electricity demand (GIZ, 2023). To combat rising emissions, the state and the city of Panaji are focused on transitioning to renewable energy (Times of India, n.d.).

Existing Conditions and Key Challenges

Goa does not have its own source of power generation and procures more than 90% of its power from the western and southern grids. The Electricity Department of Goa (EDG) carries out the distribution of electricity for 20 divisions spread across the state.

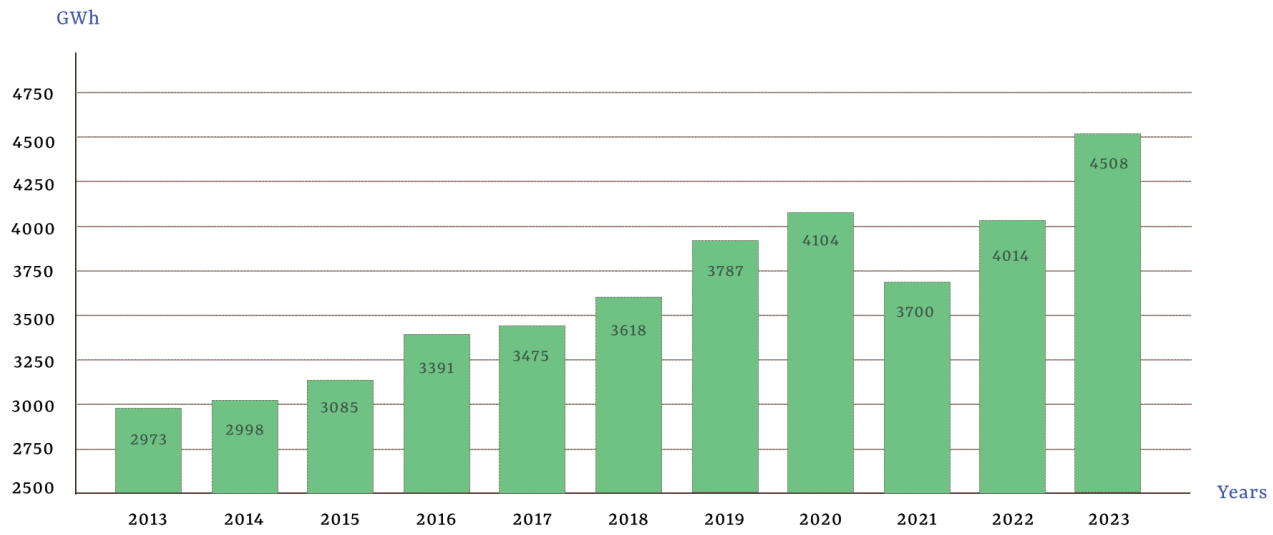


Figure 1: Goa's Rising Electricity Consumption | Source: CEIC

Approximately 94% of its power is received from thermal power plants, while the rest is generated by nuclear, renewables and hydro power plants (Sethi & Sreekumar, 2021).

The Electricity Department of Goa (EDG) carries out the distribution of electricity for 20 divisions spread across the state. There are 0.66m customers connected to this grid. 81.1% of consumers are domestic and 15% are commercial (Sethi & Sreekumar, 2021).

Goa's dependence on the neighbouring states for power generation raises questions of reliability and security of the state's power sector. The state and city's ambition to diversify towards renewable energy and generate their own power must address several technical, social and environmental barriers:

The EDG has to ensure that the grid infrastructure can cope with the increased demand for power (Refer to Figure 1), given the expected growth of renewables and demand as the population grows. The infrastructure in Panaji, specifically the EHV substations, are overloaded or inefficient and will not be able to accommodate the expected growth in demand for electricity.

There are issues regarding Variable Renewable Energy (VRE) integration. Variable renewable energy like rooftop solar PV (photovoltaic), wind, tidal and other renewable sources require adequate infrastructure to tackle technical challenges. Power quality issues like harmonic distortions, peak load management as a result of intermittent nature of renewable generation, phase balancing – occurring due to unequal phase current flowing in the system from the penetration of VRE – can have impacts on the life span of the grid infrastructure. Given the intermittent nature of RE, particularly solar, the grid requires storage facilities to enable a reliable supply of electricity. (Sethi & Sreekumar, 2021).

DISCOMs (Distribution Companies) in Goa do not have skilled labour for RE application processing, inspection, connectivity, metering, and billing. There is an urgent need for more skilled professionals to streamline these challenges. (Singh, et al., 2019).

Despite the government's promotion of rooftop solar PV, public acceptance of the technology remains a challenge, as evidenced by the limited uptake of rooftop solar in buildings in Panaji. The aesthetics and impact of certain renewable energy systems, specifically wind turbines and tidal current turbines, could impact tourism and the landscape in the state and city.

Existing Policies to Address Renewable Energy Challenges

Decarbonisation of the energy sector in Goa has focused on large-scale implementation of renewable energy systems (RES) and energy-efficient technologies through incentives, awareness, subsidies and public-private partnerships.

Central and State Schemes to Promote Renewable Energy

New and Renewable Sources of Energy (NRSE) Scheme:
The Goa Energy Development Agency (GEDA) will identify and promote viable renewable energy systems like solar PV, wind turbines, tidal energy, biomass, small hydro energy from urban and industrial waste and harness the maximum potential of these resources. Technologies like solar water heaters, solar stills, solar dryers, dish-type and box-type solar cookers, solar photovoltaic technologies like solar street lights, solar home lighting systems, etc., are being promoted for adoption by the public through financial incentives to reduce their electricity consumption.

Wind Power Programme:
Goa is promoting onshore wind turbines under the Wind Power Programme. In collaboration with the Centre for Wind Energy Technology (C-WET) in Chennai, and partly sponsored by the Ministry of New and Renewable Energy, GEDA was mapping potential sites for wind energy in Goa. Given the unstable wind speeds and high net-present cost of electricity, they felt it was not cost-effective to implement large onshore wind turbines. However, small wind turbines could supplement clean energy generation.

Kitchen Waste Biogas Plant Scheme:
GEDA also implemented a kitchen waste biogas plant scheme across Goa, to generate clean cooking fuel for residential and commercial sectors. An installation with a capacity of 1 cubic metre of biogas can generate 400 grams of gas that can be used for 2 – 2.5 hours. Commercial establishments like hotels, canteens in government and private institutions, residential schools, and complexes are allowed to install biogas plants of between 4 – 10 cum to manage their everyday waste. Subsidies for this scheme start from Rs. 10,000 for domestic households generating between 1 kg to 5 kg of daily waste, to Rs. 40,000 for commercial sectors that generate more than 50 kg of waste each day.

The Pradhan Mantri Surya Ghar Muft Bijli Yojana (PMSGMBY) aims to provide free rooftop solar (RTS) for low-consumption households across India, including in Panaji. Under this scheme, households consuming 0–150 units per month can receive subsidies up to ₹60,000 for installing 1–2 kW solar systems, reducing electricity costs and promoting clean energy adoption. Additionally, low-interest loans at 7% interest are available for installations up to 3 kW, making solar energy accessible to more residents (Ministry of New and Renewable Energy, 2025). Implementing this scheme in Panaji can enhance energy security, reduce dependence on the grid, and support India's transition to decentralized renewable energy.

Initiatives to Promote Renewable Energy in Panaji

Rooftop Solar Programme:
The municipality of Panaji, in partnership with GEDA and MNRE, has determined that the city can implement 20 MW of rooftop solar PV. Under Phase-II of the Rooftop Solar Programme, the State Government offers the following subsidies to residential consumers: 50% for the first 10 kWp (kilowatt-peak) and 10% beyond that, up to 30 kWp, based on MNRE benchmark costs. GEDA also provides free technical support to encourage the uptake of net metering for consumers

Schemes to Improve Grid Infrastructure

EDG is upgrading its power infrastructure to improve reliability, meet demand, and integrate renewable energy. Enhancements include improved grid infrastructure, smart meters, energy forecasting, load management, underground cabling, and new substations. EDG is enhancing its power transmission and distribution infrastructure, including underground cabling, and establishing new substations to improve reliability and meet rising demand.

It will integrate RES by improving grid infrastructure, enhancing load management and expanding the use of EHVs. It will also implement smart meters for efficient billing and data collection, develop energy forecasting models for uninterrupted supply, and implement demand-side management software for load optimisation. In Ribandar and Panaji, electrical networks have been overhauled, coordinated by Imagine Panaji Smart City Development Ltd. (IPSCDL). Overhead lines have moved underground and SCADA technology has been implemented for improved performance. The upgrade fortifies against weather disruptions and replaces manned power stations with unmanned, high-tech equivalents.

The EDG will be implementing the following schemes:

- Extra High Voltage (EHV) New Transmission/Substation/Capacitor banks
- Restructured Accelerated Power Development and Reforms Programme (R-APDRP) Part A
- Restructured Accelerated Power Development and Reforms Programme (RAPDRP) Part B/ Integrated Power Development Scheme IPDS)
- Underground cabling scheme
- Infrastructure development through Electricity Duty (Plan)
- System improvement scheme
- Strengthening of 220 KV Transmission Network.

However, increasing the capacity of renewables in Panaji remains a challenge. Without social acceptance and financial support for rooftop solar PV technology, the government cannot fully harness solar energy. Onshore and offshore wind turbines are aesthetically unacceptable and would impact tourism. Harnessing tidal energy in the Mandovi River flowing through Panaji would hinder tourism and fishing, and affect livelihoods of those dependent on the river.

Solution 1

Rooftop Solar PV

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

With ample space on rooftops of residential, commercial, and industrial buildings in Panaji, and annual solar irradiation of 2096.5 kWh/m2/year, Panaji can potentially generate 35.62 GWh/year (Global Solar Atlas, n.d.). To increase from 0.5 MW of currently installed solar PV to 20 MW in the coming years, the public has to accept the technology. This would require support from the government, DISCOMS, and financial institutions, through:

Increased Incentives

Besides the 50% subsidies for rooftop solar PV, the State government could offer low interest rates and benefits like tax credits and rebates. In the USA, Federal Investment Tax Credit (ITC) allows consumers to deduct a percentage of the cost of their solar installation from their federal taxes (SEIA - Solar Energy Industries Association). Public and private financial institutions should also offer attractive interest rates to consumers.

Making the Model Economically Attractive

Rooftop solar investments are economically viable under net-metering, but only if consumers receive electricity tariffs exceeding the solar's Levelised Cost of Electricity (LCOE) – the average cost per unit of electricity generated, considering the total lifecycle cost of the generation infrastructure/solar panels. However, in Goa the domestic energy charges are not high enough to make rooftop solar financially feasible, typically ranging from INR 1.5 to INR 4.25 per kWh. Therefore, the Electricity Department of Goa (EDG) must establish tariffs higher than the LCOE to incentivise adoption of rooftop solar systems.

However, there should be precautions against inflation as well as consideration for urban poor communities: slab-based rates could be a solution.

New Business Models to Incentivise Adoption

Given the high costs of adoption, new business models may help generate a demand for rooftop solar:

Solar leasing:
Solar power can be used without the upfront investment. A third-party company instals and maintains a solar panel system on a rooftop, and the property owner leases the system for a fixed monthly fee over a long-term contract (typically 15-20 years). The property owner benefits from lower electricity bills by using the solar-generated power, while avoiding the initial cost of purchase and installation. However, the lengthy contract locks the property owner into a fixed rate, and they do not own the system at the end of the lease.consistent outreach and communication.

Renewable Energy Service Company (RESCO):
The RESCO model has a third-party company finance, install, operate, and maintain renewable energy systems. Customers pay for the energy used via a

power purchase agreement (PPA) or lease, without upfront costs. This model lowers barriers to renewable energy adoption, with the RESCO assuming performance risks and benefiting from incentives and energy savings. It is widely used for solar, wind, and other renewable installations. In Goa, these models are in the process of being implemented. Round table fora with private sector actors and solar rooftop providers can help improve GEDA's tendering process to facilitate implementation. These business models would reduce the burden on DISCOMS and other stakeholders responsible for the rollout of rooftop solar PV, peak load demand burden, and T&D (transmission and distribution) losses through decentralised power generation. DISCOMS must take the responsibility to devise utility-based solutions for consumers for the entire system to be a win-win solution.

Community Solar PV to Reduce Energy Poverty

The government could implement community-scale solar PVs with affordable tariffs for urban poor communities, to provide clean energy for energy-deprived communities. These work well for slums since their buildings generally have structural challenges. Distributed solar PV for urban slums in Rio de Janeiro, Brazil – a tourist and coastal city – is an ideal example of a community-scale solar microgrid, involving the locals as partners, through co-management of the photovoltaic system (Jean, et al., 2023). Similarly, urban slum residents and small-scale businesses at Casa Pueblo realised the potential for replacing fossil fuel electricity with community owned-solar powered microgrids, creating livelihoods for the vulnerable communities (Rapin, 2023).

Behavioural Campaigns

GEDA's door-to-door campaigns like Solar Rath and flyers are raising awareness about the advantages of rooftop solar, to create a demand among households, business owners and institutions. A more detailed study to understand local and contextual barriers to adoption would help to better design campaigns to catalyse demand. According to, emphasis on financial and environmental benefits, influence from peer-to-peer social networks, and ownership (prosumers) of the system are strategies to convince consumers to adopt the technology.

Alternative Solar Technologies

Not all building owners may want rooftop solar PV technology, so other places within the city boundary such as building integrated photovoltaics, solar trees, solar parks, and solar parking stations are needed. Panaji has already identified locations for solar trees.

Skilling for Green Jobs

Between 2019 and 2021, rooftop solar PV in India has contributed to only 15% of the total installed solar PV capacity, but employed more than 43,000 employees. With more rooftop solar PV capacity planned for India, the government predicts that 80% of new jobs will be created in the rooftop solar segment, while only 16% will be in the utility segment (Tyagi & Nagarwal, 2022). As most of Panaji's power generation will be from rooftop solar, DISCOMS and other stakeholders should conduct capacity-building programmes on implementation, monitoring, billing etc., providing livelihoods for locals where micro-grids are to be installed in housing societies or slums.

Solution 2

Wind Turbines

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

Goa has implemented a 50 kW wind-solar hybrid energy plant at Verna. The Central and State Governments have funded the installation of wind turbines in Goa through Public-Private-Partnership (PPP), Build-Operate-Own (BOO) and Build-Operate-Own-Transfer (BOOT). However, with the negative impact on the aesthetics of the landscape and therefore possibly on tourism – which is one of the major GDP generating sectors in Panaji – its implementation is limited.

Mapping potential sites

Panaji is a heritage city with historical buildings. Since placing onshore wind turbines within the city could harm tourism, suitable locations must be mapped. Offshore wind farms can affect fishing communities by displacing fish and increasing fuel costs for vessels. To protect these communities, it is vital to avoid fishing areas and ensure offshore wind farms do not disrupt their livelihoods.

Infrastructure for Onshore Wind Turbines

Onshore wind turbines in an urban environment are comparatively smaller than utility-scale wind turbines. Site selection processes for wind turbines should consider the availability of wind resources– lower wind turbulence, steady wind speed, and proximity to the grid. These sites should be distant from environmental and social constraints like heritage sites, wildlife habitats, aviation concerns, etc. Micro- and small-scale wind turbines could generate more power if they were placed on rooftops of high-rise buildings rather than shorter buildings. Places closer to the beach, and rounded hills, are also potential sites for placing wind turbines.

New Stakeholder Forums and Institutional Arrangements

“Community wind,” a locally-owned, multi-stakeholder model, which originated in European countries, places wind turbines within available community spaces. It offers numerous advantages over corporate- and government-owned models, as it fosters stakeholder involvement and support. In Sweden, real estate owners pool funds to construct turbines.

The electricity generated is sold to the grid by the commune at a fair price. The revenue is distributed among the investors. This collaborative approach ensures the success of community wind projects while preserving scenic landscapes and promoting sustainable energy transitions. Institutional arrangements involving municipal authorities, tourist agencies, and residential builders are crucial in order to address visual impact and enhance policy-building activities.

Mitigating Biodiversity Impacts from Wind Turbines

While wind turbines are one of the most important renewable energy sources, they are also a source of environmental pollution and disturbances. Noise pollution is high, leading to the "NIMBY (Not-in-my-backyard) culture". The high cost of land in cities also leads to turbines and wind farms being located in rural areas. However, this has implications for biodiversity, especially in a state like Goa, which is home to the Western Ghats and a high density of biodiversity.

To prevent noise pollution, technological modifications to the turbines, choice and configuration of the tower and base components can reduce vibrations. Lower peripheral velocity of the rotor blades minimises noise emissions by the vertical wind turbines (Amin, et al., 2021). It is difficult to prevent the deaths of birds and bats due to collisions. Denmark and Norway, have used ultraviolet light on the turbine wings, and booming boxes that generate high-frequency sounds to prevent fauna from colliding with the turbines (Robin Radar System, 2021).

Livelihood Opportunities

India plans to install an additional 19.4 GW of onshore wind, creating around 1 million direct and indirect jobs over a 25-year period, in the wind turbine manufacturing, construction, installation, and operation and maintenance (O&M) sectors (Tyagi & Nagarwal, 2022). In Panaji, wind-solar hybrid power plants could generate livelihood opportunities, particularly in the O&M segment. Capacity building and training programmes, especially targeting youth and women from urban areas, could create green jobs and enhance the skills of urban youth, including those from slums, and significantly boost their employability in related sectors (Tyagi & Nagarwal, 2022).

Solution 3

Tidal Energy

Public Participation and Trust | Livelihoods and Social Protection

India's long coastline could allow for harnessing tidal energy. Among the six potential inlets identified along the Mandovi river, one of the locations which is closer to Panaji has the ability to produce 3,108.09 kW energy. However, its placement along the current flow of the river, either floating or attached to the river bed, will challenge non-technical activities such as fishing, tourism, etc.

Site Selection Analysis

Cruising down the Mandovi River in Panaji is a popular tourist activity. Therefore, mapping exercises are required to locate potential sites for horizontal axial tidal current turbines (HATTs), so that ferries and cruise ships are not hindered by them.

Stakeholder Engagement to Understand Tradeoffs and Implementation Pathways

For tidal energy projects to succeed, it is imperative to engage with a range of stakeholders including owners, developers, suppliers, employees, unions, tourism agencies, local fishing communities, and government representatives at various levels, as approvals are needed and regulatory procedures have to be followed. Meanwhile, offering targeted financial incentives will help to garner support. Local communities, businesses, and organisations dependent on the river should endorse the technology for its seamless functioning (MacDougall & Colton, 2013). Project credibility can be enhanced by addressing community requirements through stakeholder engagement – town halls, awareness campaigns and capacity-building initiatives targeting schools, public groups, and fishing communities. The European Commission is encouraging local communities to develop "community-owned" tidal energy projects that will generate income for the locals, by supporting such projects with 50% funding by the government. The Scottish government has allocated a sum of £103 million to support the local communities and rural businesses to develop tidal projects. (Bolinger, 2001).

Training for Green Job Creation

Training programmes for local communities and youth, who are already familiar with water body conditions, can create clean energy jobs in operation and maintenance (O&M)

Solution 4

Bioenergy

Equity and Justice | Livelihoods and Social Protection

The daily municipal solid waste generated in Panaji is 40 – 50 TPD, of which almost 70% is wet waste. Panaji is aiming to manage wet waste at its source through decentralised units. This can be utilised for low carbon transitions through:

Bioenergy to Address Energy Poverty

In Panaji, urban poor households rely on firewood and kerosene, as LPG cylinders are very expensive. They could be powered through cleaner sources, such as biogas, generated from wet waste. The government should set up biogas plants in their locality free of cost/at a cost lower than the market price charged for the gas supplied to households.

Decentralised biogas plants set up in residential societies can ensure a supply of clean fuel to the residents. Commercial and educational institutions could act as "energy entrepreneurs" by supplying their surplus clean fuel to the nearby slums at a cost lower than the market price. The government could pay the difference, similar to cross-subsidies in the power sector.

Incentives and Financial Options for Biogas Plants

Increasing subsidies for biogas digester plants—over ₹10,000 for domestic consumers and ₹40,000 for commercial users—could make them a more attractive option, especially given the rising cost of LPG cylinders. The high capital cost is a barrier, but offering financial incentives and subsidies for pipeline setup could encourage investment. Multi-stakeholder involvement and public-private partnerships can further promote biogas plant implementation. Assam's recent "pro-poor public-private partnership" model, which includes biogas plant development, has garnered significant attention and serves as a promising example. In Bangladesh the "Grameen Shakti" initiative provides a number of financial options to rural households to adapt to renewable energy technologies. The Government encourages partnerships between NGOs, microfinance institutions and international donor agencies to promote the implementation of biogas plants for rural households. Similar partnerships and business models can be encouraged for Panaji to drive the rollout of biogas plants for below-poverty households (Raha, et al., 2013).

Livelihood Options

Community-level biogas initiatives would encourage entrepreneurship and lead to income-generating activities for small businesses like poultry rearing, and provide energy to commercial establishments like restaurants. This would improve livelihood opportunities and the quality of life.

Offering training programmes and capacity building to urban slum dwellers through grassroot or community-based organisations may increase awareness among women. Bangladesh serves as an example for training women to act as energy service technicians and earn incomes through servicing and training other users

Solution 5

Transmission and Distribution

Behaviour Change and Public Acceptance | Institutional Innovation

Goa has to strengthen its transmission and distribution (T&D) networks to ensure a reliable supply of renewable energy to consumers. Panaji's drive towards achieving net zero, calls for greater efforts at decarbonising the power sector and integrating large capacities of renewables into the grid:

Grid Upgradation

Goa's current T&D infrastructure and grid network are not capable of integrating decentralised energy production. With the increase in decentralised renewable energy production, especially from rooftop solar, the grid needs to be upgraded to handle the interactions between generation and consumption, or else it risks failures in transmission. The T&D network must adopt a 'multi-dividing, multi-connecting system' with suitable switches for improved reliability, similar to Panipat's smart grid project.

