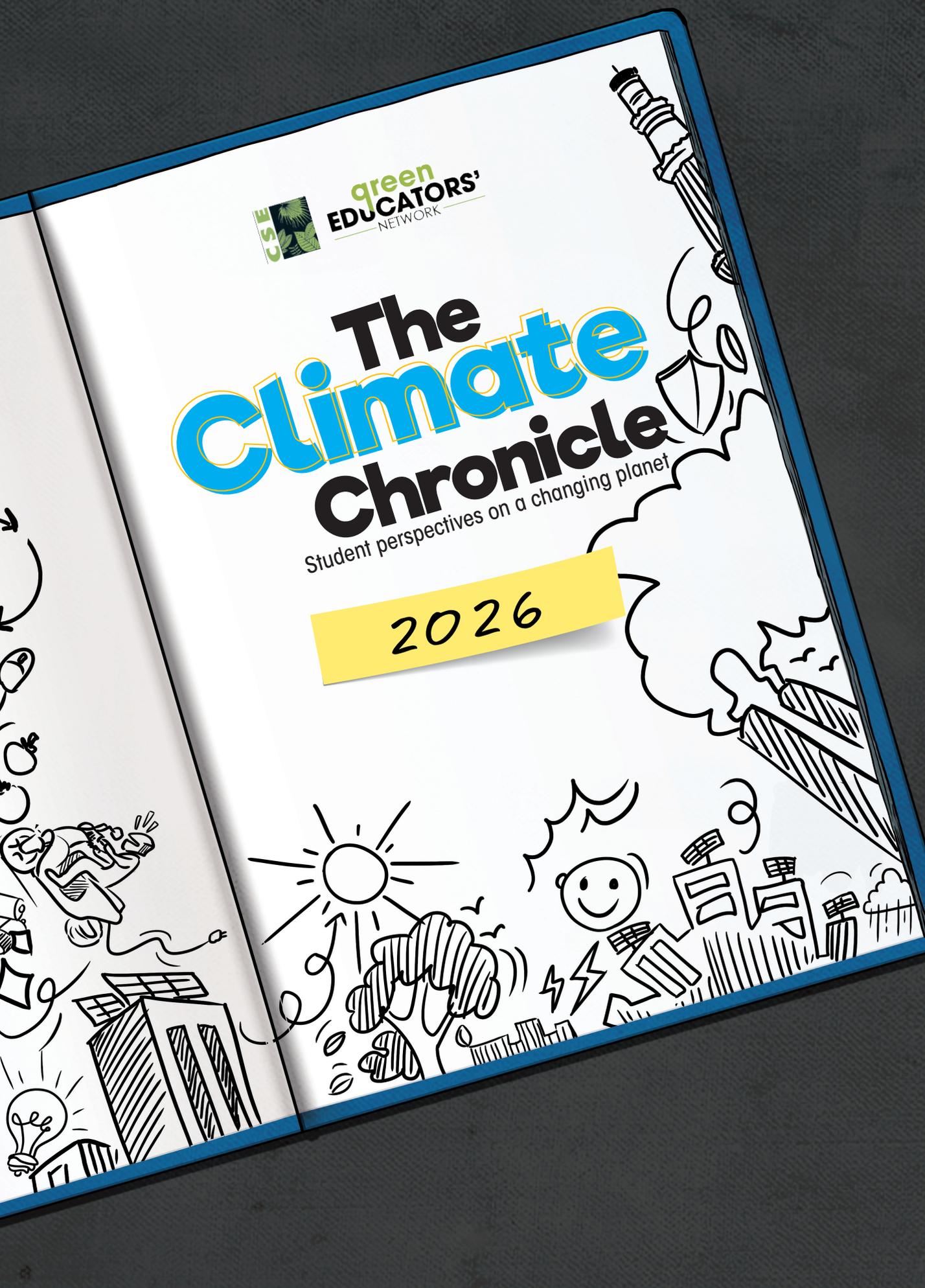




The Climate Chronicle

Student perspectives on a changing planet

2026



"Now we know the air we breathe is toxic and the water we drink is poisoned; climate change is threatening our food, livelihood and housing security; and we are losing our rich biodiversity. The situation is dire indeed. But we must fight these threats to our existence, and we must win. But to fight and win—as we must—we must learn about the issues so that we can be part of the change. I believe, each one of us is part of the problem and so can be the solution. You must be that solution."