Adoption of Cost-Effective Transformer Mending Techniques

The failure rate of distribution transformers in Goa, due to overloading, oil leakage, poor maintenance, LV faults, surges, load unbalancing, and low entry barriers in the distribution transformer market, is 7%. Preventive mending techniques using rust removal liquid, primer paste, and putty could ensure the healthy maintenance of transformers, decreasing the cost of repair of failed transformers. The capacity building of utility officials for preventive maintenance/mending and development of best-operating manuals for inspection and repair will help to reduce transformer failure (Sethi & Sreekumar, 2021).

Integrating AMI Through Smart Community Projects

Advanced Metering Infrastructure (AMI) monitors and measures consumer details through smart meters installed at the consumer's end. Monitoring and analysing the consumption patterns of the consumers could reduce peak load demand, decrease the ramping of demand, reduce the overload on transformers, and help utilities better manage their demand-side response. Deployment of AMI among industrial and large commercial consumers in Panaji would be helpful in dynamic load shifting to off-peak hours.

Renewables Forecasting Methods

Given the intermittent nature of renewables, especially solar PV, forecasting methods must become an integral part of the grid upgrade. The energy production by different renewables also has to be monitored, to ensure a reliable supply to the consumers. Panaji can become net zero in the power sector only through the integration of distributed renewables.

Capacity Building and Training for Stakeholders

The lack of knowledge on energy efficiency and renewable energy among various stakeholders – utility officials, financial institutions, and local service providers – should be remedied through capacity building and training. An understanding of load management, benefits of adapting renewable energy systems, and financial models involved in power consumption would help the large-scale deployment of renewable energy technologies.

Solution 6

Transport

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

To meet the increase in the number of EVs in the city (Refer to Figure 2), the electricity demand is expected to rise to 57.4 GWh by 2050 (GIZ, 2023). Since this demand will be met from the power generated by Variable Renewable Energy sources, the city is expected to upgrade its grid infrastructure to accommodate and manage the supply and demand.

Figure 2: Electric Vehicles are Gaining Popularity | Source: Herald Goa

Grid Reinforcement

One of the major challenges for the grid, posed by the EV charging infrastructure, is to mitigate fluctuations in voltage rise caused by overloading.

This can be tackled by:

- Allowing the distributed generators to absorb the reactive power
- Installing auto-transformers/voltage regulators
- Increasing conductor size and reducing line impedances
- Storing power surplus using battery storage systems (BSS).

However, there are technical and economic challenges associated with each of these solutions. Therefore, it is important to conduct an extensive research and analysis before adopting the strategies.

Smart Grid

Establishing a modern and more efficient power grid infrastructure to increase the reliability and quality of power, with the ability to interact and manage demand and supply, and overcome challenges associated with distributed power generation from renewable energy sources, promoting efficiency and involving passive final users.

Vehicle-to-Grid (V2G) Administration

This is a bi-directional flow of power from electric vehicles, acting as mobile storage units to the grid during demand hours. EV purchasers are offered vehicle-to-grid administration by the vitality provider and a unique type of charger is set up at the automobile owner's house. This charger will enable the owner to exchange power with the grid from the auto's battery at peak hours when the costs are high, giving money to the owner. The automobile's battery is charged during off-peak hours, when the electricity

costs are low. V2G will reduce charging costs and the pressure on the grid during peak hours. The Singapore government has taken initiatives to employ V2G infrastructure into the grid in the wake of its growing EV demand.

Encouraging Time-Based Charging for EV Owners

Encouraging off-peak/night time charging at a lower price to reduce grid congestion during the day would require additional battery backups for the household grid-connected rooftop solar PV owners, making the system expensive. Conversely, encouraging daytime charging when the solar generation is maximum through attractive policies on cost of electricity for daytime charging, would encourage a paradigm behavioural shift in charging patterns of consumers.

Obtaining data on charging patterns, charging databases, and GPS systems could help to develop a top-down approach to encourage and promote daytime charging and for policy makers to provide insights for modelling EV uptake and charging profiles. Besides grid congestion, avoiding emissions from grid electricity for grid-connected solar PV systems could add additional environmental benefits for daytime charging. Studies such as Garg et al. (2014) at the UCSD campus demonstrate that EV charging behaviours can be reshaped using financial incentives and informational prompts.

Although EV owners did not fully adopt daytime charging, their habits shifted to earlier in the morning and later in the evening, outside of peak demand periods. Additionally, passive measures like regulating the start/stop times of charging and power modulation can help reduce the peak load on the grid. These strategies collectively contribute to more efficient grid management and better integration of EVs.

Public-Private Partnerships

Fostering and realising the potential of partnerships between public and private entities would help in identifying the key features necessary to encourage the adoption of EV and EV-related infrastructure. The collective capabilities of designing, distribution and marketing of EVs by the private sector could be assessed. Meanwhile, addressing administrative and financial challenges on subsidies, low-interest loans, and tax benefits by the public players could influence consumer interest and adoption of EVs, and develop the required EV ecosystem. Financial burdens could be reduced by pooling resources for building and maintaining charging infrastructure, making it a more viable and sustainable investment.

MG Motor and Tata Power combined efforts to establish an extensive fast-charging network across India's major cities. With MG Motor's commitment to environmentally friendly vehicles and Tata Power's expertise in supplying charging infrastructure, this partnership instils confidence in EV owners for long-distance travel. These partnerships demonstrate the potential for society to leverage the environmental and economic benefits of EVs.

Malaysia has increased tax incentives for private sector charger businesses and for PV adoption, especially for rooftop solar PV, to meet its national targets for EV (Longo, et al., 2017).

Chapter 2

Green Buildings

Green Buildings

Sector Overview

The buildings and construction sector plays a key role in accelerating the transition towards a low-carbon, resilient, and sustainable future in Goa. Energy consumption and carbon emissions in the built environment are largely from the use of electricity and building materials (Tackling embodied carbon from India's building sector, 2024). 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 life, are termed embodied emissions.

In the year 2013-2014, residential and commercial buildings together used around 35% of energy in Panaji, contributing to 55.7% of the city's greenhouse gas emissions (Towards low carbon and resilient pathways, n.d.). With increasing urban growth all across Goa, it is clear that more sustainable practices in existing buildings and greener construction of newer buildings is crucial to achieving Panaji's target of net zero by 2050.

Existing Conditions and Key Challenges

Panaji, Goa's capital, is a focal point for tourism, commerce and culture. Investment in public infrastructure – improved road networks and upgraded transportation facilities such as the new Mopa Airport and Zuari Bridge, linking Panaji with other areas, has not only facilitated accessibility but also fuelled the demand for real estate, driving buildings and construction in the city limits and the metropolitan area.

In the year 2013-2014 Residential and Commercial Buildings in Panaji, together

Used around
35%
of Energy in Panaji

Contributing to
55.7%
of the City's Greenhouse Gas Emissions

The drive to privatise public assets to cater to the growing demand presents a dilemma for city planners. Easily developable land parcels within the city are scarce, leading to unsustainable development as ecologically-sensitive areas are built up; there is rampant development in vulnerable and suburban areas, exacerbating concerns such as natural resource depletion, utility strain, pollution, and soaring rents, to the detriment of local residents.

The urban landscape is evolving. Government offices are relocating to the emerging business district of Patto to alleviate congestion and decentralise administrative functions. Realtors are converting older residential

apartments into hotels, offices, and retail spaces, altering the city's fabric and raising questions about the preservation of its unique character amidst rapid growth (New Food Buzz in Goa's Latin Quarter, 2024).

Panaji is looked at as a modern city with high-end villas and gated communities, flourishing cafes and restaurants, bustling with tourists and cultural festivals. However, a report by Centre for Urban and Environmental Studies (RCUES), supported by the Union Ministry of Urban Development in 2015, identified 2,517 households in Panaji, home to about 8,368 people in 24 of Panaji's 30 wards that could be categorised as slums (TNN / Mar 7, Slumming it out in Panaji: Goa News - Times of India).

The 2016 Swachh Sarvekshan Survey identified slums in Marivel village, Cacra ward, Cabesa ward, Boca De Vaca, Bhatlem, along the St Inez Creek and even in Caranzalem, which is a fairly upmarket area.

These slums are better than others such as Dharavi in Mumbai, which do not have electricity, water and sanitation facilities, but they certainly need attention, especially given Panaji's push as a Smart City and its net zero ambitions. However, Goa does not have a Slum Development Committee or State Slum Redevelopment Authority, as mandated under the Goa Rehabilitation Act (The Goan EveryDay, 2023). With the slums in the State not officially identified and notified, slum rehabilitation is not possible, even though a budget may be allocated for it.

As Panaji grows, green building norms and guidelines are urgently needed to reduce emissions related to new constructions and retrofits in and around the city.

There are several challenges:

- Consumers and developers lack awareness
- Greener constructions are costlier
- Dearth of skilled labour
- Unfavourable market conditions
- Central codes and guidelines for sustainable buildings have not been mainstreamed
- Approval process for green building compliance and the complex documentation required deter developers

Consumers and developers lack awareness about sustainable building practices, so business-as-usual construction is one of the major obstacles to the growth of the green building market. With limited understanding of the benefits of green building and the process of low-carbon construction, people still perceive sustainable buildings as an expensive option.

Many developers are still not familiar with some of the green building materials and continue to use traditional methods. With resistance to change, people find it difficult to step out of their comfort zone and opt for a new method of building.

Greener constructions are costlier than conventional construction methods. Most developers and consumers are unwilling to pay more, even though green infrastructure is proven to yield significant financial benefits and cost-savings over the medium to long term.

There is a dearth of skilled labour 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 can be a challenge to energy efficiency. In some cases, energy-efficient technology or material may not be available in certain markets, or competition among suppliers 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.

Central codes and guidelines for sustainable buildings have not been mainstreamed into the local regulatory frameworks, resulting in a higher incremental cost due to much lower existing baselines for construction. The government at the local level should incorporate efficiency considerations in construction and procurement guidelines and establish benchmarks for building energy use.

The approval process for green building compliance and the complex documentation required can deter developers from opting for Green Ratings. There are no experts in Goa to assist developers with the documentation and approvals.

Existing Policies for Sustainable Buildings

The Government of Goa has begun to promote green and low-carbon buildings across cities. The construction sector in Goa is governed by The Goa (Regulation of Land Development and Building Construction) Act, 2008 and its subsequent amendments.

Initial Efforts

The first effort to encourage Green Buildings in Goa was made by the late Chief Minister Shri Manohar Parrikar in 2015-16 (Goa implements scheme to encourage renewable energy 2016). Training and workshops on rating systems were organised, and an incentive of 25% reduction in infrastructure tax was given to builders opting for a Green Rating. This was however deemed insubstantial by the builder lobby and didn't see much success.

Multi-stakeholder Efforts for Green Buildings

In 2023, the Goa government collaborated with the Indian Green Building Council (IGBC) to ensure that the State has green certification for buildings and upcoming government projects in the State (Goa, 2023). Now a move to provide increased FSI to Green Rated projects is awaiting cabinet approval.

The IGBC Goa Chapter which comprises three student chapters, in association with architecture and civil engineering colleges in the State, has been formed. It encourages individuals and firms to get certified as IGBC Accredited Professionals (IGBC AP) and organises training programmes and workshops for various stakeholders.

Who is responsible for green buildings?

The construction and buildings sector requires the cooperation of many actors: government bodies such as TCP (Town and Country Planning), CCP, GSPCB (Goa State Pollution Control Board) wet, set land use and development, control regulations and approve new buildings/retrofits; the private sector is largely involved in the planning, design and financing of new buildings. Material 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

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

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 and covers the following domains

- Sustainable Architecture and Design
- Site Selection and Planning
- Water Conservation
- Energy Efficiency
- Building Materials and Resources
- Indoor Environmental Quality
- Innovation and Development (Indian Green Building Council)

Various government-recognised bodies such as Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy & 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 certified to silver to gold and platinum which demonstrates the highest level of sustainability and green features implemented. A certification allows developers to not only demonstrate a commitment towards being sustainable, but also for the building users to benefit from the green features like improved comfort, productivity and cost savings.

However, awareness programmes and incentives are needed to address the high incremental cost of construction and knowledge gaps about the benefits of green buildings.

Incentives to Developers

Design phase: An incentive of special loans or expedited permitting 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 of 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 Space Index (FSI). Higher FSI, which is the ratio of a buildings total floor area to the size of the land it is built on, enables a larger built-up space which significantly compensates for the incremental cost of going green. Another 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 reduced house-tax for homeowners. A builder may be encouraged to opt for a green certification because of increased consumer demand for greener real estate.

Partnerships with Green Certification Agencies

Through agreements 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, material and service providers, colleges 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 Repository for Green Sourcing

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

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 material and services, and also influence consumers to opt for more sustainable spaces. Giving awards and recognition to such projects could also provide a nudge 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

Behaviour Change and Public Acceptance | Institutional Innovation

Environmental clearance (EC) was required for projects with a built-up-area (BuA) of 20,000 sq.mt., but a recent amendment to the law requires only those above 50,000 sq.mt 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 may 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 (Types of solar cells: Comprehensive guide on top varieties, 2024).

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.

Glass: should be reduced in the southern and western facades in a window/wall ratio of 40% to reduce electricity consumption and load on air-conditioning (Influence of window-to-wall ratio on building energy load, n.d.). Glass with low U-values (a metric for insulation) and Solar Heat Gain Coefficient (SHGC) as per energy conservation building code (ECBC), 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 recommended Solar Reflective Index (SRI) value for a low-sloped roof is >90 and for a steep-sloped roof is >29 (LEED Rating).

Wall: should meet prescriptive requirements as per ECBC for all air-conditioned spaces by using appropriate insulation. Material such as 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).

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).

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

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).

Solution 3

Reducing Embodied Energy in Retrofitting of Old Buildings

Behaviour Change and Public Acceptance | Institutional Innovation

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 (The secret to better building retrofits).

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

Behaviour Change and Public Acceptance | Institutional Innovation

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

Made from 100% recycled plastic. 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 product 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

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

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.

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

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, 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.

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.

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

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

Goa's per capita consumption of energy is double the national average with the demand rising, especially in Panaji. To counter the resultant rising emissions, Goa is focused on transitioning to renewable energy. Most of these efforts are being championed by the Goa Energy Development Agency (GEDA) (GEDA, n.d.), which was established in 1996 exclusively to undertake the development of low-carbon energy sources. While the state has been making strides in RE, electricity conservation behaviours are also key for mitigation (GEDA, n.d.).

Goa's thirstiest sector in terms of electricity consumption is industry (Cabral, n.d.) (GEDA classifies hotels and similar commercial enterprises under "Industry") (Refer to Figure 3), with the domestic sector a close second. In FY 2013-14, the state had around 5.4 lakhs registered electricity consumers, 80% of which were domestic (Goa Electricity, n.d.).

Of these households, just over 50% are rural (ibid.). Since Goa's electric grid is extensive and power supply is remarkably steady, there is little difference in per-consumer electricity demand across the urban vs. rural

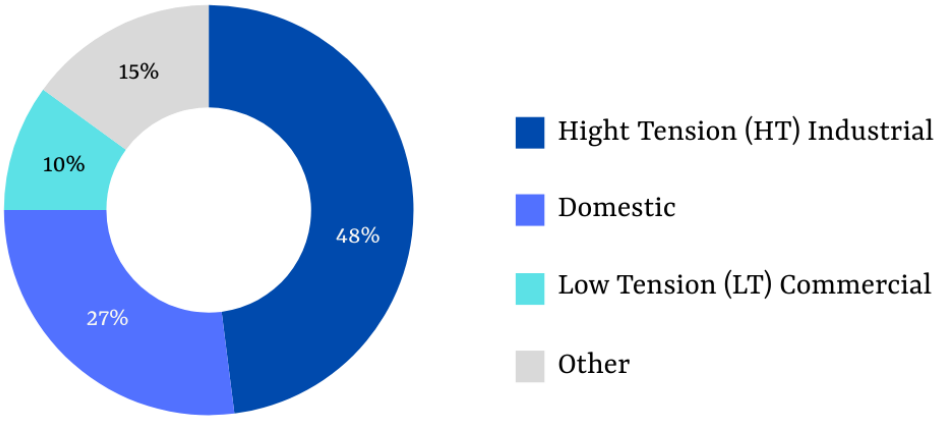


Figure 3 : Goa's Electricity Consumption is Driven by HT Industrial and Domestic Demand | Source: 24x7 Goa

Existing Conditions and Key Challenges

Electricity consumption in Goa has grown rapidly, with generative capacity struggling to keep pace (Sharma, 2021). The response has focused on sector decarbonisation using renewable energy, rather than moderating electricity consumption (Renewable Watch, 2023). The state also prides itself on the efficiency of its electricity

distribution network (Times of India, 2023), which is important, since large amounts of electricity are often wasted in the grid.

Tariffs are a good starting point to encourage lower consumption of electricity. Power tariffs in Goa vary by sector and by total monthly meter reading, ranging from 100 paisa/unit (for domestic, low-tension-power agricultural consumers, and for iron manufacturing) to 380 paise/unit (for commercial enterprises consuming more than 500 units/month). Tariffs vary based on total consumption in the domestic (four consumption brackets), commercial (three brackets), and industrial sectors (three brackets) (Goa Electricity, n.d.).

Electricity tariffs across India are among the lowest in the world (Goswami, 2023). In Goa, tariffs are among the lowest in India (Goa Electricity, n.d.). across multiple sectors, including domestic (Jain, 2022), where tariffs for the highest consumption bracket are lower than corresponding tariffs in other states and union territories. Low tariffs in Goa are probably responsible for the high rates of consumption. While they may seem a good sign for development indices (Goswami, 2023), we must also consider the environmental effects of high rates of consumption of fossil-fuel-dependent electricity.

Other challenges for sustainable electricity consumption include: Carbon lock-in where large existing investments in fossil-fuel-powered infrastructure, including power plants and the power grid, represent sunk costs in a high-carbon modus operandi, and create inertia. At the level of consumers, investments in inefficient household devices, and in ACs as a mode of cooling, are examples of lock-in, and barriers to behaviour change. Furthermore, there is low awareness about energy-efficient electrical appliances. A 2020 study found that only 25% 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. The drive to privatise public assets to cater to the growing demand presents a dilemma for city planners. Easily developable land parcels within the city are scarce, leading to unsustainable development as ecologically-sensitive areas are built up; there is rampant development in vulnerable and suburban areas, exacerbating concerns such as natural resource depletion, utility strain, pollution, and soaring rents, to the detriment of local residents.

The urban landscape is evolving. Government offices are relocating to the emerging business district of Patto to alleviate congestion and decentralise administrative functions. Realtors are converting older residential apartments into hotels, offices, and retail spaces, altering the city's fabric and raising questions about the preservation of its unique character amidst rapid growth (New Food Buzz in Goa's Latin Quarter, 2024).

Panaji is looked at as a modern city with high-end villas and gated communities, flourishing cafes and restaurants, bustling with tourists and cultural festivals. However, a report by Centre for Urban and Environmental Studies (RCUES), supported by the Union Ministry of Urban Development.

Existing Policies for Reducing Energy Consumption

National Level Programs

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

Bureau of Energy Efficiency (BEE)'s demand-side management (BEE, n.d.) in the agricultural and municipal sectors has focussed 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 tonnes 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, and 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, Sen, & Kunte, 2020), leading to a cumulative reduction in consumers' electricity bills of Rs.94,00 crores 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 397 million tons of avoided carbon dioxide emissions from refrigerators and air-conditioners alone (Joshi, Sen, & Kunte, 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).

The Bachat Lamp Yojana and the Ujala Scheme

These schemes have been implemented over the last 15 years to promote LED lights across India and reduce emissions from lighting. Close to 40 crore LEDs lightbulbs have been distributed across the country (Ministry of Power, 2022) as these schemes have reduced the price of LED bulbs from INR 300-350 to INR 70-80, increasing the affordability of this technology. The State Government of Goa also launched the Jyotirmay Scheme in 2016 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.

State Level Programs

Energy-Specific Recommendations

Goa's government has made energy-specific sustainability recommendations to all sectors (Energy World, 2023), in line with the recommendations of the United Nations Industrial Development Organisation (UNIDO). However, these are primarily focussed on providing renewable energy and achieving net-zero targets, rather than on reducing energy consumption (Economic Times, 2023).

The "24X7 Power for All Goa"

The "24X7 Power for All Goa" (Goa Electricity, n.d.) scheme is a joint initiative of the national and Goa governments, to promote inclusive development by electrifying 100% of households, industry, and agricultural concerns. This scheme focuses on energy efficiency. Demand-side management is through sector-specific tactics (ibid):

Agricultural: replacing water pumps with energy-efficient iterations.

Commercial: retrofitting with energy-efficient equipment; implementing Energy Conservation Building Code (ECBC) (Energy Conservation Act, 2001).

Industry: Implementing ECBC; energy audits.

Household: replacing incandescent and other light sources with LED lights.

Smart Meters

In November 2023, the state government started equipping Panaji households with prepaid smart meters (Patnaik, 2023), as a pilot project to study the feasibility of using smart meters. This is part of a larger drive by the government to upgrade meters from mechanical to digital/electronic, and to achieve full meter coverage of all consumers. The proposed smart meters will 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 & 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 Panaji's plan to reach net zero.