Sunita Narain

The **Climate** Chronicle

Student perspectives on a changing planet **2026**

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Contents

Clearing the Air	2
Breathing Across Borders	4
Cities in Suspension	6
The Mineral Leash	8
The Lithium Loop	10
Holding the Coast	12
Facing the Heat	14
Fragile Frontiers	16
Too Ripe for the Road	18
Mangrove Under Siege	20
The Unseen Current	22
Outsourcing Risk	24
Integrating Solar into Structure	26
Policy vs Practice	28
Rethinking Urban Energy	30
Solar on the Rooftops	32



Archith J

Clearing the Air

Decoding Kochi's Emerging Smog Story

Kochi is a rapidly urbanising coastal metropolitan city along the southwestern coast of India. It plays a critical economic role as a major port, commercial and transport hub. Due to its tropical maritime climate, frequent rainfall, and sea-land breeze circulation, Kochi has traditionally maintained relatively better air quality compared to many Indian cities. However, in recent years, the city has begun to experience increasing concentrations of key pollutants and smog-like conditions, particularly during dry and winter months. Rapid urbanisation, expansion of transport infrastructure, construction activity and changing meteorological patterns have contributed to emerging air quality concerns. Although AQI levels generally remain moderate, certain periods now record deterioration.

Rapid urban growth and increased vehicular density have significantly altered the city's emission profile. Vehicular emissions now constitute a major source of particulate matter

such as PM_{2.5} and PM₁₀, along with nitrogen oxides and carbon monoxide in densely populated areas.

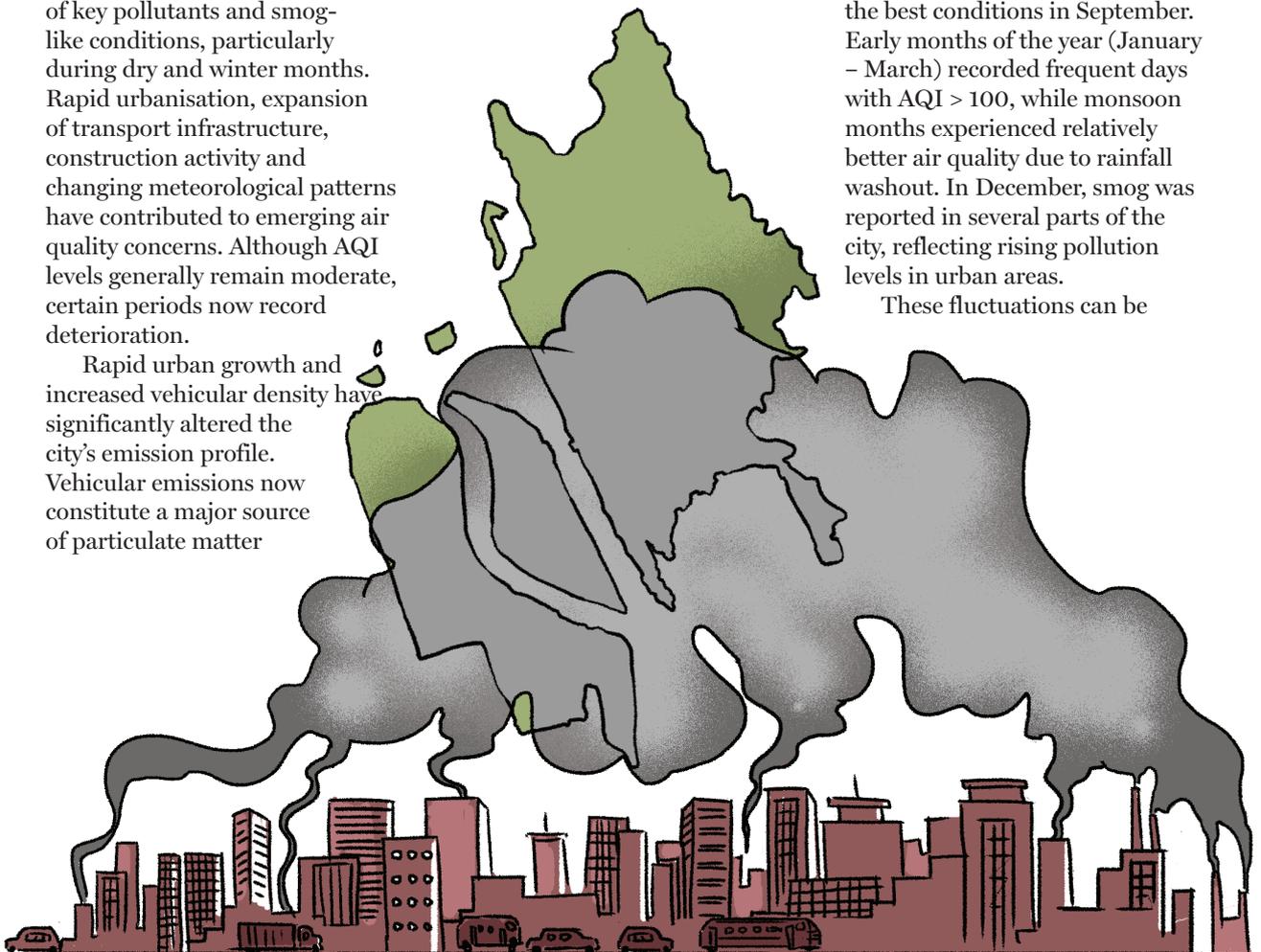
From 2018 to 2024, pollution levels in Kochi showed an uneven but worrying pattern. There was a temporary decline in 2020, but levels rose again afterward, with a sharp spike in 2022. In recent years, PM₁₀ exceeded the safe limit of 60 $\mu\text{g}/\text{m}^3$ multiple times and PM_{2.5} crossed the 40 $\mu\text{g}/\text{m}^3$ standard, showing that air

quality has repeatedly exceeded recommended limits.

According to the Ministry of Road Transport and Highways data, registered vehicles increased from about 9,34,041 in 2019 to 9,56,561 in 2020, with continued growth, including nearly 97,000 new vehicles added in 2024 alone, contributing to rising particulate levels.

Annual analysis shows that in 2025, Kochi's AQI varied across the year, with the most severe air quality observed in December and the best conditions in September. Early months of the year (January – March) recorded frequent days with AQI > 100, while monsoon months experienced relatively better air quality due to rainfall washout. In December, smog was reported in several parts of the city, reflecting rising pollution levels in urban areas.

These fluctuations can be



attributed to a combination of vehicular emissions, rapid urbanisation, and meteorological factors. During winter, low wind speeds and temperature inversion trap pollutants near the surface, resulting in smog-like conditions. Core urban areas also experience the Urban Heat Island effect, where temperatures are higher than surrounding regions, further influencing pollutant concentration. The permissible annual limit for PM_{2.5} is 40 µg/m³ and for PM₁₀ is 60 µg/m³, yet Kochi has exceeded these limits in multiple years, indicating the need for stronger air quality management.

Air pollution affects public health, urban planning, economic productivity, and environmental stability. Ecologically, particulate deposition damages vegetation, reduces photosynthesis, and may alter soil and water chemistry in coastal and backwater ecosystems. Increased aerosol loading can also influence local microclimate and radiation balance.

From a public health perspective, sustained exposure to PM_{2.5} and PM₁₀ increases respiratory and cardiovascular risks, particularly during winter smog episodes when dispersion is limited. A WRI India assessment from 2017 to 2020 found that over 30 per cent of Kochi's population is exposed to temperatures above 35 degrees Celsius during winter, compounding environmental stress.

AQI values above 100 during several months indicate moderate to poor air quality, which can trigger asthma, bronchitis, and allergic reactions. Reduced visibility during smog episodes also affects mobility and urban liveability. Pulmonologists from the Cochin Thoracic Society have reported an increase in young asthma patients. A screening study of 6,920 individuals recorded a

36.5 per cent asthma prevalence rate, significantly higher than earlier government estimates of 10 to 15 per cent.

Children, the elderly, and individuals with pre-existing respiratory conditions remain particularly vulnerable to air pollution. At the same time, outdoor workers, including traffic police, street vendors, construction labourers and port workers, face prolonged exposure due to the nature of their work. Low-income communities living near traffic corridors or industrial zones bear a disproportionate burden of health risks, compounded by limited access to healthcare and protective measures.