Solution 1

Restructuring Electricity Tariffs to Incentivise Reduced Power Consumption

Behaviour Change and Public Acceptance

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. For instance, the tourism industry in Panaji could pass on to their clients the higher costs of their higher power consumption. Since per-unit power tariffs in India are very low to begin with, and are especially low in Goa (Goa Electricity, n.d.), raising tariffs, particularly in the higher-consumption brackets, would allow the market to internalise some of the negative externalities of high power consumption. Businesses would then be incentivised to reduce electricity consumption in innovative ways.

Price sensitivity (also called 'price elasticity of demand') is good-specific, and is a measure of the number of units by which demand falls for each unit of price increase. Before restructuring electricity tariffs, it would be useful to perform a study on price sensitivity for electricity among domestic, industrial, and commercial consumers in Goa. Some studies in other nations have looked at the price elasticity for electricity, specifically with respect to renewable energy, where measurements are collected in the form of how much of a premium consumers are willing to pay for renewable electricity (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, Karathanasis, & Burri, 2008), which means that restructuring tariffs alone may not be enough to discourage consumption. However, restructuring would help to distribute more fairly the emissions costs of power consumption by the highest-consuming brackets. (Data on income elasticity of electricity demand do exist for India, though income elasticity differs from price elasticity.) (Bose & Shukla, 1999).

Solution 2

Incentivising Electricity-Conserving Business Models

Behaviour Change and Public Acceptance

Rewards and penalties could recognise or discourage energy in-/efficiencies. Businesses should be financially incentivised to take steps like upgrading their heating and cooling systems, and lighting and water-heating equipment, installing weather-proof windows, sealing air ducts to minimise unintended heat transfer, and retrofitting for energy efficiency. Increasing levels of concern among consumers, and the desire of businesses to maintain a positive public image, can be harnessed as additional motives, by creating a standardised and trustworthy system of energy-auditing and certification that companies can strive to earn for use in their marketing (Tomassi et al, 2022).

Solution 3

Encouraging a Shift to Low-Carbon and Energy Efficient Cooling

Behaviour Change and Public Acceptance | Institutional Innovation

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. Applying these norms lowers a building's energy requirement without affecting the comfort, health, or productivity of the occupants. In the commercial sector, which is "expanding at 9% per year," the ECBC encourages architectural strategies such as passive design and light integration, and focuses on renewable energy and the life-cycle cost of the building.

The commercial sector is the biggest employer in Panaji (tourism, banking, and health) (Panaji Online, n.d.), and the biggest consumer of electricity. This sector must be incentivised to implement green building codes, including the use of low-carbon cooling technologies, for new and existing buildings. Goa's humid climate rules out the use of cooling methods based on evaporation (like desert coolers). Realistic options would include heat pumps, highly-efficient air-conditioners, natural ventilation, and shading (IEA, n.d.). While some of these options (e.g., heat pumps) involve high upfront costs, the high per capita incomes across the State (Kamat, 2003) suggests these technologies (as well as low-tech options) would pay off in the long run. All kinds of developments can register to get the Indian Green Building Council (IGBC) certification; Goa currently has 40 IGBC-registered projects. IGBC measures impact of energy savings, water savings, carbon dioxide reduction, and waste reduction (IGBC, n.d.).

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 Panaji's buildings. (For more, see: Ch 2: Green 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, waterbodies, and wetlands within Panaji will mitigate rising land surface temperatures, since greenery and water bodies reduce ambient temperatures. With shade-giving trees on roads and public squares, public spaces will remain relatively cool, and reduce the demand for air-conditioned spaces. A move away from large concrete spaces (Newslaundry, 2016) (which can increase surface temperatures by up to 6 degrees Celsius (EPA, n.d.), and which, on hot days, can reach temperatures as high as 32 degrees Celsius) (VOA News, 2023), towards spaces with plants, will help keep outdoor urban spaces cool. On hot days, the maximum surface temperature reached by grass, which absorbs a far lower percent of incident solar radiation, vs. concrete in the same location can differ by as much as 25 degrees Celsius (ibid). As a corollary benefit, a cooler outdoor space radiates less heat onto nearby buildings, which could lower cooling needs inside buildings. Other nature-based solutions include green roofs and reflective paint on houses.

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 turning ceiling fans off when the roof is heated, can greatly reduce both the reliance on and the effectiveness of, air-conditioners and other power-consuming cooling devices.

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

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

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.

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

However, 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 which 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.

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. Product features and brand reputation are cited as the next most important criteria for selecting household appliances (ibid). Manufacturers of energy-efficient appliances would benefit from focussing on their products' many desirable features, such as, in the case of ACs, 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.

Another 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 (Wright, 1990), on, for instance, the east coast of Africa, by people very different socio-demographically from the AC user (ibid). Therefore, our motivation to make sustainable choices is low. However, if the effects of our actions were concrete, that would address one set of barriers.

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 sometimes given 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.

Solution 5

Encouraging Smart Meters for Real-Time Feedback on Consumption

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

Currently, smart meters of the type that record units generated vs. units consumed are being installed by DISCOMs across Goa for consumers who install rooftop solar panels (Navhind Times, 2023), so that electricity bills can be adjusted. Private businesses have been contracted by the government to manufacture and install smart meters, which has generated many new jobs nationwide. Smart meters of a different type, which offer real-time information on electricity usage (Genus Power, n.d.), can help consumers monitor their usage patterns on an hourly basis, and identify peak consumption hours (which are generally in the evenings in India for domestic settings, and during the workday for industrial settings).

India plans to upgrade all existing metres to prepaid smart meters by 2025-26 (Outlook India, 2023). This will help reduce electricity consumption, by encouraging consumers to plan ahead for their monthly needs (Genus Power, n.d.), and also allow providers to plan production better and avoid costly grid imbalances. This move is expected to result in greater efficiency and lower financial and environmental costs. In pilot studies, approximately 38% of households with smart meters report consumption reductions (Outlook India, 2023).

By linking to artificial intelligence analytical tools, smart meters can also help provide broader guidelines to industrial and residential consumers to reduce consumption (SAP, n.d.).
Goa already plans to install smart meters for 7.4 lakh consumers, and use this information to help consumers manage and moderate their consumption (Monteiro, 2022).

Consumers could also lower their consumption by shifting usage from peak to off-peak hours:

Recent amendments to the tariff system have altered tariff rates for peak hours vs. off-peak hours (Economic Times, 2023), with the former being 10-20% higher on average. Smart meters can help both domestic and industrial users to identify their own patterns of usage, and shift some of their peak-time usage to off-peak hours (e.g., running domestic washing machines or industrial cleaning machines during off-peak hours). This would benefit individual users by reducing their electricity bills, and also help balance the power grid by reducing total load during peak hours, which in turn would reduce the frequency of load shedding and other grid-balancing events.

Reducing Overall Energy Consumption

An unexpectedly high monthly bill might result in short-term consternation, and resolutions. But checking the smart meter and realising that the current consumption is high is far more likely to motivate users to switch off some non-essential appliances (or readjust the thermostat on the air-conditioning) right now. Smart meters can thus incentivise the immediate and consistent reduction of electricity consumption.

Incentivising Regular Maintenance

Faulty wiring or outdated appliances can lead to increases in electricity usage. Smart meters can help users detect anomalies and schedule maintenance visits in good time, preventing the consumption of excess electricity.

Incentives to Shift to Energy-Efficient Appliances and Technologies

One of the barriers to adopting energy-efficient appliances is the delay between their higher upfront costs and their eventual payoffs. Smart meters show the user their exact current usage, which they can tally in real-time against the appliances or lightbulb points currently in use. This information could incentivise users to switch to efficient appliances, e.g., replacing fluorescent bulbs with LEDs. By linking appliance efficiency visibly and immediately with the concrete outcome of units being consumed, smart meters can incentivise a switch to energy-efficient appliances.

Solution 6

Nudges to Lower Consumption Via Electricity Bills

Behaviour Change and Public Acceptance

Nudging has become a well-known technique to shift consumer preferences without limiting choice or imposing costly financial dis/incentives. Popular and effective nudges to reduce electricity consumption could include smiley faces indicating consumption compared to other houses in the neighbourhood, or numerical information, perhaps about the household's consumption percentile. Such nudges can appeal to consumers' emotions and competitiveness.

In other developing countries, nudges based on social norms, and on real-time feedback from prepaid smart meters (such as those currently being installed in Panaji), have found success (Sudarmaji & Ambarwati, 2023). Since most of the electricity consumption in Panaji is from commercial and industrial sources, such nudges would ideally be modified to target large consumers.

The monthly bill gives consumers a summary of their monthly consumption, but is neither intended nor able to influence consumption patterns. Furthermore, consumers often struggle to correlate their perception of their own consumption with the data offered by bills (Joshi & Sen, 2021). A bill with a modified format offering both broad consumption-reducing tips and also specific tips tailored to each consumer's consumption patterns via smart meters (which relay real-time consumption information to both consumers and electricity boards), can help educate consumers to moderate their electricity consumption (Bruhl, Smith, & Wisser, 2019).

Currently, electricity bills in Panaji and across India are heavy on numbers, in tiny font sizes which consumers struggle to read. Research suggests that information presented in graphical formats is understood with less cognitive effort, without losing accuracy. Bright colours, clear legends, and fonts in legible sizes simplify information processing. This includes:

Simple Data Representations

Simple data representations included in the electricity bill could help moderate electricity consumption based on data specific to that household's consumption:

A pie chart showing **consumption patterns over the course of the day and week.** Consumers can moderate their consumption during times when they consume more.

A pie chart showing **consumption during peak and off-peak hours** can help consumers shift use of their energy-intensive appliance to off-peak hours.

Bills can Also Offer More Broadly Applicable Tips

Bills can also offer more broadly applicable tips for moderating electricity consumption, such as: unplugging appliances when not in use; switching from incandescent and fluorescent bulbs to LEDs; setting air-conditioners and heating devices to optimal temperatures and settings to reduce energy use; and using other appliances on energy-saving settings. Many of these behaviours require low cognitive effort, but are easy for consumers to overlook – making them excellent candidates for nudges (Karlin, Zinger, & Ford, 2015). For optimal effect, each month's bill should include only one or two tips, written in positive language (using "Do" rather than "Don't"), and in an optimistic tone ("Together we can do better..." vs. "We're all doomed..."), and focussed on specific, concrete actions.

Nudges Based on Descriptive and Prescriptive Norms

Human behaviour is greatly influenced by other members of our social reference groups, i.e., people we look to for ideas about what we can and should be doing. Descriptive norms contain statistical information about what other members of our social reference groups are doing. Prescriptive norms contain information about what other people value. Electricity bills could contain both, i.e., nudges based on:

Descriptive norms: "Last month, you consumed more electricity than 90% of your neighbours. Here are some ways in which you can consume less this month..." "Last month, you consumed less electricity than 50% of residents with a similar income in your city. Here's how you can keep being a power-saving champion..."

Prescriptive norms: "60% of your neighbours believe that we're all responsible for moderating our power consumption. Here's how we can all be power-saving champions..." "85% of people in your city want to reduce their power consumption. Here's how..." Or, appealing to people's desire for internal consistency, i.e., our desire for our different behaviours to be consistent with each other: "Last month, you reduced your consumption by turning off appliances when not in use. This month, let's keep up the good work by committing to upgrading one household appliance with a more efficient one. Contact us for attractive subsidies and buyback-and-exchange programmes!"

Nudges delivered in simple graphical format, power-saving tips, and the use of norms can help make the monthly electricity bill a tool for lowering electricity consumption.

Chapter 4

Mobility

Mobility

Sector Overview

Transportation in Panaji is the single largest contributor to greenhouse gas emissions. In 2013-14, it contributed to 41% of the city's emissions (ICLEI, 2018) and in Goa, it is set to grow from 41% in 2020 to 62% by 2050 (Kamat, 2023). However, there is potential to transform this sector to help Panaji reach net zero by 2050.

A small city with an area of only 8.2 km², much of Panaji's layout is designed as a grid, which is well suited for non-motorised transport. However, about 80,500 private vehicles are registered in Goa every year, with vehicle density at one per person (Refer to Figure 4). Traffic congestion in Panaji puts an overwhelming strain on its roads. The solution is to curb private vehicle ownership and promote low-carbon mobility.

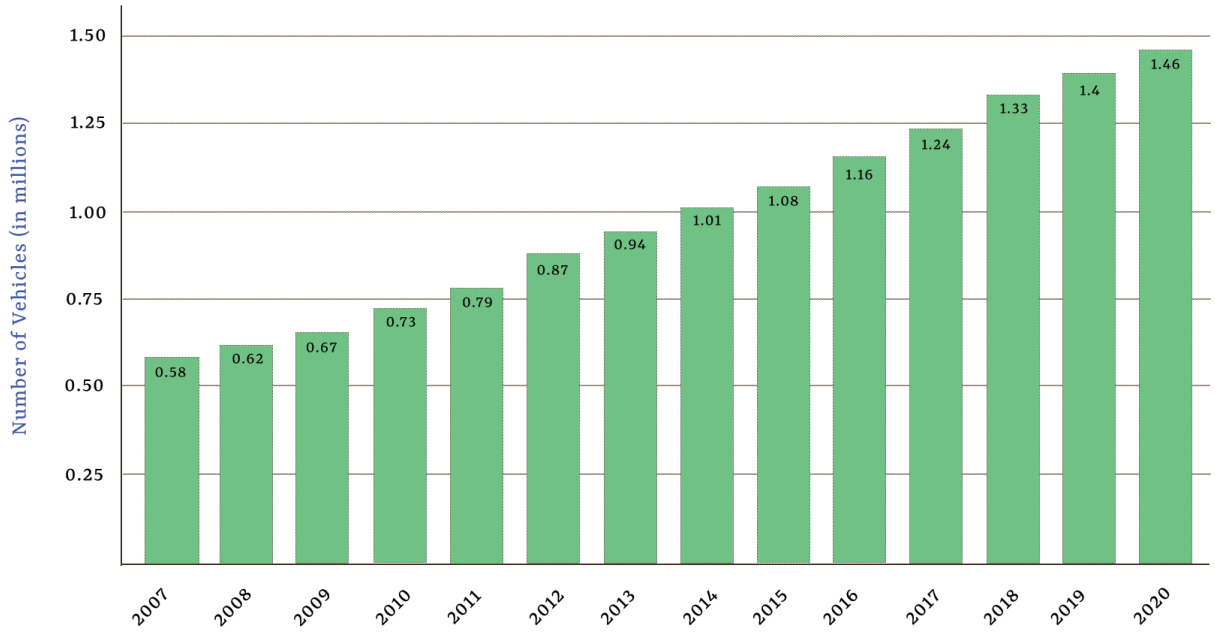


Figure 4: A 150% Surge in Registered Motor Vehicles in Goa from 2007 to 2020 | Source:Statista 2025

Existing Conditions and Key Challenges

The use of low-carbon mobility modes in Panaji is limited. As of 2012-2013, 88% of Panaji's population commutes using a private vehicle. Only 1% of the population use buses and 2% use pilots (ICLEI, 2018) (motorcycle pilots are an organised motorcycle taxi service in Goa) (Desouza, 2017). With poor infrastructure for alternative modes, it will continue to increase. There are several reasons for this.

Non-motorised transportation infrastructure is poorly maintained: 85% of Panaji's streets do not have good quality footpaths; they are not continuous, safe or maintained (Bhandari et al., 2021). Cycling infrastructure also barely exists: there are few safe bike lanes for cyclists. Cycling is primarily a recreational activity; most of those who cycle to work cannot afford other forms of transport.

The city's bus network relies on private actors who choose profitable routes. Infrequent and overcrowded public buses push people to use private cars, thus making congestion and parking worse.

In Goa a car or motorcycle is a status symbol. To shift to public transport, there must be incentives in terms of efficiency and costs, and an appreciation of the environmental benefits. Reducing emissions needs a normative shift.

Private vehicles carrying commuters and tourists travel in and out of Panaji from other cities. Their taxis and rented vehicles add to carbon emissions. Therefore, intra-city transport as well as intercity transport have to improve.

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 Panaji possible.

Existing Policies to Address Mobility Challenges

Panaji has several policies to address mobility challenges, under the following categories: Road and Parking Infrastructure, Electric Vehicle Promotion, Beautification and Pedestrianisation, Inventories and Information Gathering.

Road and Parking Infrastructure Improvement Schemes

The State and local body/city corporation have various schemes to ease congestion, improve roads and parking infrastructure. These include:

The City Mobility Plan (2013) to develop a vision, strategies, and policies for efficient accessibility and mobility of individuals and goods within the city (UMTC, 2018)

The Comprehensive Mobility Plan for the State (2022), a 20-year Low-Carbon Comprehensive Mobility Plan ("CMP") for sustainable regional transport The Parking Master Plan for Panaji city (2022) to manage the existing parking better and increase parking infrastructure (Govt. of Goa, Draft of Goa Electric Mobility Promotion Policy 2021)

The Decongestion Model by Charles Correa Foundation (2013) to organise traffic patterns, improve public transport, introduce parking lots, and create more pedestrian-friendly environments (Charles Correa Foundation, 2018)

The Revised City Development Plan (2015) proposed upgrades in traffic management, road geometry, parking structures, bus stands, streetlights etc.

Electric Vehicle Promotion

Electric Vehicle Promotion is a key strategy to combat high emissions from vehicular traffic in Panaji. The city has invested in e-buses, committed to purchasing only electric vehicles and two-wheeler rentals for tourists from 2024, and will replace diesel pumps with solar pumps by 2030, connecting them to the electric grid by 2050. The city and relevant state authorities have implemented the following policies and schemes:

Goa Electric Mobility Promotion Policy (2021) From 2025, 30% of annual vehicles registered in Goa should be electric. From 2021 till July of 2022, there was a subsidy for up to a maximum of 3,000 electric two-wheelers, 50 three-wheelers, and 300 four-wheelers, capped per electric vehicle at Rs 30,000 for two-wheelers, Rs 60,000 for three-wheelers, and Rs 3 lakh for four-wheelers (Sahil Kukreja, 2022). In 2023, it was proposed that the subsidy for e-vehicles be re-introduced at 30% for two-wheelers, 40% for three wheelers and up to Rs. 3 lakhs for four-wheelers (The Goan EveryDay, 2023). There are also exemptions on road tax (TOI, 2018) and registration fees (Goa Electric Mobility Promotion policy, 2021).

A Metrobus System, and promotion of electric buses under the Smart City Mission and Goa Liberation Fund

The Goa State EV Concessional Charging Infrastructure Policy (2021) was enacted by the Goa Energy Development Agency (GEDA) to promote EV charging infrastructure across the state.

The Solar City Masterplan (2015) proposed off-grid charging stations to charge all EVs.

Beautification and Pedestrianisation Efforts

Infrastructure development to encourage people to walk instead of using vehicles includes adding pavers, designing safer footpaths, improving street drainage, adding clear traffic signage, etc. Beautification measures have included painting murals which can help create more appealing environments for active mobility (Nunno, 2021).

The Smart City (IPSCDL) has implemented the following:

Development of pedestrian spine and revitalisation of the Patto area

Extension of the Mandovi river promenade, pedestrian spine from Miramar beach to ESG building.

Schemes to Improve Grid Infrastructure

The Corporation of the City of Panaji (CCP) has been collecting information on the amount and sources of emissions, as well as the layout of roads and buildings:

- AMRUT GIS-Mapping to geo-tag buildings and all structures in the capital, including bridges, roads, and ecological spaces as a baseline for future land use planning
- Greenhouse Gas Emissions Inventory of 2013-2014 for Panaji City (2015)
- Urban Vulnerability Assessment, Panaji (2013)

These programmes are run primarily by the following organisations: Imagine Panaji Smart City Development Limited (IPSCDL), Corporation of the City of Panaji (CCP), Public Works Department (PWD), Goa Energy Development Agency (GEDA), and the Transport Authority.

Despite these policies and programmes, emissions from the transport sector are growing at a high rate in Panaji. The adoption of low-carbon options has been low because of societal norms and lack of infrastructure. Policies and infrastructure are needed to discourage the use of motorised vehicles.

Solution 1

Electric Buses (E-buses)

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

E-buses can solve mobility challenges like congestion, high use of private vehicles, and access to the city, while also reducing emissions. The Smart City initiative is launching an e-bus system in the city but a multi-pronged approach to ensure its efficacy would entail:

Strategic Route Planning and Optimisation

Panaji's bus routes are concentrated along 2-3 key corridors. Route planning must consider demand and equity, ensuring that the neglected marginalised or urban poor have access to the city. It should also take into account morning and evening rush hours and school schedules. Tiered pricing schemes and passes would make these buses more accessible.

Bus Shelters

Currently, people hail buses from wherever it is convenient as the bus drivers are willing to stop anywhere along the route to maximise the number of passengers they pick up. This makes route schedules inefficient. Buses should stop only at designated bus shelters, many of which are currently poorly maintained and are not used. Bus shelters provide protection from inclement weather and if improved, they would attract people to wait at the designated stops.

Efficient Operations

The current bus service is perceived as inefficient. Therefore e-buses must be reliable, with timed and regular stops.

Customer Service

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

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.

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.

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 Panaji attracts students, office workers and travellers from all over Goa, a reduction in emissions from intercity commuting would prove beneficial. Currently, there is an electric bus service from Panaji bus stand and other areas around Goa to the airport. Tickets need to be booked in advance and their timings often vary (The Economic Times, 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

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

Two wheelers, private cars, tourist vehicles and rented vehicles are responsible for emissions in the transport sector. Moving to electric vehicles could significantly reduce emissions (Moseman & Paltsev, 2022). Goa is already trying to increase the purchase of EVs through the Goa Electric Mobility Promotion Policy 2021.