Kochi's emerging smog episodes reveal how rapid urbanisation and vehicular growth are straining a once clean coastal city, highlighting the need for stronger air quality management and urban planning

Air quality management in Kochi operates within the National Regulatory Framework of the Central Pollution Control Board under the National Ambient Air Quality Standards, 2009. Real-time monitoring is conducted through the National Air Quality Index system, while the Kerala

State Pollution Control Board monitors ambient air quality and enforces emission norms. The implementation of Bharat Stage VI vehicular emission standards in 2020 represents a major national intervention to reduce particulate emissions.

The Greater Cochin Development Authority influences air quality indirectly through master planning, land use regulation, transport corridor management, and green space allocation. Urban mobility improvements and metro expansion under Kochi Metro Rail Limited aim to reduce vehicular emissions. Civil society organisations, including the Centre for Public Policy Research, have highlighted declining air quality trends and advocated for stricter enforcement of construction dust control, waste burning regulations, and vehicular emission compliance.

Despite these measures, structural barriers persist. Limited monitoring coverage restricts identification of intra-city pollution hotspots, while the absence of detailed emission inventories and ward-level assessments weakens targeted interventions. Rapid urbanisation and rising private vehicle ownership continue to compound the challenge.

Addressing smog requires expanding air-quality monitoring and developing ward-level emission inventories to identify local sources. Transport reforms, including strengthening public transport and promoting electric mobility, can reduce vehicular emissions, while stricter control of construction and road dust remains essential.

Protecting vulnerable groups calls for stronger AQI advisories, effective early warning systems, and timely alerts for schools, hospitals, and outdoor workers.

*Ishaan Khemani*

Breathing Across Borders

Comparing Urban Air Governance in China, UK, and India

The World Health Organization attributes millions of premature deaths each year to exposure to ambient air pollution, largely due to cardiovascular and respiratory diseases. Rapid urbanisation, industrial expansion, and increasing motorisation have intensified air quality deterioration across both developed and developing economies. China, India, and the United Kingdom—particularly London—represent contrasting developmental trajectories and governance structures, making them valuable cases for comparative analysis.

A comparative analysis of China, India, and the UK demonstrates improvements in urban air quality depend on integrating regulatory reform, transport policy, and social equity into a coherent governance framework

China's rapid industrial growth and coal-dependent energy system resulted in severe urban pollution during the early 2000s, prompting national and international concern. India faces a more complex and fragmented pollution profile, driven by vehicular emissions, construction dust, biomass burning, informal industrial activity, and weak regulatory enforcement. The United Kingdom, by contrast, reduced industrial emissions through early legislative interventions, yet London continues to struggle with transport-related pollution. Examining these three contexts provides insight into how governance capacity, institutional arrangements, and policy design influence air quality outcomes, a question of particular relevance for India.

The objective of this study is to compare urban air quality conditions, pollution sources, and governance frameworks in China, London, and India. It assesses policy effectiveness, identifies institutional gaps, and draws lessons to strengthen air pollution management, especially in the Indian context.

Urban air pollution has evolved differently across China, India, and the United Kingdom due to differences in economic structure, energy use, and governance capacity. In China, rapid industrialisation and coal-based energy led to extremely high particulate matter and nitrogen dioxide levels in the

early 2000s, prompting the state to treat air pollution as a national priority under public and political pressure. India's pollution is more heterogeneous and spatially dispersed, driven by transport emissions, construction dust, waste burning, small-scale industries, biomass use in peri-urban areas, and seasonal crop residue burning in northern cities such as Delhi. Fragmented sources, institutional overlap, and limited enforcement complicate regulation. The United Kingdom reduced industrial pollution through legislation such as the Clean Air Acts, yet London continues to face elevated nitrogen dioxide levels from diesel-dominated transport, with implementation often encountering economic and political resistance despite strong monitoring systems.

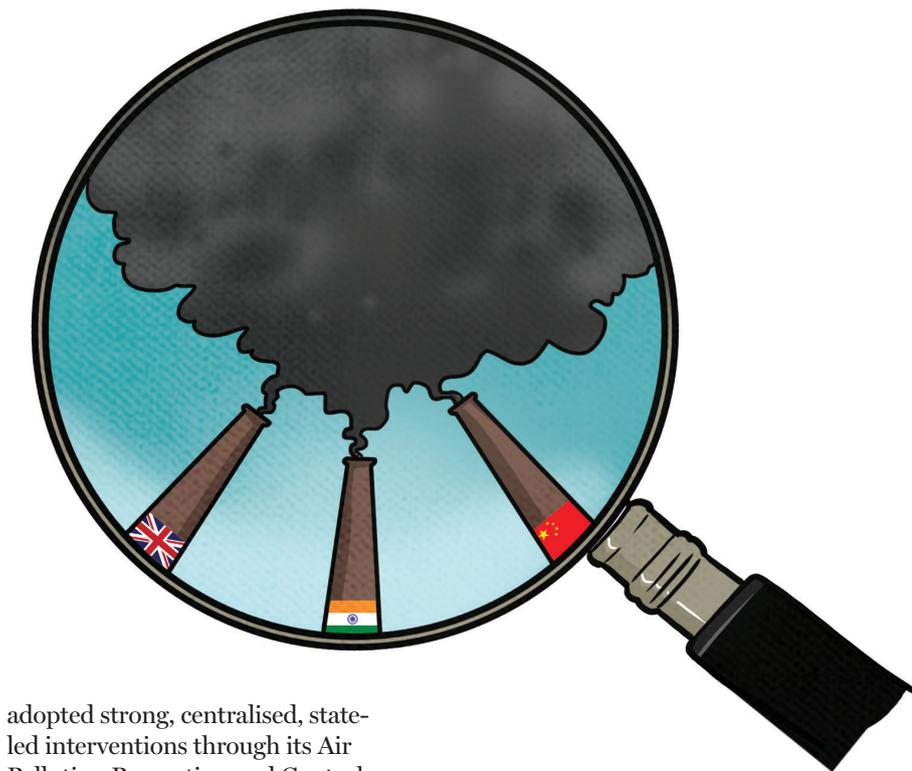
Comparative indicators reveal clear differences. Average urban PM_{2.5} concentrations in China range between 35 and 40 micrograms per cubic metre, in India between 45 and 50, and in London between 10 and 12, all exceeding the WHO guideline of 5. China's pollution is dominated by coal and industry, London's by road transport, and India's by a multi-source mix including transport, dust, and biomass. Pollution patterns also differ. China exhibits concentration around industrial clusters, London around transport corridors, and India shows seasonal and multi-source variation. These disparities reflect

differences in governance capacity and enforcement.

The ecological, health, and socio-economic consequences of urban air pollution are significant. High concentrations of particulate matter and nitrogen oxides contribute to haze, acid deposition, and damage to vegetation. In China and India, prolonged exposure has degraded urban ecosystems and affected peri-urban agriculture. While pollution levels are lower in the UK, nitrogen dioxide in London continues to challenge compliance and threaten biodiversity. From a public health perspective, long-term exposure to PM_{2.5} increases the risk of cardiovascular disease, respiratory illness, stroke, and lung cancer. China and India bear a disproportionately high burden due to sustained high pollution levels, whereas London experiences more moderate but persistent health impacts related to transport emissions.

The distribution of impacts is uneven. Children face risks linked to lung development and outdoor exposure, particularly in India and China. The elderly are vulnerable to chronic exposure across all three contexts. Urban poor populations in India often live near roads or industrial sites, increasing exposure. Migrant workers in China face occupational risks, while outdoor workers in India encounter pollution from traffic and construction. Disease burdens are high in China and very high in India, while London's remains moderate. Economic impacts vary as well. China faces rising healthcare costs, London experiences productivity losses, and India endures both health and income losses. These patterns highlight how environmental degradation intersects with social inequality.

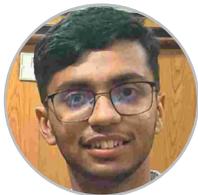
Policy responses reflect distinct governance models. China has



adopted strong, centralised, state-led interventions through its Air Pollution Prevention and Control Action Plan and related initiatives, introducing strict emission standards, coal transitions, and rigorous enforcement that have led to measurable improvements in urban air quality. The United Kingdom combines regulatory frameworks with market-based instruments, with London's low emission zone and ultra low emission zone targeting vehicular emissions under strong monitoring and legal accountability, supported by active civil society campaigns and litigation. India has implemented national programmes such as the National Clean Air Programme and city-level action plans, with judicial interventions and civil society activism highlighting governance failures; however, enforcement remains weak to moderate, institutional fragmentation persists, and partial fund utilisation along with overemphasis on specific pollution sources have constrained outcomes.