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

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 and standardised designs for EV chargers across the city and fast chargers should be placed at popular destinations, eg., near markets, tourist destinations like beaches, and business districts like Patto, where people park long enough to recharge their cars. This will also cater to pilot drivers and ensure their upgrade to e-vehicles.

(For more information about energy transitions for electric mobility: see Solution 6 in Chapter 1: Energy.)

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.

Sales Staff Training

A lack of knowledge could make customers hesitant to purchase EVs. To bolster EV sales, the areas of concern – range, charging facilities and times etc. – should be identified and sales staff trained to manage such queries.

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 (like free courses) would upskill automotive workers to handle newer EV batteries, charging equipment and even manufacturing.

Solution 3

Cycles

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

In Panaji, 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 Panaji, biking lanes should be created, especially from hotels to nearby attractions for tourists. Bike racks for parking should be added for those who commute using cycles.

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

Earlier public bike sharing systems in Panaji have had limited capacity and uptake. Making the system more convenient would improve usership. Bike docking stations should be strategically placed between common destinations across the city, and App integration could let people know where they are.

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 Goa 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:** There are a number of benefits to e-cycles that people in Panaji may not be aware of. These include emission mitigation benefits, 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 Rs. 2 per km for a petrol bike. Advertising these factors will be crucial to combatting a lack of public awareness and increasing 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 Panaji 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:** Targeted advertising campaigns and working with the tourism agencies to promote e-cycle tours would cut down the use of conventional vehicles, and mitigate a significant portion of emissions from tourism in Panaji.

Solution 4

Walking

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

Panaji was originally designed for pedestrians, but the roads and pedestrian areas are overrun with motor vehicles. Only 30% of the city has pedestrian infrastructure, which is not maintained properly. 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 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 enough space, 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.

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.

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.

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.

Lighting

Ensuring good visibility for pedestrians in the city increases their safety and their perception of safety. Streetlights can be powered by solar energy – Panaji has already installed many such lights (TOI, 2023).

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).

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

Institutional Innovation

A comprehensive policy for better traffic management and parking infrastructure would alleviate congestion and mitigate emissions in Panaji. Strategically coordinated smart red-light signals and better traffic police training would decrease congestion on the roads, especially in Panaji which attracts many tourists and frequently hosts 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. Panaji has begun such a project in Patto that could be expanded (Team Herald, 2021). Traffic police must be correctly trained 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 like markets could earn Panaji 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 Panaji like the International Film Festival of India and the Serendipity Arts Festival when demand surges. Panaji could employ a dynamic parking solution to help manage parking during these times by providing real time information about parking availability, directing drives to available spaces and thus reducing congestion (Raghuraman et al., 2023). The system could adjust parking fees based on demand to encourage optimal use of spaces as well.

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.

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 Panaji, creating usable LEZs would probably require infrastructure upgrades and street redesigns.

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

Equity and Justice | Institutional Innovation

Panaji's comprehensive mobility plans are not statutory documents and have no legal standing. Panaji must integrate sustainable mobility within statutory planning frameworks to enable net zero transitions.

Land-Use Planning Regulations

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. 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 DCRs and building codes to promote TOD by regulating floor space index and floor area ratios to encourage denser development. 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 Panaji 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

Revisions to Schedule 12 of the 74th Amendment of the Indian Constitution and then State Legislature delineating urban mobility as a city level subject, are urgently needed to empower urban local bodies to implement and finance mobility recommendations in cities. However, this is not a Goa-specific challenge, and applies broadly to cities across the country.

Chapter 5

Waste Management

Waste Management

Sector Overview

In Panaji, as in other Indian cities, there is a growth in the volume of waste generated due to economic growth, increased disposable incomes and growing consumption. This presents a dual challenge: first, the existing waste management infrastructure risks being overwhelmed, leading to reduced efficiency, poor quality output and segregation; second, this mismanagement could exacerbate issues such as pollution, environmental hazards, health risks, and social problems.

Waste is one of the smaller sectoral emitters and contributes to 5.5% of the city's emissions (Refer to Figure 5) (Towards low carbon and resilient pathways, n.d.). The city has been working to resolve waste management challenges over the last 20 years. In 2003, a landslide at the Curca garbage dump, which received all of the city's waste, served as a rude awakening for the State and local government to the need for a holistic, systematic and collective effort to free Panaji from all its waste management woes. The Corporation of the City of Panaji (CCP) sprang into action with The Municipal Commissioner and the Waste Management Officer organising community meetings, cultural programmes with a specific theme and message, integrating schools and colleges as part of the larger awareness campaign and also introducing waste management as a subject for children from primary school onwards.

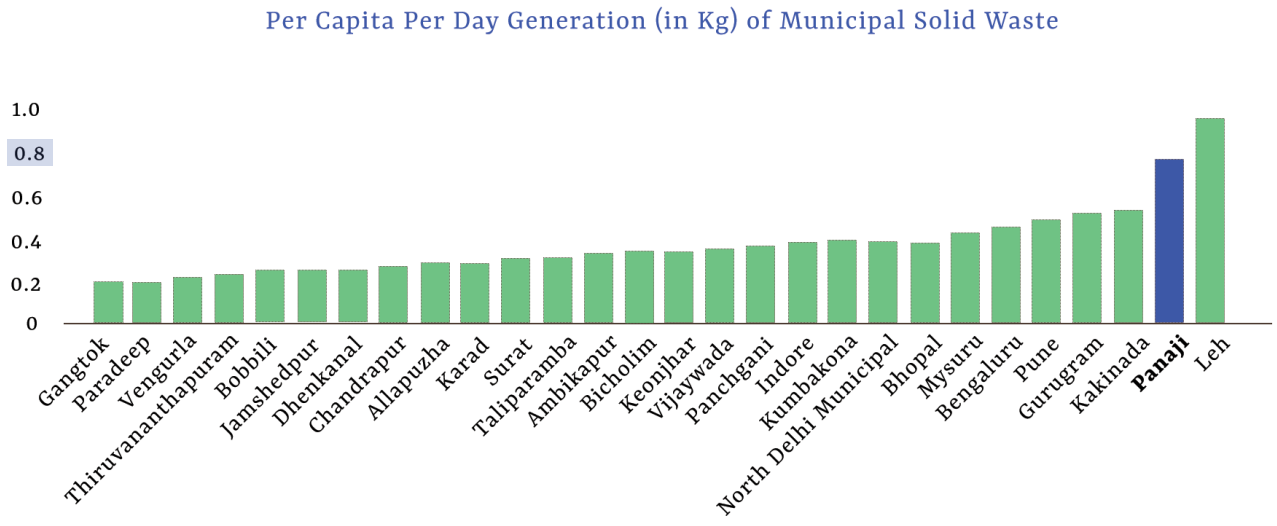


Figure 5: Panaji's Per Capita Waste Generation Far Exceeds the Average for Mid-Sized Cities | Source:Data by ULBs

Existing Conditions and Key Challenges

As per available data, Panaji generates around 43 tonnes of waste per day (TPD) – 17 TPD dry and 26 TPD wet waste (Panaji's innovative model of Solid Waste Management 2023). After segregation, part of the wet waste is composted within the city, while the rest is sent to Saligao for treatment at its bio-methanation plant. Dry waste is sorted and segregated at 3 sorting stations at a Material Recovery Facility (MRF), with the recyclables sent to recyclers, and non-recyclables known as Refuse Derived Fuel (RDF), sent to cement kilns for co-processing. Panaji is therefore a zero-landfill and a bin-free city. A further 8 TPD garden and horticultural waste and 10 TPD Construction and Demolition (C&D) Waste is also generated (CSE and NITI Aayog release 'waste-wise cities').

However, in spite of a host of initiatives by the CCP and projects undertaken by national and international agencies, Panaji still faces a few challenges with management of its solid waste:

The only composting facility, behind the Heera Petrol Pump, is currently catering to more than double its designed capacity of 5 MT. The CCP has incentivized in-house composting through changes in bye-laws (CCP Solid Waste (Amendment) Bye-laws 2021) and incentives to generators (Herald, 2021) to treat their wet waste within their own premises, but it continues to send over 10 MT per day of wet waste to Saligao Waste Treatment Facility for composting. An integrated solid waste treatment facility is planned in neighbouring Bainguinim (Bainguinim Waste Plant: Govt invites bidders once again, 2022), to cater to all of Panaji's Municipal Solid Waste (MSW), but interim measures for wet waste reduction and increased in-situ management are needed.

The management of increasing quantities of dry waste and litter is a challenge, despite the robust systems for dry waste segregation and collection in the city. In order to reduce the load on existing systems more impetus must be given to waste reduction. Panaji attracts hundreds of tourists through the year, leading to a significant increase in dry waste volumes as well as littering, especially at popular areas such as Miramar Beach; clogged drains is one of the many reasons for increased flooding in the city. It is therefore crucial to bring about a behavioural change among residents, businesses and tourists.

Sanitary waste, which includes hygiene products like sanitary napkins and baby or adult diapers contaminated with blood, urine and faeces, is not properly segregated. This waste has for long been disposed of along with wet or dry fractions. Workers involved in waste management, such as waste pickers and ragpickers, face risk of infections and diseases through handling sanitary waste. Households often choose to burn their sanitary waste contributing to GHG emissions in addition to dioxins and furans. Decentralised incineration as a method of disposal is also emission-intensive and must only be undertaken where air pollution control devices are installed. While an agency, Biotic Waste Solutions, has been entrusted with collecting such waste from the MRF at Panaji, the volumes indicate a significant waste quantum still being mixed with other streams or disposed of through other means.

C&D waste consists of building materials, debris and rubble from construction, re-modelling, repair and demolition of any civil structure. In India, when old buildings are demolished the major demolition waste includes soil, sand and gravel for bricks (26%) masonry (32%), concrete (28%), metal (6%), wood (3%), and others (5%) (Utilisation of recycled produce of Construction & ..., n.d.). Bricks, tiles, wood and iron/metal are sold for reuse/recycling. At present, with no recycling facility, most of the C&D waste from Panaji is disposed of along national highways, low-lying areas and abandoned stone quarries. If construction waste is not treated it has a significant negative effect on the environment, ultimately leading to severe air pollution with increased concentrations of particulate matter and aerosols.

Existing Policies And Efforts To Address Waste Management Challenges

Despite these challenges, the city has been quite successful in waste management, through the coordinated efforts of a range of stakeholders including government entities, private sector and NGOs, along with strong community participation and a variety of policies put in place.

Infrastructure and Service Delivery Initiatives

Door-to-Door Collection

CCP is responsible for formulation of policies around waste and providing door-to-door collection services on a daily basis.

Investment in Developing a 10 TPD MRF

Panaji's 10 TPD MRF was part of a nationwide project by the United Nations Development Programme (UNDP) aimed at strengthening sustainable waste management practices in India. UNDP funded the technology and infrastructure at the facility, such as the conveyor belts and baling machines as well as operation costs and awareness creation activities, for a specific time. The MRF operations are currently funded by HDFC Foundation through gap funding of a private entity, Feedback Foundation, in charge of operation and maintenance at the MRF. All non-recyclable waste or refuse derived fuel (RDF) is transported to cement kilns in the neighbouring Belagavi District of Karnataka for co-processing by the GWMC (Panaji's innovative model of Solid Waste Management 2023).

Creation of a Waste Sorting and Procurement Centre

Ayya Waste Management (Ayya - Cleanse up) was tasked with the setting up of a waste sorting and procurement centre which allows citizens to sell various fractions of segregated waste. Dry waste collected from certain areas is also segregated by the firm. Various NGOs have been part of awareness creation in Panaji.

Behaviour Change

Awareness Campaigns

NAMA (Nationally Appropriate Mitigation Action), a waste management initiative by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and The Energy Resources Institute (TERI) is also helping to demonstrate better waste management practices with the objective of spreading awareness among citizens and reducing GHG emissions from the waste sector (GIZ-Teri to help Panjim reduce GHG emissions through Municipal Waste Management).

Institutional Arrangements

Innovation in 16-way Segregation

Panaji has received multiple accolades for its initiatives in waste management such as the 16-way source segregation model mandated for all bulk waste generators, including housing societies, since October 2020. The 16-way segregation model is efficient, improves quality of recyclables, requires minimal manual or mechanical sorting, and reduces the burden on the environment by minimising RDF generation. This is a first of its kind in India and the fact that around 8 fractions of waste are purchased by authorised agencies within the city only adds to the efficiency and sustainability of the model. As per available information, around 40 of the 84 housing societies identified as bulk waste generators (BWG's), have implemented the system, through which over 200 MT of waste has been handled (Panaji's innovative model of Solid Waste Management 2023).

Wealth from Waste and Shop with Your Waste Campaigns

Other initiatives include Panaji's Wealth from Waste campaign where people are remunerated for dropping off various fractions of recyclable waste at a predetermined rate per kg. A Shop with Your Waste Campaign (Two more stores join CCP's 'shop-with-your-waste' plan) was also initiated by the Corporation, which essentially allowed locals to barter their recyclable waste for groceries at select shops. This was carried out by assigning a value/kg to various categories of recyclables which were then purchased from the retailer at a marginally higher cost. An added advantage to the retailer was improved sales and recognition from people participating in the campaign.

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

Solution 1

Wet Waste Management

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

The almost 30 MT of wet waste generated in Panaji is only bound to increase in the coming years owing to increasing population and the flourishing food and restaurant businesses in the city (Mini treatment plant at Panaji in 10 days to handle wet waste, 2019). This poses a range of challenges for the city authorities including having adequate space and infrastructure to be able to treat such waste and a robust collection system that not only covers the entire CCP jurisdiction but also addresses issues of hygiene, smell and leachate generation while doing so. In addition, if this waste is not properly segregated, it can disrupt the composting process and add to the quantum of waste required to be landfilled. To effectively address these issues, there is a need to reduce quantums of wet waste generated in the city while simultaneously incentivising decentralised treatment and setting up a robust collection and treatment system for its management:

Centralised Wet Waste Management

Most ULBs including the city of Panaji still practise windrow composting, which is the piling of biodegradable waste in rows, which are generally turned to improve porosity and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile. Improved technologies such as biomethanation are now gaining popularity as minimal manual intervention is required. It is also far more sustainable as along with generating compost, biogas can be used to generate electricity while significantly reducing airborne GHG emissions. The leachate generated from the process can be treated and reused within the site. The existing composting site or suitable land around the city could be identified for setting up of a biomethanation unit.

Mandating In-Situ Composting by BWGs

The Model Municipal Solid Waste (Management and Handling) Bye-laws, 2020 encourage BWG's to treat their waste in-situ. 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. A positive behavioural change among residents is crucial to efficiently implement these measures. Incentives could be designed for residents treating their own wet waste, and avenues for sale of resultant compost explored. To create behavioural change, training workshops and demonstrations could be conducted at Resident Welfare Associations (RWAs) and BWGs.

Composting at Household Level

Panaji is a high-density city with a significant number of multi-dwelling units where individual composting may pose a challenge. The Khamba Composter (Khamba composter: 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 etc. A No Wet Waste Generation Day could also trigger positive behavioural change.

Improved Management of Leaf Litter

Leaf litter can be a nuisance in areas with large gardens or open areas. It is typically collected and burnt, but it could also be used as a mulch or disposed of in overflowing pits within the premises. Institutions and residential societies that do not have an in-house wet waste management system could use cost-effective leaf composters. The practice of mulching should be promoted to reduce water use and improve soil fertility. A no-burning policy should be imposed in the city with App-based monitoring systems to document open burning of such waste.

Engagement with Educational Institutes

To create awareness and initiate behavioural change, an effective way to start is through schools and colleges. Campaigns, competitions and workshops on how to reduce wet waste generation, composting methods and living more sustainable lifestyles should be periodically conducted at educational institutions.

Solution 2

Reduction and Improved Management of Dry Waste

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

As per records from the Goa Waste Management Corporation (GWMC), the Material Recovery Facility (MRF) in Panaji sends around 200 MT per month of refuse derived fuel (RDF) for co-processing to Belagavi District in Karnataka. (Natekar, 2024). While this system reduces the need for open burning and landfilling, it is still extremely emission-intensive owing to interstate transportation as well as release of flue gases from the incineration process. Recent studies in all of Goa's rivers and water distribution network have indicated the presence of microplastics which poses a serious health risk to residents. Therefore, there is a need to reduce generation of such waste, improve collection and treatment systems, and use more sustainable packaging material for consumer goods through the following:

Policy Measures for Waste Reduction

The Goa MSW Policy suggests phasing out certain kinds of packaging materials, including small PET bottles, milk pouches, consumable sachets etc (Revised - SWM Policy for Goa, 2024). A more proactive approach is required to create awareness on better management, identification of suitable alternatives and stricter implementation of local bye-laws.

CSR Funds for iInfrastructure Set Up and Operations

CSR has proven to be a very effective tool for setting up of waste collection and treatment infrastructure, as well as creating awareness. In order to get clarity and spark the interest of possible funders, varied decks clearly identifying the problem areas with the details of expected interventions and its benefits must be created.

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, and a pro-recycler regulation do not allow the desired impact on stray and low/negative value plastics. EPR could effectively help to set up improved collection systems, fund increased workforce for waste sorting, positively influence consumer actions and undertake clean-up drives to reduce generation and improve channelisation of stray plastic into formal waste management systems.

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, RFID to assess the extent of collection,

QR codes to analyse the extent of segregation, D2D collection coverage, CCTV networks to identify blackspots, sensor bins at high tourist footfall locations, etc., can be initiated and developed in a phased manner throughout Panaji. 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 be explored.

Waste Reduction Campaigns

So far, the impetus has been on source segregation and recycling. Little attention has been paid to reducing the quantum of waste, understanding types of waste in terms of recyclability, value, ease of handling or disposal processes. Campaigns could help raise awareness and bring about behavioural change among residents through more sustainable consumer choices.

Promotion of Greener/Biodegradable Alternatives

There are various alternatives to conventional plastic cutlery and packaging. Mandating use of such green products by street vendors, food hawkers, institutions and businesses within the city, promoting entrepreneurs of green products, incentivising their use and improving availability are crucial to wider use and acceptance of biodegradable products. The government could introduce guidelines for the adoption of eco-labelling standards for product packaging of consumables.

Incentivising Improved Waste Management

Campaigns such as waste bartering, setting up of waste procurement points, exchange offers, recognition of good/sustainable practices, plastic taxes 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.

Integration of Informal Sector Players

To improve accountability and traceability of waste, guidelines must be established for registration and/or formalisation of all levels of the informal sector (waste pickers, scrap dealers, aggregators etc.). As part of the formalisation, strict guidelines must also be formulated on design, amenities, hygiene and occupational safety in informal working areas. Informal sector collectors and aggregators should be sensitised on safe disposal of non-recyclable and hazardous substances. The CCP should undertake drives to register informal workers to make them eligible for existing government schemes.

Improved Awareness and Behavioural Practices by Tourists

To improve accountability and traceability of waste, guidelines must be established for registration and/or formalisation of all levels of the informal sector (waste pickers, scrap dealers, aggregators etc.). As part of the formalisation, strict guidelines must also be formulated on design, amenities, hygiene and occupational safety in informal working areas. Informal sector collectors and aggregators should be sensitised on safe disposal of non-recyclable and hazardous substances. The CCP should undertake drives to register informal workers to make them eligible for existing government schemes.

Solution 3

Sanitary Waste Management

Behaviour Change and Public Acceptance | Institutional Innovation

Disposable sanitary pads and diapers are predominantly made of non-biodegradable materials like plastic which take hundreds of years to decompose . Menstrual hygiene management and the proper disposal of sanitary napkins are not widely understood or discussed in many parts of India. Lack of awareness and education about sustainable alternatives and proper disposal methods contribute to the problem. Therefore, an improved system of collection and awareness on sustainable substitutes and menstrual hygiene must be integrated into the system:

Standardised Management Guidelines

A mechanism for segregation, collection and disposal of sanitary waste is essential. While large residential societies are mandated to undertake a 16-way segregation of MSW, small establishments continue to find disposal of sanitary waste a challenge. Current guidelines are varied. Clear and streamlined guidelines must be developed for disposal means, mode and frequency of collection, means of storage and handover, setting up of collection points, colour category etc. They must be based on ground interaction and assessment of universal best practices.

Proper Disposal and Treatment of Sanitary Waste

While collection of sanitary waste may be streamlined, its disposal is challenging owing to its infectious nature and because more than 60% is plastic (Borunda, 2019). Burning and landfilling must be discouraged. The MSW Rules allow for disposal of such wastes at Common Biomedical Waste Treatment Facilities (CBWTFs). Just over 2 MT of sanitary waste is disposed of monthly through Biotic Waste Solutions, indicating a need to strengthen the segregation and collection system. The treatment cost is 18/kg in the State. Budgetary and fund allocation for which provisions are made well in advance, are critical for successful disposal.

Small Decentralised Incinerators

Controlled decentralised incineration of soiled sanitary pads is used quite extensively in the country. It destroys the pathogens and pad material, and helps in overall sanitary waste management, as without it such wastes either get mixed with MSW or landfilled. However, these incinerators often perform poorly, are energy-intensive to operate, generate toxic fumes from burning plastics (e.g., furans and dioxins) and require high maintenance (Small-scale incinerators for sanitary pad disposal are not a good idea, n.d.). Therefore, they must only be used in the absence of a centralised incineration option.

EPR

While EPR guidelines for manufacturers of sanitary napkins and diapers are slightly ambiguous regarding responsibility and which authority is to collect them, there is an urgent need for manufacturers to pool funds for improved management. These funds could be used to set up improved collection systems and compensate for the high cost of disposal of waste.

Promotion of Greener Alternatives

While greener alternatives to sanitary pads and diapers have long existed, they have not had the desired impact possibly due to poor effectiveness, challenges with availability, convenience and ease of disposal, societal stigmas or mere lack of awareness of such products. Examples include the menstrual cup or the 'she cup' and reusable cotton diapers which are cost effective and are more comfortable. Biodegradable sanitary pads are also available as a substitute to conventional ones.

Solution 4

Construction and Demolition Waste Management

Public Participation and Trust | Institutional Innovation

The construction sector is the major emitter of greenhouse gases. Since 2018-19 the State has intended to construct a C&D Plant to deal with construction debris, but there has been little progress on that front (Proposed construction & demolition waste management facility, n.d.). A C&D Plant grinds and then grades construction debris to produce aggregates of varying dimensions, and sand which can be reused in the construction industry or converted into blocks. Shortage of landfill sites and non-availability of materials such as aggregates, create a need for incorporation of reduce, reuse, recycle, recovery in the Indian construction sector. This can be done through:

Identify C&D Waste Disposal/Recycling Sites

One primary role of the CCP is to identify suitable sites within their jurisdiction where C&D waste may be collected for further disposal or recycling. A lack of clarity on disposal locations can lead to haphazard dumping. In the absence of recycling facilities, such waste may be sustainably disposed of in old laterite quarries. A mechanism may also be set up where building contractors who need C&D waste for backfilling or levelling may approach the CCP, who will in turn direct generators to transport the waste directly to such locations, thereby reducing the need for further processing and transportation.

Licensing for C&D Transportation Providers

Local authorities should be responsible for arranging the collection and transportation of C&D waste, either on their own, or through authorised agencies. Interested service providers must register with the CCP for transporting such waste and report to the corporation on the daily trips, waste quantum and location of disposal, which allows transparency and traceability. Based on waste quantum, a minimum fee may be imposed on the owner up to a specified distance, after which additional charges may apply. If a recycling facility is available, landfilling charges must be sufficiently high to dissuade service providers from using that option.

Enlist and Define Specifications/Standards for Recycled C&D Waste Products

Contractors are often reluctant to use recycled products (M T Saju, 2020) for construction due to concerns about the strength, durability and lack of standards for quality control. Therefore, the relevant regulations and bye-laws for civil construction would have to be changed so that the recycled C&D material can be used legitimately.

Norms for Renovation Projects

The CCP should set standards and recommendations for deconstruction and waste material to ensure

maximum reuse instead of breaking everything to rubble, which is the current standard. The contractor should submit a detailed and safe deconstruction/ demolition plan for vetting. The list of reuse and salvage materials could include appliances, bathroom fixtures, bricks, blocks, masonry stone, structural steel, cabinets, carpeting, ceiling tiles, timber and timber-based boards, door and window frames and shutters, flooring tiles, stone tiles/platforms, insulation, landscaping materials, lighting fixtures, metal framing including for partitions and ceiling, panelling, pipes, antique mouldings, accessories and hardware of furniture, PVC water tanks, roofing sheets used for garages, outdoor areas, fabric of tensile structures etc. A set of guidelines detailing technologies, techniques and material better suited to deconstruction could also be developed to reduce C&D waste for both new and renovation projects.

Mandating use of Recycled Construction Waste

In municipal and government contracts, the use of materials made from construction and demolition waste should be made mandatory, to a certain percentage (say 10-20%), subject to strict quality control. The standard for coarse and fine aggregates for use in concrete was revised in January 2016 (Indian concrete institute, 2016), permitting use of recycled aggregates up to 25% in plain concrete, 20% in reinforced concrete of M-25 or lower grade and up to 100% in lean concretes of grade less than M-15. Code of practices/standards for using recycled materials and products of C&D waste could also be prepared for use in the sub-base layer of road works.

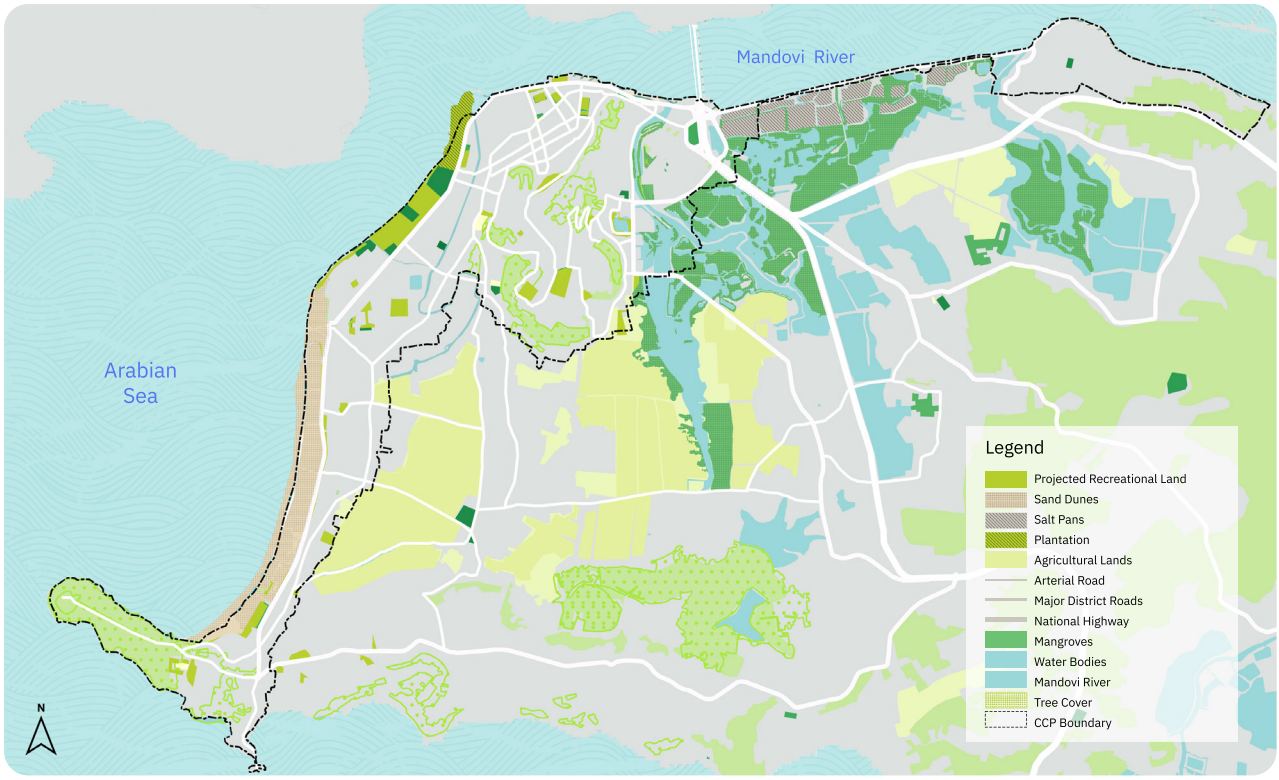
Chapter 6

Nature-Based Solutions

Nature-Based Solutions

Sector Overview

Panaji is situated in a complex water ecology, located at the mouth of the Mandovi river, which opens into the Arabian Sea. Since the 1800s, reclaiming, levelling and draining of the diverse ecology have transformed the once permeable landscape into a city designed for modern habitation. Today, mounting pressures of urbanisation have led to indiscriminate development and encroachment on the already fragile urban ecology of the city, adversely affecting the city's sand dunes, mangrove areas, freshwater ponds and unique low-lying agricultural ecosystems (the Khazan lands) [see Map 2].



Map 2: Panaji's Ecological Assets

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).

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 Solution has contributed to a larger discourse on ecosystem restoration for climate change adaptation and mitigation. However, the role of nature in cities like Panaji, 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.

Existing Conditions and Key Challenges

Estimations by the Ministry of Housing and Urban Affairs suggest that Goa's urban population will grow by 62% between 2011 and 2036 (Census of India, 2011). Rapid urbanisation in Panaji has led to urban sprawl, as the city has expanded into neighbouring villages such as Taleigao, Merces, Santa Cruz and Chimbel. Nature in the city is being encroached upon, limiting its ability to serve as a buffer to climate risks.
The State Development Control Regulations (DCRs) and the city's Master Plan often ignore local geography, terrain, and ecology, leading to unaddressed and worsening ecological challenges in the city:

Panaji's drainage network has not been extended to keep up with the city's growth, resulting in development that obstructs natural water flows and encroaches on water bodies, leading to more urban flooding (Lobo & Bhandari, 2021).

Unchecked urban expansion and increasing impervious cover in soak spaces such as freshwater ponds, creeks and green spaces in Panaji reduce the recharge capacity of the aquifer (Choudri & Chachadi, n.d.; Lobo & Bhandari, 2021). The resultant low water table levels and salinity intrusion, combined with untreated effluent and waste discharge, contaminate water supplies, reducing potable water availability.

The city's sand dunes have been flattened, exacerbating the city's risk to coastal erosion (Mascarenhas, 2009), which increases infrastructural costs, jeopardises the real estate market, and impacts the local economy and livelihoods dependent on natural resources, such as fishing communities.

Panaji is facing the challenge of mitigating the damage caused by frequent and severe cyclones in the Arabian Sea (Lobo & Bhandari, 2021; Vidya et al., 2023). The city could implement form-based zoning codes, along with water-sensitive urban design, and contextual building codes prohibiting new development in low-lying areas and near the shoreline.

Existing Policies on Environment

The Department of Environment and Climate Change in Goa must utilise existing laws and implement sound environmental management practices to preserve the abundant biodiversity in the state. Existing policies to restore urban nature include:

Climate Adaptation and Mitigation

The Goa State Action Plan on Climate Change 2023 has identified sector-specific issues and suggested adaptation strategies, including:

Revise regional land use planning maps of the most vulnerable ecosystems, taking into account climatic factors;

Relocate/compensate and identify new means or alternate skills for the owners of Khazan lands as the likelihood of submergence due to climate change increases, and;

Identify and explore natural mechanisms, such as increased mangroves or sea walls, to protect against rising sea levels in habitat management.

Protection of Natural Resources

The Coastal Zone Management Plan (CZMP) 2019 is being prepared according to The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India's Coastal Regulation Zone (CRZ) Notification, 2011. It identifies several ecologically valuable areas:

Coastal Regulation Zones CRZ I and II forbid construction in sensitive areas along water bodies such as the Mandovi River and Ourem Creek;

Mangroves are under CRZ I and are allocated an additional buffer of 50 metres (National Centre for Sustainable Coastal Management, 2022);

The Salt Pans around the Ponte de Linhares Causeway, alongside the Mandovi River, are also restricted under CRZ I with a 50-metre Mangrove Buffer.

The Khazan Lands Management Plan is being prepared by the Committee for Preparation of Khazan Land Management Plan. It aims to identify land ownership and the role of tenants' associations, promote new methods for bund construction, provide training and technology demonstrations for different crop cultivation techniques, identify mangroves falling within the Khazan zones, and regulate fishing in and around Khazans by restricting it to areas where agriculture is not possible at all (Committee for Preparation of Khazan Land Management Plan, Government of Goa, 2023).

The Plan for Management of Mangroves (PMM) will manage, control, and develop mangroves along the coast of Goa (Committee for the Preparation of Management Plan for Mangroves, Government of Goa, 2023). It recommends actions to conserve and protect mangroves, including expanding the total area, restoring degraded cover, legislation to prevent damage, promoting non-intrusive ecotourism, identifying and promoting protected marine areas, exploring apiculture, promoting research, and forming a committee for sustainable conservation. The PMM aims to ensure the sustainable development and management of Goa's mangroves while boosting livelihood opportunities of coastal communities.

The River Rejuvenation Action Plan for Mandovi River (River Rejuvenation Committee, 2019) suggests implementing source control for industrial pollution and sewage treatment, regulating activity in flood zones, managing different types of waste, periodic quality assessment of groundwater extraction, and developing greenery along the riverbanks.

Master Plan of Panaji:
The Panaji Development Plan, 2021 marks out existing agricultural fields, green spaces as well as water bodies in and around the city. However, the generic representation of similar categories does not differentiate between green cover (e.g., buffer zones and recreational parks), which may undermine their value. Such challenges are expected to be addressed in the currently ongoing plan for 2031 led by IPSDCL, where more granular data using high resolution satellite imagery and GIS-based zoning will highlight nuances of different assets, and if used effectively, serve as a tool for conservation and vigilant land use monitoring. Plans should consider communities such as those living in low-lying areas, that are particularly vulnerable to effects of climate change.

Livelihoods

The Comprehensive Plan for Fisherman Community living in CRZ Areas is being prepared by the Committee for the Preparation of Draft Comprehensive Plan for Fisherman Community living in CRZ areas. It focuses on sustainable development, livelihood security, and environmental preservation. The committee recommends reserving beach areas for fishing activities, identifying housing needs for fishing communities, and establishing local fishing and sanitary facilities.

Solution 1

Khazan Restoration

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

Indigenous to Goa, the Khazan lands are low-lying estuarine wetlands reclaimed from mangroves over centuries with an intricate system of embankments or bunds, canals, sluice gates to regulate salinity and tides and function as community managed, integrated agro-fishery-salt pan ecosystems (Sharma, 2016). Productive use of these lands is marked by seasonality, where main practices include cultivation of salt-tolerant paddy, rearing of fish and shellfish, and production of salt. Spanning across Taleigao, Santa Cruz and Merces, the Khazans cover almost 2.37 km^2, of which, approximately 1.54 km^2 falls under the jurisdiction of the Corporation of the City of Panaji (CCP) and Taleigao planning area[2]

Since paddy cultivation is the predominant practice, the carbon content of these lands is around 1.525^{-9} kg/m^2 (IPCC, 2006) (Panwar et al., 2022), contributing to their potential to sequester carbon. The carbon sequestration potential of Khazan Lands within the CCP boundary is estimated to be 0.00235 kg^3. From the perspective of negative emissions, the potential of Khazan Lands for achieving the net zero target must be considered.

Khazans of Goa. Source: Jason Taylor

The Khazan lands were once lush mangrove areas that became fallow, but are now used for farming and fishing. For centuries, local communities have built bunds to keep saltwater out of the fields. However, the poor management of the bunds results in frequent breaches, which destroy the land's farming potential. As the city expands, significant portions of Khazan lands surrounding Panaji, such as St. Cruz and Calapor-Merces, are increasingly used for real estate development, landfilling and encroachment (e.g., Merces scrapyard). Infrastructure projects cut through Khazans, causing fragmentation, bottlenecks and disruptions in the existing drainage networks.

Many land parcels around Panaji, in Tiswadi taluka, are owned privately, potentially limiting the scope of intervention. The Committee for Preparation of Khazan Land Management Plan has recommended the establishment of an Agency for Planning and Management of Estuarine and Khazan Area. This suggestion was also made by an Agricultural Land Development Panel appointed by the government in 1992. However, no action has been taken. Restoration activities include:

Integrated Water and Salinity Management

The salinity and tidal patterns in the Khazan lands rely on bunds, which are currently mismanaged. The balance between freshwater and saline water dictates the Khazans' existence (Kamat, 2004). Too much salt makes the land unsuitable for agriculture, while excess freshwater leads to weed proliferation. Precise salinity management is needed for uninterrupted economic operation. Proper use of bunds, embankments, and sluice gates can help regulate water levels and tidal influence, enhance agricultural productivity, protect against soil degradation, and preserve biodiversity in the wetland. Many present-day farmers lack a clear understanding of Khazan farming practices (Iyer, 2014). Private owners and local land associations (comunidades) – the primary stakeholders – facilitated by the City Corporation of Panaji in collaboration with CSOs, should focus on Khazan restoration and management by repairing any damage to the bunds, rethinking their usage, and promoting knowledge-sharing among residents.

In a joint effort by the Goa state government, the National Bank for Agriculture and Rural Development (NABARD), Indian Council of Agricultural Research (ICAR), and Central Coastal Agricultural Research Institute (CCARI), a pilot project focused on the rejuvenation of Khazan lands is currently ongoing in Merces. If successful, it could be scaled in Panaji to secure these lands and livelihoods. Additionally, ICLEI-Local Governments for Sustainability, and South Asia and Azim Premji University are preparing a local strategy and action plan for Khazans and integrating them with mainstream urban planning.

Reviving and scaling the cultivation of salt-tolerant paddy is important for Khazan communities as well as the agro-economy of Goa. This requires policy and market-level interventions to create consumer demand and improve value chains.

Current policies promote the costly and environmentally unsustainable use of concrete in bunds. Local materials should be used.

Co-designing and Collaborative Decision-Making

Restoration of fallow Khazan requires the collaboration of diverse stakeholders, such as local communities, government agencies, NGOs, urban planners, ecologists, and researchers. Communities

should be involved in discussions, planning and decision-making to understand the current status and challenges faced in maintaining Khazan lands, shift in livelihoods, and scope of intervention in a changing socio-economic and political context. Awareness campaigns, exhibitions, walks, and community gatherings can foster a robust exchange of local knowledge and practices across generations. This is crucial to safeguard traditional practices from being lost as individuals migrate from Goa to other regions and new settlers arrive, altering the population dynamics. Co-designed projects prioritise equity, innovation, and consensus-building, and co-benefits such as improved livelihoods, enhanced ecosystem services, and strengthened resilience.

Stakeholders must collaborate to monitor progress, share knowledge, and adapt strategies, to ensure that the restoration efforts benefit everyone involved –the local community, the environment, and future generations –by establishing a community-based platform to train farmers and support the maintenance of the Khazan restoration system. This work aligns with the visions and goals of the work under the State's Coastal Zone Management Plan.

Aquaculture Integration

Integrating fish farming with rice cultivation is important for restoring Khazan areas. This mutually beneficial relationship has many advantages, such as enhanced nutrient cycling, superior water quality, and greater productivity. The natural fertilisation provided by fish excreta significantly reduces the need for external inputs in rice fields while serving as a habitat and nutrient source for fish (Liu et al., 2021). This sustainable practice generates diversified income sources, contributes to ecosystem health and promotes resilient land use in Khazan areas. The City Corporation of Panaji, in collaboration with NGOs working on environmental, agricultural, and community initiatives, could develop awareness campaigns, and have discussions with the farming and fishing communities

Urban Farming

Khazan restoration can blend urban farming practices with ecosystem rehabilitation and livelihood enhancement. Community-led Khazan agroecosystems combine traditional farming techniques with modern urban agriculture methods, emphasising community participation in decision-making and land management. These agroecosystems are designed based on sustainable principles, promoting biodiversity, soil health, and ecosystem resilience (TERI Web Desk, 2018). Training on sustainable farming practices and entrepreneurship, fostering socio-economic integration and building food system resilience would build capacity. Communities can cultivate various crops, medicinal plants, and ornamentals using different techniques, maximising land use efficiency and productivity. These income-generating activities would diversify their livelihoods. Diverse actors – The City Corporation of Panaji and the Committee for Preparation of Khazan Land Management Plan – can collaborate with civil society/non-governmental organisations to generate awareness on urban farming practices.

In accordance with district-level agroforestry suitability index in areas identified as wastelands in Goa, certain areas could be prioritised for agroforestry practices (NITI Aayog, 2024). To boost productivity and generate additional income, pilot regeneration activities of cultivating salt-tolerant paddy varieties while growing vegetables and herbs on bunds using mixed cropping methods, could be carried out in agricultural lands including Khazans, in collaboration with farmers' clubs such as in Taleigaon, Merces.

Land Use and Zoning Regulations

Successful restoration of Khazans needs land use planning. It balances conservation, development, and community needs, guaranteeing minimal conflicts by identifying conservation priorities, mapping ecological sensitivity, and developing conservation, agricultural, aquaculture, urban development, and ecotourism zoning ordinances. This safeguards habitats, promotes sustainable farming, diversifies livelihoods, manages population growth, and encourages responsible tourism. These regulations promote long-term ecological health, and the involvement of local communities in participatory planning processes fosters a sense of ownership and social cohesion, while an adaptive management approach ensures long-term sustainability.

Solution 2

Mangroves

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

Mangroves are a diverse group of trees and shrubs that have successfully adapted to thrive in the intertidal areas of coastal and estuarine ecosystems. They are not wastelands or swamps; mangroves are ecologically rich and support diverse flora and fauna, including migratory birds, and serve as vital nurseries for a wide variety of marine species.

Mangroves cover almost 1.82 km2 across Taleigao, Santa Cruz and Merces, of which approximately 0.23 km2 falls under the jurisdiction of the Corporation of the City of Panaji (CCP) and Taleigao planning area[4].

With an estimated biomass of 11.71 kg/m² (Harishma et al., 2020) and conversion factor of 0.5 (IPCC, 2006), the carbon content of the mangroves within the project area is 5.855 kg/m². Thus, the carbon sequestration potential of mangroves is estimated to be close to 1.3 million kg[5], underscoring their importance as a carbon sink, supporting India's NDCs and net zero targets.

Mangroves thrive at or above the average sea level, often in areas partially or completely submerged during high tides. In Panaji, mangroves are found primarily in the Calapor-Ourem Creek, in smaller areas along the St. Inez Creek, and in Poiem's brackish waterways, which play an integral role in Goa's Khazan ecosystem. Mangroves provide a plethora of ecosystem services including water purification, and soil erosion control, and play a vital role in protecting communities and infrastructure from extreme weather events.