Comparative analysis highlights key lessons. Strong institutions, enforceable regulations, and coordinated

policy design are essential. China's experience demonstrates that stringent emission standards, continuous monitoring, and penalties can achieve sustained reductions when backed by political commitment and administrative capacity. India can improve accountability by linking city-level targets under its National Clean Air Programme to financial incentives and penalties. Transport reform must also be prioritised in India. London's congestion pricing, emission zones, and expanded public transport show that regulatory and pricing tools can shape mobility patterns, though measures must remain affordable to avoid regressive effects on low-income groups. Policy frameworks should explicitly protect vulnerable populations by improving healthcare access, upgrading housing near major roads, and reducing occupational exposure for outdoor workers. Stronger civil society engagement can further enhance transparency and responsiveness.



Manthan Pasricha

Cities in Suspension

A Comparative Study of Pollution in India

India's rapid urbanisation, industrial expansion, and vehicular growth have fundamentally altered the atmospheric composition of its cities. Concentrations of particulate matter and gaseous pollutants have risen to hazardous levels, though this transformation is not uniform. It reflects a complex interplay of geography, emission sources, and meteorological patterns. The Indo-Gangetic Plain acts as a natural pollution trap during winter, while coastal cities historically relied on sea breeze circulation for dispersion. However, recent monitoring data from the Central Pollution Control Board indicates that this natural advantage is increasingly overwhelmed by anthropogenic emissions, contributing to a nationwide crisis affecting over 1.4 billion people.

The socio-economic and public health implications are severe. Air pollution is now the leading environmental health risk in India, responsible for over 1.6 million premature deaths annually and reducing life expectancy by more than five years. The economic burden from lost productivity, healthcare costs, and agricultural losses amounts to nearly 8.5 per cent of GDP. In this context, air quality management has become central to national survival and sustainable development. This study uses standardised CAAQMS data to analyse trends in PM_{2.5}, PM₁₀, NO₂, and ozone across major metropolitan centres and rapidly growing Tier-II cities between 2023 and 2025.

The objective is to conduct an exhaustive comparative

analysis of air quality trends and pollutant interactions across eight cities—Delhi, Mumbai, Jaipur, Lucknow and others, establishing baseline particulate trends, examining diurnal and seasonal patterns of NO₂, and exploring its photochemical link with ground-level ozone. It also assesses the effectiveness of policy interventions under the National Clean Air Programme and proposes integrated responses to protect vulnerable populations.

India's air crisis is characterised by a multi-pollutant mix where PM_{2.5} remains the primary health concern while gaseous precursors like NO₂ and CO contribute to secondary aerosols and ozone formation. The problem is compounded by weak public transport systems, rapid growth in private vehicles, and widespread waste burning.



Recent data show divergent city trends. Delhi recorded a winter PM_{2.5} average of 175 $\mu\text{g}/\text{m}^3$ in 2024–25, reflecting a seven per cent decline from the previous year but still exceeding national standards. It experienced eight days of *severe-plus* and 68 days of *very poor* air quality that winter. Lucknow reported 162 $\mu\text{g}/\text{m}^3$ in winter 2024–25, showing a 41.2 per cent five-year reduction under NCAP, yet remaining in the severe category. Jaipur recorded an annual PM_{2.5} average of 63 $\mu\text{g}/\text{m}^3$ in 2024, with deteriorating PM₁₀ levels linked to arid dust and vehicles. Mumbai's winter average stood at 50 $\mu\text{g}/\text{m}^3$, reflecting a 16 per cent improvement, influenced by construction activity and sea breeze patterns.

Southern cities present a shifting pattern. Bengaluru recorded a winter PM_{2.5} average of 37 $\mu\text{g}/\text{m}^3$, showing a downward air quality trend and a 22 per cent AQI decline in 2025 compared to 2024. Chennai reported 36 $\mu\text{g}/\text{m}^3$, meeting standards seasonally but showing a slight upward trend. Kolkata and Hyderabad, at 65 and 52 $\mu\text{g}/\text{m}^3$ respectively, also exceeded standards despite moderate improvements.