Under the AMRUT Smart City Mission, the Imagine Panaji Smart City Development Ltd (IPSCDL) conceptualised and built the second Mangrove Boardwalk in the country, in Patto overlooking Ourem Creek and spreading over 1,100 square metres. It is a tourist attraction, which provides an opportunity for recreation, while generating local awareness about mangroves with informational boards about the flora and fauna. However, it requires constant maintenance to serve as a nature education tool in the city.

Conservation of mangroves faces significant challenges, including insufficient awareness, weak governance, and inadequate law enforcement, leaving them unprotected. The unplanned construction of tourist resorts, ports, and urbanisation, in coastal areas causes encroachment and fragmentation of mangrove ecosystems, making them more susceptible to erosion and pollution. Restoration of mangroves includes:

Water Quality Improvement

To enhance mangrove health, productivity, and resilience, measures to reduce pollution and sedimentation in coastal waters such as wastewater treatment, erosion control, and land use planning are crucial. Regulating activities in and around the coastal zone can prevent pollution and sedimentation in the first place. Treating wastewater prior to its release into the ocean, can remove harmful pollutants, and planting vegetation, constructing retaining walls, and creating artificial reefs to trap sediment before it enters the mangrove ecosystem can help protect mangroves. CCP, The Water and Resources Department and CZMP must collaborate to ensure water treatment and regulation of activities across the CRZ.

Coastal Management

To protect mangroves the State Forest Dept has notified the entire Goan coast as North and South Goa marine ranges and the Goa Coastal Zone Management Authority has recommended classification of mangroves as CRZ IA category, for protection beyond the CRZ or within the Khazan ecosystem.

Mangrove restoration integrated with broader coastal management strategies and climate change adaptation would mitigate the impacts of climate change on mangrove ecosystems and promote their conservation and restoration, allowing for biodiversity benefits as well.

In the context of climate resilience, mangrove ecosystems have high blue carbon sequestration potential and their restoration should be prioritised for dual benefits of adaptation and mitigation in riverside or estuarine landscapes. Involving communities such as Khazan land owners in collaborative mangrove restoration efforts could reduce labour cost, strengthen government-community relations and maximise opportunities for benefit sharing, such as through the emerging national schemes on carbon markets and green credits. There are also opportunities to leverage microfinance instruments, where coastal microbusinesses receive microloans for participating in all mangrove-related initiatives (Systemiq, 2023).

Marine macroalgae also constitute an important blue carbon sink, and regenerative farming of macroalgae (such as seaweed) as a natural climate solution can increase potential of carbon capture (Zhong et al., 2023). The scope of farming seaweed and other macroalgae could be explored in the Mandovi river basin and along the Miramar beach of Panaji (Goa State Biodiversity Board, 2019; Palanisamy & Yadav, 2022) for economic potential and climate adaptation benefits for coastal communities.

Community Engagement and Livelihoods

Involving local communities in planting, managing, monitoring and restoring the mangroves builds capacity, develops a sense of stewardship and ownership, and supports livelihoods. The community becomes more invested in mangrove conservation, identifying and addressing potential issues or challenges, resulting in more effective and efficient management and ensuring their long-term sustainability. Restoration promotes diversification, which fosters sustainable development, strengthens resilience, and empowers communities to secure a better future for themselves. Mangroves offer numerous benefits – enhancing fishery habitats, promoting eco-tourism, serving as sustainable sources of wood and non-timber products, such as foliage, fruits (e.g., mangrove apple) and flowers, and protecting communities and infrastructure from natural hazards. The CCP can collaborate with civil society, non-governmental organisations, schools and other community centres to hold awareness campaigns and walks to highlight the co-benefits and conservation methods for mangrove ecosystems.

Protecting existing mangroves is more effective and efficient than restoring them. Surat and Kachchh districts of Gujarat have demonstrated that the PPP model, involving government agencies, local communities, and the private sector, can be successful for mangrove conservation and development (Padma, T. V., 2022). The City Corporation of Panaji, along with the Goa Coastal Zone Management Authority and Goa's Environment and Climate Change Department, could employ a similar model.

Solution 3

Urban Green Infrastructure

Public Participation and Trust | Institutional Innovation

Panaji has been experiencing a net decline in urban green spaces, including tree cover and density, due to land clearance for infrastructure projects (Anujan et al., 2024; MoHUA-NIUA, 2021). Urban green spaces, strategically planned as a network of natural and designed spaces, can deliver a wider array of ecosystem services. This includes regulating services such as mitigation of heat island effect, absorption of particulate matter and air pollutants, carbon sequestration, increased water percolation through porous surfaces and resilience to flooding, while providing opportunities for recreation and social cohesion, boosting human health and well-being.

This requires integrated and long-range planning, focused on the aesthetic aspect of nature as well as its benefits for biodiversity, mental and physical wellbeing, and to reduce the impact of climate change. Potential interventions include:

Integrate Nature in Spatial Planning to Conserve and Restore Green Spaces

Currently, the Panaji Outline Development Plan 2021 does not categorise ecological systems. Green spaces are listed only as agricultural spaces, parks and recreational spaces, and natural reserves/orchards, which limits ecological planning, as interventions cannot be tailored to unique ecosystems. Urban planners must revise planning norms and build the capacity to map ecologically distinct green spaces within city boundaries, to enable city-level ecosystem planning for a network of green spaces. Real-time status of green spaces could be monitored through high-resolution satellite imagery and GIS tools.

Across Panaji, areas at risk from urban heat island effect, heavy traffic and high vehicular pollution should be identified and prioritised for planning of urban green infrastructure. The feasibility of creating, conserving and restoring green spaces should be assessed by relevant institutions, and earmarked for future development by the state and citizens, in alignment with smart city guidelines.

Green Corridors and Urban Forestry

The scope of well-engineered green corridors along roads and waterways for shading travel routes and pedestrian paths, while ensuring inter-connectivity of green spaces (parks, sidewalks, urban trees and forests, creek vegetation) would have immense potential in mitigating urban heat island effect and reducing risks from heatwaves, while significantly contributing to carbon sequestration and improving quality of life (Yeung, 2024).

Although haphazard re-greening activities have been planned in Panaji (e.g., planting canopy trees from Madhuban complex to St. Inez Cemetery junction), the city would significantly benefit from participatory planning to conserve and restore green spaces. Tree plantation activities at the individual or community level could be aligned with the Central ‘Green Credit Program’.

Since urban expansion continues in the city, it is imperative to preserve street trees as well as heritage trees, and urban forests, and monitor their health for long-term resilience. Urban forestry is integral to the conservation and restoration of green infrastructure in cities, and suitable areas in Panaji should be earmarked for the creation or restoration of urban parks/gardens, urban tree canopy and bio-shields.

Urban Nature in Green Buildings

With increasing urbanisation in mid-sized cities like Panaji, 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:

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 Panaji would be multi-purposeful in cooling, trapping air pollutants and beautifying the city further.

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 Ch 2.)

Solution 4

Sand Dunes

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

Sand dunes are a highly economical and efficient natural defence against winds and waves, especially in coastal cities, where they safeguard coastal infrastructure from strong winds, storm surges, and floods. Dune vegetation, which includes a wide variety of flora, binds the sand together, gradually building up the dunes. Therefore, dune restoration and protection are crucial for preserving critical habitats for coastal flora and fauna, promoting a healthy and diverse ecosystem, maintaining natural coastal processes, and safeguarding the coastline from the effects of erosion and storm damage.

Sand dunes spread 0.64 km² across the jurisdiction of the Corporation of the City of Panaji (CCP) and Taleigao planning area. Miramar beach in Panaji has sand dunes stretching for about 4.5 km, but they are not as large as they once were.

The carbon sequestration potential of sand dunes is generally low, but in a degraded condition, can be close to zero. Details of specific species in the surrounding vegetation are needed to calculate that. In the absence of specific Indian studies, the current reference number is taken from a global case study. With a conversion factor of 0.47 and carbon content of 0.207 kg/m² (Del Vecchio et al., 2022), the carbon sequestration potential of sand dunes is estimated to be 131,350.6 (about 0.13 million) kg[7].

Sand dunes offer a secure storage space for equipment like boats and nets, provide shelter and shade, and safeguard the residents from flooding. However, this leads to flattening and degradation of these dunes, hindering their ability to capture carbon (Del Vecchio et al., 2022).

Coastal infrastructure, trampling, and linear intrusions such as pathways that break dunes, along with pollution through contaminants, debris, and invasive species, are significant threats to the dune ecosystem's health and biodiversity. Restoration of coastal dunes while considering the needs and livelihoods of the locals, particularly the fishing communities, is a priority to attain net zero. Sand dunes can be restored in cost-effective and eco-friendly ways.

Sand Fencing

Sand fencing is a physical barrier that reduces the amount of sand that is blown away by the wind, so sand accumulates on the beach, which rebuilds the sand dunes. The fences also create a natural habitat for plants and animals, which is important for the overall health of the beach ecosystem. As demonstrated in a pilot project at Miramar Beach in 2007 (Mascarenhas, 2002), this method works well where the sand dunes are flattened by excessive trampling. The fences should be around 1 metre high and made of evenly spaced bamboo or wooden vertical slats connected with twisted wire. They should be placed perpendicular to the prevailing wind direction, and as far landward as possible to allow for beach use. CCP should incorporate Sand Fencing in the CRZ buffer zone along the Panaji coastline under the Coastal Zone Management Plan of Goa.

Dune Restoration Zones

A study of the sand dunes in the city must be conducted, identifying areas of human activity, health and activity on the dunes. Areas requiring conservation and restoration should be identified and designated as dune restoration zones. In these zones, activity must be limited, allowing the dunes to recover and stabilise naturally. Plant cover is known to prevent overwash and dune erosion (Martinez et al., 2016). Where required, public access should be maintained in a zigzag fashion, and sign boards installed to raise awareness about dune restoration.

Sand dunes are an integral part of the life of the coastal population. Fishing communities utilise foredunes and beaches for various purposes, such as landing boats, mending nets, auctioning fish, sorting catch, drying fish, and even settlements. The Comprehensive Plan for Fisherman Community Living in CRZ Areas recognizes these dependencies and recommends the reservation of beach areas for rampon fishing (traditional Goan fishing technique) and fish landing canoes/boats, and the construction of fishing facilities with a 200-500 m buffer of the CRZ. The City Corporation for Panaji should incorporate the Plan's recommendations when preparing a dune restoration project.

A regional approach, incorporating private sector and civil society actors along with government, must be adopted for restoration of dunes outside of CCP limits.

Beach Nourishment

Contractors are often reluctant to use recycled products (M T Saju, 2020) for construction due to concerns about the strength, durability and lack of standards for quality control. Therefore, the relevant regulations and bye-laws for civil construction would have to be changed so that the recycled C&D material can be used legitimately.

Collaborative Approaches

Collaborative conservation is needed for ecosystem management. Different financial incentives could ensure equal efforts from the community. For example, in Belize, the Fisheries Department has partnered with the Toledo Institute for Development and Environment (TIDE) to co-manage a marine reserve. TIDE offers incentives for conservation, including alternative livelihoods, environmental projects driven by sporting activities for children, and scholarship programmes for fishing communities who abandon unsustainable practices (Niesten & Gjertsen, 2010). Similarly, in Indonesia, WWF-Indonesia, in collaboration with the government's nature conservation agency, employed local villagers to patrol the beach and collect nesting data to create incentives for turtle conservation and have included small-scale alternative livelihood projects

(Niesten & Gjertsen, 2010). In Puerto Rico, The Nature Conservancy (TNC) implemented livelihood and capacity-building programmes. Over several weeks, they trained community members for various qualified roles required for a marine protected area (MPA) management plan (Niesten & Gjertsen, 2010).

In Goa an informal awareness and education campaign was started in Morjim in 1995-96 to assist unemployed fisherfolk (WWF-India 2013). By 1998 it had become an education and awareness programme to incentivise local youth to begin turtle conservation, and was then adopted by the Goa Forest Department. The beaches of Mandrem, Morjim, Agonda, and Galgibaga have become well-known for their successful joint management of natural resources. Many domestic and foreign tourists visit these beaches specifically to learn about conservation initiatives and witness the release of hatchlings. The Sea Turtle Nesting and Habitat Management Plan 2020 focuses on protecting and conserving sea turtles and their nesting habitats in Goa.

Solution 5

Salt Pans

Public Participation and Trust | Institutional Innovation

The Linhares wetlands, located next to the famous Ponte Linhares causeway built in 1633 to connect old Goa to the city of Panaji, also have an extensive mangrove swamp. This area is well-known for producing solar salt and serves as an essential green soak area of the town, buffering flooding caused by tidal fluxes and monsoon waters. These salt pans are threatened by several factors, ranging from industrial and agricultural pollution to dredging, land reclamation, and unregulated coastal development. Climate change causes rising sea levels and altered precipitation patterns affecting this delicate ecosystem. Recreational activities, colonisation by invasive species, and overexploitation of resources add to the challenges.

Government agencies, conservation organisations, local communities, and industry partners must work together to preserve and safeguard the long-term health and ecological resilience of the salt pans. Sustainable management practices, enhanced habitat protection measures, and efforts to minimise the impacts of human activities are all necessary to ensure the survival of these unique ecosystems. This requires:

Policy Support

The crucial protection and sustainable management of salt pans could include establishing protected areas, implementing regulatory frameworks, offering conservation incentives, integrating salt pan restoration into coastal management plans, adopting ecosystem-based strategies, encouraging stakeholder engagement, and investing in capacity building. This would effectively minimise habitat disturbance, pollution, and habitat loss while promoting conservation, recreation, tourism, and economic development. Stakeholder collaboration, institutional capacity enhancement, and adaptive management strategies are needed to ensure the long-term ecological integrity, resilience, and sustainability of these critical coastal habitats.

Capacity building for salt pan preservation and management

Capacity building of stakeholders – both public officials and private players like the owners of the salt pans – through training programmes and workshops by the City Corporation of Panaji, with support from the Goa Coastal Zone Management Authority, would enable them to make informed decisions, develop innovative solutions, and implement best practices for salt pan preservation. It would improve the technical expertise of policymakers, resource managers, researchers, and community leaders involved in salt pan restoration and conservation. The topics covered in these capacity-building programmes could include ecosystem ecology, habitat restoration techniques, water quality monitoring, and participatory governance approaches. Collaborative learning platforms, knowledge-sharing networks, and joint projects can facilitate collective learning and expertise-building for salt pan management, while promoting stakeholder synergy and coordination.

Solution 6

Water Bodies

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

Panaji fortunately has abundant freshwater sources crucial for maintaining its urban resilience. Despite being surrounded by saline backwaters, the city's forested hills and lateritic plateaus enable recharge of the aquifers of wells located in the foothills during the monsoons. In the 19th century, two natural springs served as a source of drinking water for the city, which were later converted into fountains. The water from these fountains was transported through a trough to a tank, which supplied various parts of the city. However, most of the city's water supply now comes from a treatment plant built in 1957. This disconnects citizens from the deteriorating state of the city's freshwater bodies, leading to neglect of many of these bodies.

Excluding the river Mandovi, water bodies within the jurisdiction of the Corporation of the City of Panaji (CCP) and the Taleigao planning area cover an area of 0.26 square km[8].

> Given the growth of water hyacinth, the biomass of 20 kg/m² (Lahon et al., 2023) and a conversion factor of 0.47 (IPCC, 2006) was estimated to calculate the carbon content of these water bodies within the project area to be 9.4 kg/m². Thus, the carbon sequestration potential of water bodies, excluding the Mandovi River, is estimated to be 2,457,996.6 (2.4 million) kg, which must be considered while working towards the net zero target.

Although CCP has well-functioning solid waste management, its water bodies, especially St. Inez Creek, remain receptacles for domestic and construction waste. The runoff of raw sewage and fertilisers leads to eutrophication and the development of harmful algal blooms and invasive aquatic weeds, such as water hyacinth (Eichornia crassipes), water lettuce (Pistia stratiotes), and the giant salvinia (Salvinia molesta). The proliferation of these aquatic weeds impairs the water's oxygenation, encouraging mosquito breeding and spreading vector-borne diseases. Invasive species, including fish and other aquatic life, threaten biodiversity by living below the floating vegetation, and weeds threaten the smooth-coated otter (Lutrogale perspicillata), the mugger or marsh crocodile (Crocodylus palustris), and a variety of waterfowl that inhabit Panaji's wetlands, and also significantly affect the ecosystem services of these wetlands, such as their capacity to buffer urban floods.

The over-extraction of groundwater across the city, the degradation of Khazan lands, especially the bundhs, and the contraction of sand dunes have led to the intrusion of saline water into various wetlands, ponds, and wells in Panaji and its surrounding villages. This could lead to erosion, flooding, and contamination of aquifers and agricultural soils, resulting in reduced freshwater resources and habitat loss (Goa State Action Plan on Climate Change, 2023). Various solutions integrated into the larger urban landscape and better connectivity between

the different Nature-based Solutions, such as cultivated Khazan lands with well-preserved embankments and sand dunes could limit the intrusion of saline water, thus preserving ecosystem integrity and improving the availability and quality of water for agriculture and human consumption. Some other ways to restore these water bodies include:

Riparian Buffer Zones

To create riparian buffer zones, which are valuable areas adjacent to bodies of water that can enhance water quality, support wildlife, and reinforce banks, the unique features of the location and the regulatory requirements to determine the most suitable width and composition of the buffer must be taken into account. Erosion can be halted by native trees, shrubs, and grasses, which effectively filter runoff, and control methods like mulching, bioengineering, or erosion control blankets. CCP can integrate the riparian buffer zones with the CRZ buffers as suggested by the CZMP 2019.

Water Quality Monitoring and Management

To preserve the environment, water quality, especially in Panaji's freshwater ponds and small water bodies like Mala Lake and the two freshwater springs and fountains in the city: Fonte Phoenix and Fonte Boca de Vaca, must be maintained. This requires a comprehensive monitoring and management programme that covers various parameters, including temperature, dissolved oxygen, pH, nutrients, and pollutants.

First, data on the quality of the water bodies must be collected and analysed to identify trends, pollution sources, and areas that require attention, but currently this is not being done. Based on the analysis, management strategies including pollution prevention measures, habitat restoration, and regulatory controls could be developed and implemented. Stakeholders and the community must be involved in water quality monitoring and management, through outreach, education, and collaboration.

Second, solutions must fit the context. For example, bioremediation uses natural methods which are cost-effective and eco-friendly, to clean polluted water and soil. Other solutions include aeration, which involves exposing water to air or introducing air bubbles to eliminate dissolved metals, to manage water pollution caused by human activities such as sewage discharge, agricultural runoff, and solid waste disposal. Mechanical aerators can be installed in stagnant water areas with low operating and maintenance costs (Ramanathan et al., 2021).

Third, the city must consider wastewater as a valuable resource, and with 85% coverage of sewerage network in Panaji (Singh et al., 2015), the city has the potential to reuse treated wastewater for various purposes. The state government of Goa has an action plan to use treated wastewater for sustainable sanitation, agriculture, industrial and commercial uses. Integrated infrastructure planning is crucial for maintaining groundwater quality. In Fontainhas, for instance, public toilets with septic tanks have been constructed near a freshwater spring, endangering the water quality in the springs and nearby fountains.

With the city's dependence on the monsoon, rainwater harvesting by households, industries and commercial buildings could reduce the risk of water crisis in Panaji. However, though the Water Resources Department has developed a water harvesting scheme with compensation benefits and reward incentives, the uptake of rainwater harvesting is lagging in the state. An in-depth study is required to understand barriers, and potential collaboration with urban local bodies. R&D institutions could help in spreading awareness, cost-effectiveness and overall feasibility.

Endnotes and Bibliography

Introduction

Climate Ambition Alliance: Net Zero 2050 - Climate Initiatives Platform. (n.d.). Retrieved from https://climateinitiativesplatform.org/index.php/Climate_Ambition_Alliance:_Net_Zero_2050

Directorate of Census Operations: Goa. (2011). District Census Handbook: North Goa - Village and Town Wise Primary Census Abstract (PCA): Census of India 2011, Series 31, Part XII B. Census of India 2011. Census of India. Retrieved from https://censusindia.gov.in/nada/index.php/catalog/369/download/1124/DH_2011_3001_PART_B_DCHB_NORTH_GOA.pdf

Imagine Panaji Smart City Development Ltd (IPSCDL). (n.d.). Panaji Smart City Proposal: Stage 2: Smart City Challenge. National Institute of Urban Affairs (pp. 1–92). India Smart City Mission. Retrieved from https://smartnet.niua.org/sites/default/files/resources/Panaji_SCP.pdf

Lobo, A., & Bhandari, A. (2021). Nature-based Solutions Panaji: A Toolkit. Transitions Research. Retrieved from https://transitionsresearch.org/wp-content/uploads/reports/NBS%20TOOLKIT%20-%20Panaji_PULL.pdf

Lobo, A., Bhandari, A., & Kuppu, K. (2022, November 22). A city on a marsh: Why Indian coastal cities need to design and build with nature. Retrieved from https://transitionsresearch.org/a-city-on-a-marsh-why-indian-coastal-cities-need-to-design-and-build-with-nature/

National Commission on Population, Ministry of Health and Family Welfare. (2020, July). Population Projections for India and States 2011-2036: Report on the Technical Group on Population Projections.

Census of India 2011. Census of India 2011. Retrieved from https://main.mohfw.gov.in/sites/default/files/Population%20Projection%20Report%202011-2036%20-%20upload_compressed_0.pdf

Office of the Registrar General & Census Commissioner, India. (2011). Table A-04 (I): Towns and urban agglomerations classified by population size class in 2011 with variation between 1901 and 2011 - Class I (population of 100,000 and above) [Dataset]. Retrieved from https://censusindia.gov.in/nada/index.php/catalog/42876

PTI. (2016, July 1). Greenhouse gas emission in Panaji 3 times more than national average - study. The Indian Express. Retrieved from https://indianexpress.com

PTI. (2024, February 7). Post-Covid tourist footfalls going up in Goa: Minister. The Times of India. Retrieved from https://timesofindia.indiatimes.com/india/postcovid-tourist-footfalls-surge-in-goa-minister-reveals-impact/articleshow/107486367.cms

Team Herald. (2023, December 5). 40 E-buses to start services in Panjim. oHeraldo. Retrieved from https://www.heraldgoa.in

Tnn. (2023, September 20). Panaji 2025: Rs 541cr to create solar city. The Times of India. Retrieved from https://timesofindia.indiatimes.com

Chapter 1: Energy

Times of India. (n.d.). Panaji 2025: Rs 541cr to create solar city . Retrieved 2023

Hyams, M. A. (2012). Wind energy in the built environment. Science Direct.

NT Desk. (2019). “Feasibility of harnessing wind energy in Goa.”

Solarizing Panaji. (2023). Rooftop Solar PV potential assessment.

Global Solar Atlas. (n.d.). Retrieved from https://globalsolaratlas.info/map?c=20.43763,72.68486,11&s=20.408351,72.857895&m=site

Sethi, Rishabh, & Narayan Kumar Sreekumar. (2021). Ensuring 24X7 reliable power supply to the people of Goa. TERI.

GEDA. (2021). “Citizen Charter - Goa Energy Development Agency.” Panaji.

GEDA. (2014). Draft of the Goa State Government Policy towards renewable, solar energy and energy conservation - Goa. Goa Energy Development Agency (GEDA).

Ministry of New and Renewable Energy. “PM Surya Ghar: Muft Bijli Yojana Turns One Powering India’s Solar Revolution.” 12 February 2025, https://pib.gov.in/PressReleasePage.aspx?PRID=2102149&utm.com. Accessed 10 Jan 2025.

EDG. (2021). “BUSINESS PLAN FOR THE CONTROL PERIOD FY 2022-23 TO FY 2024-25.” Gurgoan.

Robin Radar System. (2021, July). Can UV lights prevent bird deaths at wind farm? Retrieved from https://www.robinradar.com/blog/do-birds-in-flight-respond-to-ultraviolet-lighting

Mendi, Vikas, Jayakumar Seelam, & Subba Rao. (2019). Evaluation of tidal stream energy at major tidal inlets of Goa, India. ResearchGate.

MacDougall, Shelley, & John Colton. (2013). Community and Business Toolkit for Tidal Energy Development. Acadia Tidal Energy Institute.

Tonkoski, Reinaldo, Luiz Lopes, & Tarek H. M. El-Fouly. (2011). Coordinated Active Power Curtailment of Grid Connected PV Inverters for Overvoltage Prevention. Research Gate.

Longo, Michela, Federica Foiadelli, & Wahiba Yaïci. (2017). “Electric Vehicles Integrated with Renewable Energy Sources for Sustainable Mobility.”

IEA. (2022). Grid Integration of Electric Vehicles. IEA.

Energy Market Authority - Singapore. n.d. “Co-Creation with Industry: Facilitating Vehicle-to-Grid (V2G) Uptake in Singapore.”

Singh, R., Sethi, R. & Mazumdar, R., (2019). Solar Rooftop: Perspectives of DISCOMS, s.l.: TERI.

PwC India. (2020). Report on enhancing Solar PV rooftop uptake in India through innovative EU business models, s.l.: s.n.

Jean, W., Silva, E. C. M. d. & Junior, A. B., (2023). Smart grid systems infrastructures and distributed solar power generation in urban slums–A case study and energy policy in Rio de Janeiro, s.l.: Science Direct.

Rapin, K., (2023). The Grassroots Movement That Built Puerto Rico's First Community-Owned Microgrid. Next City.

SEIA - Solar Energy Industries Association. (n.d.). Solar Investment Tax Credit (ITC) 101. Retrieved from SEIA.

Chapter 2: Green Buildings

admin1. (2024, June 20). Tackling embodied carbon from India's building sector. Alliance for an Energy Efficient Economy. https://aeee.in/tackling-embodied-carbon-from-indias-building-sector

Towards low carbon and resilient pathways. (n.d.-b). https://niua.in/intranet/sites/default/files/2872.pdf

New Food Buzz in Goa's Latin Quarter. Mintlounge. (2024, February 9). https://lifestyle.livemint.com/food/discover/new-restaurants-panaji-latin-quarter-goa-111707415161044.html

TNN / Mar 7, 2016. (n.d.). Slumming it out in panaji: Goa News - Times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/slumming-it-out-in-panaji/articleshow/51285755.cms

The Goan EveryDay. (2023, September 7). Slum Redevelopment & Rehabilitation: A Mirage on horizon? https://www.thegoan.net/forgotten-files/slum-redevelopment-rehabilitation-a-mirage-on-horizon/103532.html

Ibrahim, S. (2023, April 12). Energy efficiency: Challenges and solutions. Energy Central. https://energycentral.com/c/ee/energy-efficiency-challenges-and-solutions#:~:text=Unfavorable%20Market%20Conditions&text=In%20some%20cases%2C%20energy%2Defficient,suppliers%2C%20leading%20to%20higher%20prices

M T Saju / Updated: Aug 25, 2020. (n.d.). India recycles only 1% of construction and demolition waste, study finds - times of India. The Times of India. https://timesofindia.indiatimes.com/business/india-business/india-recycles-only-1-of-construction-and-demolition-waste-study-finds/articleshow/77747060.cms

Goa implements scheme to encourage renewable energy. The Hindu. (2016, May 19). https://www.thehindu.com/news/national/other-states/goa-implements-scheme-to-encourage-renewable-energy/article5774107.ece#:~:text=Goa%20Chief%20Minister%20Manohar%20Parrikar%20has%20said%20that,Green%20by%20the%20Energy%20and%20Resources%20Institute%20%28TERI%29

Goa, D. (2023, July 8). Green certification for buildings and projects in Goa through IGBC. digitalgoa. https://digitalgoa.com/green-certification-for-buildings-and-projects-in-goa-through-igbc/

Indian Green Building Council. (n.d.-a). https://igbc.in/igbc-green-homes.php
Standard, B. (2019, May 17). No green nod required for construction on 20000-50000 sq metre area: Env Min's new eia notification. Business Standard. https://www.business-standard.com/article/pti-stories/no-green-nod-required-for-construction-on-20000-50000-sq-metre-area-env-min-s-new-eia-notification-119051701099_1.html

Confederation of Real Estate Developers' Association of India. (n.d.). Skill Development Trainings for Construction Workers is the Need of the Hour. CREDAI Kerala. https://credaikerala.com/skilldevelopment.php

Admin. (2024, May 29). Types of solar cells: Comprehensive guide on top varieties. Eco Solar Digest. https://ecosolardigest.com/types-of-solar-cells/#:~:text=Types%20of%20Solar%20Cells%3A%20Comprehensive%20Guide%20on%20Top,...%208%20Perovskite%20Solar%20Cells%20...%20More%20items

Influence of window-to-wall ratio on building energy load ... (n.d.-b). https://archscience.org/wp-content/uploads/2020/03/64-Influence-of-window-to-wall-ratio-on-building-energy-load-with-daylight-utilization-for-west-facade-in-office-building-in-hot-and-dry-climate-of-India-A-Simulation-based-Approach.pdf

The secret to better building retrofits. (n.d.-e). https://www.architectmagazine.com/practice/best-practices/the-secret-to-better-building-retrofits

Skinner, B., & Lalit, R. (2023, January 24). Concrete: 8% of global emissions and rising. which innovations can achieve net zero by 2050?. Energy Post. https://energypost.eu/concrete-8-of-global-emissions-and-rising-which-innovations-can-achieve-net-zero-by-2050/

What is Ferrock in construction?. The Constructor. (2022, July 25). https://theconstructor.org/concrete/ferrock-characteristics-applications/565525/#:~:text=The%20strength%20of%20ferrock%20is%20five%20times%20the,why%20it%20sustains%20movement%20and%20pressure%20without%20cracking.

Gupta, N., & Olickal, S. (2024, January 2). India's shift to low-carbon construction must not leave workers behind. World Resources Institute. https://www.wri.org/insights/india-just-transition-low-carbon-construction#:~:text=The%20vast%20majority%20of%20India%E2%80%99s%20construction%20workers%20%2884%25%29,move%20into%20higher-skilled%2C%20better-paid%20jobs%20in%20sustainable%20construction.

PTI / Sep 2, 2021. (n.d.). NBCC signs pact with CSDCI to conduct skill development programmes - times of India. The Times of India. https://timesofindia.indiatimes.com/nbcc-signs-pact-with-csdci-to-conduct-skill-development-programmes/articleshow/85863483.cms

ARHCs. (n.d.). https://arhc.mohua.gov.in/

Tarun Gopalakrishnan Research Fellow, Bethany Tietjen Research Fellow in Climate Policy, & Seth Owusu-Mante Research Fellow in International Development. (2024, May 22). Using green banks to solve America's affordable housing crisis – and climate change at the same time. The Conversation. https://theconversation.com/using-green-banks-to-solve-americas-affordable-housing-crisis-and-climate-change-at-the-same-time-208098

TOI. (2019, June 26). Mini treatment plant at Panaji in 10 days to handle wet waste. The Times of India. https://timesofindia.indiatimes.com/city/goa/mini-treatment-plant-at-panaji-in-10-days-to-handle-wet-waste/articleshow/69950020.cms

Natekar, S. (2024) Personal Communication, Goa Waste Management Corporation Office, Saligao, Goa, 17th February

Confederation of Real Estate Developers' Association of India. (n.d.). Skill Development Trainings for Construction Workers is the Need of the Hour. CREDAI kerala. https://credaikerala.com/skilldevelopment.php

Lewis, V. (2021, November 3). Construction absorbs low-skilled casual labour?. Indiaspend. https://www.indiaspend.com/data-viz/construction-sector-labour-low-skilled-migrant-population-short-term-765841

Chapter 3: Electricity Consumption

Acil Allen Consulting. (27 Mar, 2014). REPORT TO THE DEPARTMENT OF INDUSTRY ON BEHALF OF THE EQUIPMENT ENERGY EFFICIENCY COMMITTEE. Energy Rating Labels Review: Final Report.

Agrawal, Shalu, Sunil Mani, Dhruvak Aggarwal, Abhishek Jain, Chetna Hareesh Kumar and Karthik Ganesan (2020). Awareness and Adoption of Energy Efficiency in Indian Homes: Insights from the India Residential Energy consumption Survey (IRES) 2020. New Delhi: Council on Energy, Environment and Water. from https://www.ceew.in/publications/awareness-and-adoption-energy-efficiency-indian-homes

BEE, Government of India, Ministry of Power (n.d.). Demand-Side Management. https://beeindia.gov.in/en/programmes/demand-side-management-programme-dsm

BEE, Government of India, Ministry of Power. (n.d.) Perform, Achieve, and Trade. https://beeindia.gov.in/en/programmes/perform-achieve-and-trade-pat

BEE, Government of India, Ministry of Power. (n.d.) Star Label. https://beeindia.gov.in/en/star-label

BEE, Ministry of Power (n.d.). Energy Conservation Building Code https://beeindia.gov.in/en/energy-conservation-building-code-ecbc

Bose, R. K., & Shukla, M. (1999). Elasticities of electricity demand in India. Energy policy, 27(3), 137-146.

Brühl, J., Smith, G., & Visser, M. (2019). Simple is good: Redesigning utility bills to reduce complexity and increase understanding. Utilities Policy, 60, 100934.

Buildings – Energy System(n.d.). IEA. https://www.iea.org/energy-system/buildings

Business and Economy of Panaji (n.d.) Panaji Online. https://www.panajionline.in/city-guide/business-and-economy-of-panaji

Cabral, N. (n.d.) White Paper on the Complete Status of Power Situation in Goa. Goa Electricity. https://www.goaelectricity.gov.in/Regulations/White%20Paper.pdf

Casal, S., DellaValle, N., Mittone, L., & Soraperra, I. (2017). Feedback and efficient behavior. Plos one, 12(4), e0175738.

Dai, Z. (2012). Delay discounting, probability discounting, reward contrast and gambling: A cross-cultural study.

De Tommasi, L., Papadelis, S., Agrawal, R., & Lyons, P. (2022). Analysis of business models for delivering energy efficiency through smart energy services to the European commercial rented sector. Open Research Europe, 2.

Dhringra. K. (2024). Can the stars on our appliances shape an energy-efficient future? Times of India. https://timesofindia.indiatimes.com/blogs/developing-contemporary-india/can-the-stars-on-our-appliances-shape-an-energy-efficient-future/

Economic Times. (2023, January 13). Consumers can now save up to 20% in electricity bills with the new tariff rule. https://m.economictimes.com/industry/energy/power/india-to-cut-power-tariff-during-solar-hours-raise-for-peak-hours/articleshow/101209500.cms#:~:text=India's%20power%20tariffs%20are%20set,new%20amendments%20to%20electricity%20rules.

Economic Times. (2023, July 29). “100% renewable-based energy supply by 2050:” Goa CM. https://energy.economictimes.indiatimes.com/news/renewable/100-renewable-based-electricity-supply-by-2050-goa-cm/102222766

Economic Times. (2022, November 13). “India is a huge price-sensitive market; there is tremendous opportunity:” Umang Vohra, Cipla. https://economictimes.indiatimes.com/markets/expert-view/india-is-a-huge-price-sensitive-market-there-is-tremendous-opportunity-umang-vohra-cipla/articleshow/95476983.cms?from=mdr

Genus: Energising Lives. (n.d.). Understanding Your Electricity Bill & Energy Habits With Smart Meters https://genuspower.com/understanding-your-electricity-bill-energy-habits-with-smart-meters/#:~:text=Smart%20meters%20are%20next-generation,no%20more%20manual%20meter%20readings!

GfK (2023, November 8). Indian Consumers’ Evolving Priorities Towards Environment and Sustainability. https://www.gfk.com/insights/indian-consumers-evolving-priorities-towards-environment-sustainability#:~:text=In%20India%2C%201%20in%203,more%20holistic%20approach%20to%20consumption.

GIZ (2023). Clean Energy Roadmap for the State of Goa. https://geda.goa.gov.in/

Goa Electricity Department. (n.d.) 24 X 7 Power for All Goa. July 15, 2024 https://goaelectricity.gov.in/Regulations/24by7Goa.pdf

Goa Electricity. (n.d.) Tariff Pattern Category-Wise. https://goaelectricity.gov.in/

Goswani, S. (2023, April 15). Power tariffs in India are one of the lowest in the world: RK Singh. Money Control. from: https://www.moneycontrol.com/news/power/power-tariffs-in-india-are-one-of-the-lowest-in-the-world-rk-singh-10415291.html

Hari, J., Karathanasis, N., & Burri, S. (2008). Price sensitivity for green power in electricity markets: results from a conjoint analysis and a representative survey in Switzerland. In Pricing Perspectives: Marketing and Management Implications of New Theories and Applications (pp. 119-144). London: Palgrave Macmillan UK. IGBC: Indian Green Building Code. (n.d.) https://igbc.in/

Jain, A. (2022, September 19). Domestic Electricity LT Tariff Slabs and Rates for all states in India in 2024. Bijli Bachao. from: https://www.bijlibachao.com/news/domestic-electricity-lt-tariff-slabs-and-rates-for-all-states-in-india-in.html

Joshi, G., & Sen, V. (2021). Residential Consumer Understanding of Electricity Bills: The Case of the Indian Consumer. International Journal of Asian Business and Information Management (IJABIM), 12(3), 1-16.

Joshi, G., Sen, V., & Kunte, M. (2020). Do Star Ratings Matter?: A Qualitative Study on Consumer Awareness and Inclination to Purchase Energy-Efficient Home Appliances. International Journal of Social Ecology and Sustainable Development (IJSESD), 11(4), 40-55. https://www.researchgate.net/publication/343961724_Do_Star_Ratings_Matter_A_Qualitative_Study_on_Consumer_Awareness_and_Inclination_to_Purchase_Energy-Efficient_Home_Appliances

Kamat. P. (2003, Mar 29). Goa’s per capita income second highest in the country. https://economictimes.indiatimes.com/news/economy/policy/goas-per-capita-income-second-highest-in-the-country/articleshow/41773656.cms?from=mdr

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. Psychological bulletin, 141(6), 1205.

Ministry of Power. (2022, Jan 5). UJALA completes 7 years of energy-efficient and affordable LED distribution. https://pib.gov.in/PressReleasePage.aspx?PRID=1787594

Monteiro, L. (2022, Nov 12). Goa: Smart meters to now monitor power quality, consumption. Times of India. https://timesofindia.indiatimes.com/city/goa/smart-meters-to-now-monitor-power-quality-consumption/articleshow/95460507.cms

Navhind Times. (2023, April 14). Smart metering system will be introduced in Goa by 2024: Dhavalikar. https://www.navhindtimes.in/2023/04/14/goanews/smart-metering-system-will-be-introduced-in-goa-by-2024-dhavalikar/

Navhind Times. (2023, November 7) https://www.navhindtimes.in/2023/11/07/goanews/consumers-in-panaji-to-be-first-in-state-to-have-smart-meters/

Newslaundry. (2016, Jul 12). How concrete cities are building up the heat in India. https://www.newslaundry.com/2016/07/12/how-concrete-cities-are-building-up-the-heat-in-india#:~:text=Trees%2C%20shrubs%2C%20grass%20and%20soil,for%20many%20hours%20at%20night.

Outlook India. (2023, July 12).Smart Electricity Meters: Will They Reduce Your Electricity Bills? https://business.outlookindia.com/news/smart-electricity-meters-will-they-reduce-your-electricity-bills--news-305613

Patnaik, S. (2023, July 18). Consumers in Panaji to be first in state to have smart meters.
Press Trust of India (2016, July 12). 4.05 lakh LED bulbs distributed under 'Jyotirmay Goa' scheme. Business Standard. https://www.business-standard.com/article/pti-stories/4-05-lakh-led-bulbs-distributed-under-jyotirmay-goa-scheme-116071201226_1.html

Regidi, A. (2024, April 6). Refrigerator star ratings: Are they worth it? Croma. https://www.croma.com/unboxed/refrigerator-star-ratings-are-they-worth-it

Renewable Watch India (n.d.). Greening Goa: A roadmap for clean energy https://renewablewatch.in/2023/09/08/greening-goa-a-roadmap-for-clean-energy/

SAP. (n.d.) Smart metering: Helping customers reduce consumption https://www.sap.com/india/insights/smart-metering-helping-customers-reduce-consumption.html

GEDA. (n.d.). Scheme for promotion of Grid connected Solar Rooftop System with Net Metering System (Phase II) https://geda.goa.gov.in/

Schleich, J., Gassmann, X., Meissner, T., & Faure, C. (2019). A large-scale test of the effects of time discounting, risk aversion, loss aversion, and present bias on household adoption of energy-efficient technologies. Energy Economics, 80, 377-393.

Sharma, A. (2021, January 10). Electricity needs of a growing Goa. The Goan. https://www.thegoan.net/perspective/electricity-needs-of-a-growing-goa/64105.html

Ministry of Power, Government of India (n.d.) SLNP Dashboard: Total Streetlight Completed as of Date. https://slnp.eeslindia.org/

Sudarmaji, E., & Ambarwati, S. (2023, May). Do Nudges and Prepaid Electricity Token Lead to Electricity Savings? Analysis of Urban Consumption Behaviour in Indonesia. In Proceedings of the Business Innovation and Engineering Conference (BIEC 2022) (Vol. 236, p. 225). Springer Nature.

Tathagat, T. (2007, March). THE COLLABORATIVE LABELING AND APPLIANCE STANDARDS PROGRAM. India Labeling Program Impacts: Case Study. CLASP. https://www.clasp.ngo/wp-content/uploads/2021/01/2007-05_IndiaLabelingProgramImpacts.pdf
Times of India (2023, December 16). Goa 2nd among small states in energy efficiency performance. from https://timesofindia.indiatimes.com/city/goa/goa-2nd-among-small-states-in-energy-efficiency-performance/articleshow/106042243.cms

Tongia, R., & Mehta, V. (2015). The Indian Power Grid: If Renewables are the Answer, what was the Question. Blowing Hard or Shining Bright, 21-29.

United States EPA (n.d.). Heat Island Impacts. https://www.epa.gov/heat-islands/heat-island-impacts
VOA News. (2023, July 31). How Concrete, Asphalt and Urban Heat Increase Misery of Heat Waves. Reuters. https://www.voanews.com/a/how-concrete-asphalt-and-urban-heat-increase-misery-of-heat-waves-/7205299.html

Wright, J. (1990). Social discounting and the environment. Centre for Resource Management, Lincoln University & University of Canterbury.

Zheng, X., Li, C., Fang, X., & Zhang, N. (2021). Price sensitivity and consumers' support for renewable energy in China. Energy, 222, 119862.

Chapter 4: Mobility

Ampcontrol. (2022, December 6). What is ev charging load management? https://www.ampcontrol.io/post/what-is-ev-charging-load-management

Bhandari, A., Jain, S., Kappu, K., Das Roy, R., Bogra, B., & Ale, H. (2021). Inclusive Streets Inclusivity In Action - Project Urban Living Lab. https://transitionsresearch.org/wp-content/uploads/reports/InclusiveStreets_InclusivityInAction_PULL.pdf

Charles Correa Foundation. (2018, April 20). Decongestion model for Panaji City Centre. https://charlescorreafoundation.org/2018/04/19/decongestion-model-for-panaji-city-centre/

Comprehensive Mobility Plan for the State of Goa and Parking Masterplan for Panaji. Urban Mass Transit Company Limited. (n.d.). https://web.archive.org/web/20200807205328/https://www.umtc.co.in/comprehensive-mobility-plan-for-the-state-of-goa-parking-mst-umtc-266

Desouza, F. (2017, January 21). Purely goa - motorcycle pilot !. Its Goa. https://itsgoa.com/motorcycle-pilot-goa
Goa Electric Mobility Promotion policy-2021. (2021). https://www.goa.gov.in/wp-content/uploads/2021/12/Goa-Electric-Mobility-Promotion-Policy-2021.pdf

The Goan EveryDay. (2023, May 19). Soon, subsidy for EV buyers as Govt Moots New Policy. https://www.thegoan.net/goa-news/soon-subsidy-for-ev-buyers-as-govt-moots-new-policy/99115.html#google_vignette

Govt. of Goa. (n.d.). Draft of Goa Electric Mobility Promotion Policy 2021. Government of Goa. https://www.goa.gov.in/wp-content/uploads/2021/07/draft-of-Goa-Eletric-mobility-promotion-policy-2021.pdf

IANS. (2021, August 6). Hero lectro partners with Swiggy for Food Delivery - et auto. ETAuto.com. https://auto.economictimes.indiatimes.com/news/aftermarket/hero-lectro-partners-with-swiggy-for-food-delivery/85095197

ICLEI. (2018). Panaji Ecologistics City Profile. ICLEI Sustainable Mobility. https://sustainablemobility.iclei.org/wp-content/uploads/2019/06/Panaji__EcoLogistics__City__Profile2018-web.pdf

International Urban Cooperation. (2021, January 20). Smart parking solution at a pilot site in Panaji, goa. https://iuc.eu/fileadmin/templates/iuc/lib/iuc_resource//tools/push_resource_file_resource.php?uid=TwRrlw97

Kamat, S. (2023, April 27). Love for electric vehicles rapidly grows in Goa, sales shoot up. Herald Goa. https://www.heraldgoa.in/Goa/Love-for-electric-vehicles-rapidly-grows-in-Goa-sales-shoot-up/204266

Moseman, A., & Paltsev, S. (2022a, October 13). Are Electric Vehicles definitely better for the climate than gas-powered cars?. MIT Climate Portal. https://climate.mit.edu/ask-mit/are-electric-vehicles-definitely-better-climate-gas-powered-cars

Moseman, A., & Paltsev, S. (2022b, October 13). Are Electric Vehicles definitely better for the climate than gas-powered cars?. MIT Climate Portal. https://climate.mit.edu/ask-mit/are-electric-vehicles-definitely-better-climate-gas-powered-cars

Now, Book Electric AC Bus from Goa Airport to your destination at only rs 200. The Economic Times. (2022, August 17). https://economictimes.indiatimes.com/news/new-updates/now-book-electric-ac-bus-from-goa-airport-to-your-destination-at-only-rs-200/articleshow/93615086.cms?from=mdr

O Heraldo. (2021, February 16). Smart parking, intelligent traffic signals in city soon. https://www.heraldgoa.in/Goa/Smart-parking-intelligent-traffic-signals-in-city-soon/171076

PTI. (2023, July 19). All new tourist vehicles in Goa to be evs from Jan 2024: Cm Sawant - et auto. ETAuto.com. https://auto.economictimes.indiatimes.com/news/industry/all-new-tourist-vehicles-in-goa-to-be-evs-from-jan-2024-cm-sawant/101927380

Raghuraman, G., Kavitha, S., Gokulakrishnan, N., Radhakrishnan, S., & Ramakrishnan, P. (2023). Smart parking system with dynamic pricing model. Indian Journal Of Science And Technology, 16(18), 1332–1339. https://doi.org/10.17485/ijst/v16i18.2489

Richard Nunno. (2021, January 28). Why art matters: Street murals bolster community and re-imagine transportation. Environmental and Energy Study Institute. https://www.eesi.org/articles/view/why-art-matters-street-murals-bolster-community-and-re-imagine-transportation

Sahil Kukreja / TIMESOFINDIA.COM / Updated: Jul 27, 2022. (2022, July). Goa to stop offering EV subsidy from July 31: Details explained - times of India. The Times of India. https://timesofindia.indiatimes.com/auto/policy-and-industry/goa-to-stop-offering-ev-subsidy-from-july-31-details-explained/articleshow/93154612.cms?from=mdr

Sayed, N. (2023, October 11). Zebra crossings fade, Panjimites Sitting Ducks on roads: Goa News - Times of

India. The Times of India. https://timesofindia.indiatimes.com/city/goa/zebra-crossings-fade-panjimites-sitting-ducks-on-roads/articleshow/104333809.cms

Shinde, A. (2022, February 26). Electric Bike vs petrol bike- price, Range & running cost - E-vehicle info. E-Vehicle Info. https://e-vehicleinfo.com/electric-bike-vs-petrol-bike-price-range-running-cost/#:~:text=An%20electric%20bike%20requires%203,1km%2C%20it%20costs%20you%202rs.

TOI. (2018, January 13). No road tax for electric cars: Goa News - Times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/no-road-tax-for-electric-cars/articleshow/62480457.cms

TOI. (2023, April 30). Green Energy Switch: State to install 300 solar street lights: Goa news - times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/green-energy-switch-state-to-install-300-solar-street-lights/articleshow/99876077.cms

Yanocha, D., Kim, Y., & Mason, J. (2023, February). The Opportunity of Low Emission Zones: A Taming Traffic Deep Dive Report. Institute for Transportation and Development Policy. https://itdp.org/wp-content/uploads/2023/02/ITDP-LEZ-Brief.pdf

Chapter 5: Waste Management

Towards low carbon and resilient pathways. (n.d.-b). https://niua.in/intranet/sites/default/files/2872.pdf

16-ways of segregating waste: Panaji's innovative model of Solid Waste Management. UNDP. (2023a, January 18). https://www.undp.org/india/stories/16-ways-segregating-waste-panajis-innovative-model-solid-waste-management#:~:text=Panaji%20generates%20around%2042%20tonnes,RDF)%20for%20co%2Dprocessing

CSE and NITI Aayog release "waste-wise cities" – compendium of best practices in municipal solid waste management. Centre for Science and Environment. (n.d.). https://www.cseindia.org/cse-and-niti-aayog-release-waste-wise-cities-compendium-of-best-practices-in-municipal-solid-waste-management-11074

CCP Solid Waste (Management & Handling) (Amendment) Bye-laws (2021).

Herald, T. (2021, September 24). CCP solidifies waste management. oHeraldo. https://www.heraldgoa.in/Goa/CCP-solidifies-waste-management/180424

TNN / Updated: Sep 14, 2022. (n.d.). Bainguinim Waste Plant: Govt invites bidders once again: Goa News - Times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/bainguinim-waste-plant-govt-invites-bidders-once-again/articleshow/94185828.cms

Utilisation of recycled produce of Construction & ... (n.d.-c). https://www.bmtpc.org/DataFiles/CMS/file/PDF_Files/C&D_Ready_Reckoner_BMTPC_web.pdf

Cleanse up. Ayya. (n.d.). https://www.awm.co.in/#recycle

Giz-Teri to help Panjim reduce GHG emissions through Municipal Waste Management. TERI. (n.d.). https://www.teriin.org/article/giz-teri-help-panjim-reduce-ghg-emissions-through-municipal-waste-management

Newton Sequeira / TNN / Updated: Jan 26, 2023. (n.d.). Wealth and waste: CCP offers cash for trash in panaji: Goa News - Times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/wealth-and-waste-ccp-offers-cash-for-trash-in-panaji/articleshow/97339480.cms

TNN / Dec 30, 2020. (n.d.). Two more stores join CCP's "shop-with-your-waste" plan: Goa News - Times of India. The Times of India. https://timesofindia.indiatimes.com/city/goa/two-more-stores-join-ccps-shop-with-your-waste-plan/articleshow/80016134.cms

Khamba composter: Terracotta Stack Home compost bin. Daily Dump. (n.d.). https://www.dailydump.org/products/khamba-composter-terracotta-stack-home-compost-bin
Revised - SWM Policy for Goa, 2024.

Borunda, A. (2019, September 6). How tampons and pads became unsustainable and filled with plastic. Environment. https://www.nationalgeographic.com/environment/article/how-tampons-pads-became-unsustainable-story-of-plastic

Migrator. (n.d.). World menstrual hygiene day 2023: Small-scale incinerators for sanitary pad disposal in schools is not a good idea. Down To Earth. https://www.downtoearth.org.in/waste/world-menstrual-hygiene-day-2023-small-scale-incinerators-for-sanitary-pad-disposal-in-schools-is-not-a-good-idea-89617

Proposed construction & demolition waste management facility. GWMC. (n.d.). https://gwmc.goa.gov.in/construction-demolition-waste-treatment-facility/#:~:text=With%20assistance%20from%20SINTEF%20Scientific,sqm%20on%2012%2F06%2F2020

Utilisation of recycled produce of Construction & ... (n.d.-c). https://www.bmtpc.org/DataFiles/CMS/file/PDF_Files/C&D_Ready_Reckoner_BMTPC_web.pdf

Indian concrete institute -Is 383-2016. . (n.d.-a). http://icikbc.org/docs/IS383-2016.pdf

TOI. (2019, June 26). Mini treatment plant at panaji in 10 days to handle wet waste. The Times of India. https://timesofindia.indiatimes.com/city/goa/mini-treatment-plant-at-panaji-in-10-days-to-handle-wet-waste/articleshow/69950020.cms

Chapter 6: Nature-Based Solutions

Anujan, K., Velho, N., Kuriakose, G., Ebin, P. J., Pandi, V. & Nagendra, H. (2024). Beyond the metropolis: street tree communities and resident perceptions on ecosystem services in small urban centers in India. Journal of Urban Ecology, Vol 10(1). https://doi.org/10.1093/jue/juae004

Census of India 2011: Population projections for India and states 2011 - 2036. https://main.mohfw.gov.in/sites/default/files/Population%20Projection%20Report%202011-2036%20-%20upload_compressed_0.pdf

Centre for Environment Education (CEE). (2020). Sea Turtle Nesting and Habitat Management Plan 2020 (Draft). Goa State Office. Goa Coastal Zone Management Authority. https://www.czma.goa.gov.in/ViewDoc.aspx

Committee for the Preparation of Draft Comprehensive Plan for Fisherman Community living in CRZ areas, Government of Goa. (2023). Draft Comprehensive Plan for Fisherman Community living in CRZ Areas. Department of Environment and Climate Change, Government of Goa. https://www.czma.goa.gov.in/ViewDoc.aspx

Committee for Preparation of Khazan Land Management Plan, Government of Goa. (2023). Draft Khazan Land Management Plan. Department of Environment and Climate Change, Government of Goa. https://www.czma.goa.gov.in/ViewDoc.aspx

Committee for the Preparation of Management Plan for Mangroves, Government of Goa. (2023). Draft Management Plan for Mangroves. Department of Environment and Climate Change, Government of Goa. https://www.czma.goa.gov.in/ViewDoc.aspx

Choudri, B. S., & Chachadi, A. G. (n.d.). Status of groundwater availability and recharge in the mining watersheds of North Goa. Retrieved from https://www.academia.edu/9485422/Status_of_groundwater_availability_and_recharge_in_the_mining_watersheds_of_North_Goa

Del Vecchio, S., Rova, S., Fantinato, E., Pranovi, F., & Buffa, G. (2022). Disturbance affects the contribution of coastal dune vegetation to carbon storage and carbon sequestration rate. Plant Sociology, 59(1), 37-48. https://doi.org/10.3897/pls2022591/04

Fripp E. (2014). Payments for Ecosystem Services (PES): A practical guide to assessing the feasibility of PES projects. Bogor, Indonesia: CIFOR. https://www.cifor-icraf.org/publications/pdf_files/Books/BFripp1401.pdf

Goa State Action Plan on Climate Change, 2023, by Goa State Biodiversity Board prepared through NABARD Consultancy Services (NABCONS) https://gsbb.goa.gov.in/wp-content/uploads/2023/05/SAPCC%207.pdf

Goa State Biodiversity Board (2019). Glimpses of Biodiversity in Panaji. Report by Goa State Biodiversity Board and Corporation of the City of Panaji. Retrieved from https://gsbb.goa.gov.in/wp-content/uploads/2020/02/GLIMPSES-OF-BIODIVERSITY-IN-PANAJI-6.pdf

Harishma, K. M., Sandeep, S., & Sreekumar, V. B. (2020). Biomass and carbon stocks in mangrove ecosystems of Kerala, southwest coast of India. Ecology and Process, 9(1), 31. https://doi.org/10.1186/s13717-020-00227-8

ICLEI. (2018). Panaji, Goa (India): Ecologistics Project City Profile. https://sustainablemobility.iclei.org/wp-content/uploads/2019/06/Panaji_EcoLogistics_City_Profile2018-web.pdf

IPCC. (2006). Guidelines for National Greenhouse Gas Inventories: Annex 2 summary of equations. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_14_An2_SumEqua.pdf

Iyer, H. (2014). The lost Khazans of Goa. India Water Portal. Retrieved from https://www.indiawaterportal.org/articles/lost-khazans-goa

Kamat, N. (2004). History of Khazan land management in Goa: ecological, economic and political perspective. Paper presented at the Seminar on History of Agriculture in Goa, Department of History, Goa University, Goa, India. https://www.researchgate.net/publication/283475605_History_of_Khazan_land_management_in_Goa_ecological_economic_and_political_perspective

Lahon, D., Sahariah, D., Debnath, J., Nath, N., Meraj, G., Farooq, M., Kanga, S., Singh, S. K., & Chand, K. (2023). Growth of water hyacinth biomass and its impact on the floristic composition of aquatic plants in a wetland ecosystem of the Brahmaputra floodplain of Assam, India. Peer J 11:e14811 https://doi.org/10.7717/peerj.14811

Liu, D., Feng, Q., Zhang, J., Zhang, K., Tian, J., & Xie, J. (2021). Ecosystem services analysis for sustainable agriculture expansion: Rice-fish co-culture system breaking through the Hu Line. Ecological Indicators, 133, 108385. https://doi.org/10.1016/j.ecolind.2021.108385

Lobo, A. S., & Bhandari, A. (2021). Nature Based Solutions: A Tool-kit for Panaji. Project Urban Living Lab. Retrieved from https://www.transitionsresearch.org/wp-content/uploads/reports/NBS%20TOOLKIT%20-%20Panaji__PULL.pdf

Martinez, M. L., Silva, R., Mendoza, E., Oderiz, I., & Maqueo, O. P. (2016). Coastal Dunes and Plants: An Ecosystem-Based Alternative to Reduce Dune Face Erosion. Journal of Coastal Research, 75, pp. 303-307. https://doi.org/10.2112/SI75-061.1

Mascarenhas, A. (2009). An experiment to restore coastal sand dunes at Miramar beach, Goa: An appraisal. In A. Mascarenhas & G. Kalavampara (Eds.), Natural Resources of Goa: A Geological Perspective (Chapter 8). Geological Society of Goa. https://www.researchgate.net/publication/40901669_An_experiment_to_restore_coastal_sand_dunes_at_Miramar_beach_Goa_An_appraisal

Mascarenhas, A. (2002). Restoration of sand dunes along human-altered coasts: a scheme for Miramar beach, Goa. Retrieved from https://www.researchgate.net/publication/27667306_Restoration_of_sand_dunes_along_human-altered_coasts_a_scheme_for_Miramar_beach_Goa

Ministry of Environment, Forest and Climate Change, Government of India (2019). CRZ NOTIFICATION. Retrieved from https://crz.elaw.in/crz2019.html

Ministry of Housing and Urban Affairs (MoHUA) - National Institute of Urban Affairs (NIUA), 2021. Cities Readiness Report, ClimateSmart Cities Assessment Framework 2.0, National Smart Cities Mission https://niua.in/csc/assets/pdf/key-documents/Cities-Readiness-Report.pdf

National Centre for Sustainable Coastal Management. (2021). Coastal Zone Management Plan as per CRZ Notification, 2011. Ministry of Environment, Forest & Climate Change, Government of India. https://www.czma.goa.gov.in/ViewDoc.aspx

National Centre for Sustainable Coastal Management, Ministry of Environment, Forest & Climate Change, Government of India. (2022). Coastal Zone Management Plan (Map No. GA 8, Sheet No. D 43 B 15/NW). Prepared for the Department of Environment and Climate Change, Government of Goa. https://www.czma.goa.gov.in/Docs/HPSCANS/ga8.pdf

Niesten, E., & Gjertsen, H. (2010). Report: Case Studies of Three Economic Incentive Approaches in Marine Conservation. Science-to-Action. https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/Non-CRCP/Corals/Case_Studies_Economic_Incentives_Approaches_Marine_Conservation.pdf

Padma, T. V. (2022, July 21). Successful model of development in tandem with mangrove restoration. Mongabay Series: Beyond Protected Areas, Climate Connections, Eco Hope. https://india.mongabay.com/2022/07/successful-model-of-development-in-tandem-with-mangrove-restoration/

Palanisamy, M., & Yadav S. K. (2022). Seaweed Flora of Goa coast. Botanical Survey of India. BSI Publications, 121 pp, India: Kolkata. https://bsi.gov.in/uploads/documents/Public_Information/publication/books/state_flora/Seaweed%20Flora%20of%20Goa%20coast%20%20Dr.%20M.%20Palanisamy%20&%20Dr.%20S.K.%20Yadav.pdf

Panwar, P., Mahalingappa, D. G., Kaushal, R., Bhardwaj, D. R., Chakravarty, S., Shukla, G., Thakur, N. S., Chavan, S. B., Pal, S., Nayak, B. G., Srinivasaiah, H. T., Dharmaraj, R., Veerabhadraswamy, N., Apshahana, K., Suresh,

C. P., Kumar, D., Sharma, P., Kakade, V., Nagaraja, M. S., & Gurung, T. (2022). Biomass production and carbon sequestration potential of different agroforestry systems in India: A critical review. Forests, 13(8), 1274. https://doi.org/10.3390/f13081274

Ramanathan, D., Padmanabhan, V., Lassen, U., Fuentes Dellepiane, G., Holm, B., & Sulejmani, M. (2021). St. Inez Creek Rejuvenation Plan- Panaji. Project Urban Living Lab https://transitionsresearch.org/wp-content/uploads/reports/St.%20Inez%20Creek%20Rejuvenation%20Plan__PULL.pdf

River Rejuvenation Committee. (2019, April). Action Plan Report on Mandovi River. Government of Goa. https://goaspcb.gov.in/Media/Default/River-action-plan/Mandovi%20%20River%20Action%20Plan__R1__090419.pdf

Sharma, D. (2016). Climate Resilient Infrastructure Services in Visakhapatnam and Panaji, India [Case study on a project of The Energy and Resources Institute]. Ed. Rachel M. Gregg. Retrieved from CAKE: www.cakex.org/case-studies/climate-resilient-infrastructure-services-visakhapatnam-and-panaji-india

Sanchez, F. G., & Dhanapal, G. (2023). Integrating blue-green infrastructure in urban planning for climate adaptation: Lessons from Chennai and Kochi, India. Land Use Policy, Vol 124. https://doi.org.10.1016/j.landusepol.2022.106455

Singh, A., Kazmi, A., Starkl, M., & Naik, M. (2015). Sewage Treatment and Management in Goa, India: A Case Study. Expo Health, Springer. https://www.researchgate.net/publication/284715711_Sewage_Treatment_and_Management_in_Goa_India_A_Case_Study

Systemiq. (2023). The Mangrove Breakthrough Financial Roadmap: Unlocking investment at scale in critical coastal ecosystems. https://climatechampions.unfccc.int/wp-content/uploads/2023/11/SY031_MangroveBreakthrough_2023_v7_JG.pdf

TERI Web Desk. (2018, October). A Goa village that strives to protect the fast-vanishing 'Khazans'. Retrieved from https://www.teriin.org/article/goa-village-strives-protect-fast-vanishing-khazans

U.S. Fish & Wildlife Service (2024a). National Fish Passage Program. https://www.fws.gov/program/national-fish-passage

U.S. Fish & Wildlife Service (2024b). Fish Passage Portal. https://interagency-bil-fish-passage-project-1-fws.hub.arcgis.com/

Vidya, P. J., Chatterjee, S., Ravichandran, M., Gautham, S., Nuncio, M., & Murtugudde, R. (2023). Intensification of Arabian Sea cyclone genesis potential and its association with Warm Arctic Cold Eurasia pattern. Npj Climate and Atmospheric Science, 6(1), 1-9. https://doi.org/10.1038/s41612-023-00476-2

Yeung, P. (2024, March 4). How a Colombian city cooled dramatically in just three years. Reasons to be Cheerful (US). https://reasonstobecheerful.world/green-corridors-medellin-colombia-urban-heat/

Zhong, C., Li, T., Bi, R., & Du, H. (2023). A systematic overview, trends and global perspectives on blue carbon: A bibliometric study (2003–2021). Ecological Indicators, Vol 148. Retrieved from https://doi.org/10.1016/j.ecolind.2023.110063

Contact
hello@transitionsresearch.com

Transitions Research