Monthly data reinforce these findings. Delhi's Chandni Chowk station recorded repeated winter peaks near 175 $\mu\text{g}/\text{m}^3$, with severe spikes in November and December. Mumbai's Bandra Kurla station showed monsoon washout effects and relatively stable annual levels. Jaipur's monitoring reflected high PM₁₀ relative to PM_{2.5} due to dust. Lucknow's winter peaks remained extreme despite long-term reductions.

In Delhi, biomass burning combined with winter inversion traps pollutants, while in Lucknow industrial emissions and the Indo-Gangetic Plain's trapping

effect intensify winter pollution. In Jaipur, arid conditions and transport account for rising NO₂ levels, with transport contributing 25 per cent of emissions. In Mumbai, construction and urban density combine with seasonal meteorology. Waste burning and small-scale industrial activity further compound particulate concentrations across cities.

The consequences are systemic. Ecologically, ground-level ozone damages plant tissues and reduces photosynthesis, contributing to approximately three billion dollars

The crisis in India's air is as much about geography, socio-economic disparities, and governance as it is about emissions

in annual rice production losses. In Jaipur, native plant biodiversity is being replaced by pollution-tolerant species, weakening urban cooling systems.

Public health impacts are severe. Air pollution contributed to two million deaths in 2023. Emerging research links exposure to neurodegenerative diseases, with over 54,000 dementia-related deaths recorded in 2024. In Bengaluru, daily exposure levels are equivalent to smoking nearly three cigarettes, reflecting the invisible health burden.

The economic dimension is equally significant. Informal workers, including traffic police and street vendors, lost an estimated 181 billion labour hours in 2023 due to the combined effects of heat and pollution,

amounting to Rs 13 lakh crore in income loss. Children face impaired lung development, while the elderly and those with pre-existing respiratory conditions face elevated stroke and COPD risks.

Policy responses include BS-VI emission norms, FAME-II electric mobility incentives, and the PRANA tracking portal. However, implementation gaps persist. Only 40 per cent of NCAP funds were utilised between 2019 and 2023. Of the funds spent, 67 per cent targeted road dust, while industrial control and public outreach received minimal attention. Policy frameworks remain heavily particulate-focused, with limited emphasis on NO₂ and ozone management.

A transition from reactive control to sustainable urban management requires multiple interventions. Hyperlocal monitoring using AI-driven low-cost sensor networks can improve neighbourhood-level alerts. Transport reform must prioritise electric public mobility and reduce SUV dependence. Waste segregation and elimination of landfill fires are essential to control secondary particulate formation. Community-led initiatives such as the Indore waste model and NGO engagement can bridge awareness gaps.

If implemented effectively, these measures could reduce PM_{2.5} levels by up to 40 per cent, extend average life expectancy by 2.1 years, and reclaim substantial agricultural and economic value.

This comparative assessment demonstrates that India's air crisis is shaped not only by emissions but by geography, governance, and socio-economic disparities. Without structural reforms and integrated planning, metropolitan and Tier-II cities alike risk escalating from episodic pollution to chronic atmospheric instability.



Haathenlal Dimngel

The Mineral Leash

Electric Mobility in a Resource-Constrained World

The global transition to electric mobility has moved from being a niche ‘green’ alternative to becoming a central industrial priority. In India, under the PM E-Drive scheme, more than 2.2 million electric vehicles (EVs) have been deployed, particularly in the two-wheeler and e-rickshaw segments. The reasons are clear: cleaner urban air and lower operating costs in a time of volatile fuel prices.

However, as demand for EVs accelerates, industry has voiced concerns about cost and sustained accessibility of supply of critical battery minerals such as lithium, cobalt and nickel. What once seemed like a straightforward technological transition has become a resource challenge. In 2026, cross-country trade of minerals face geopolitical constraints that could be one of the challenges with meeting timelines of electrification.

The problem is structural. While a battery ‘gigafactory’ can be built in under two years, building a new lithium mine from discovery to production takes an average of eight to twelve years. This mismatch has created recurring supply deficits. Although lithium prices temporarily dropped in 2025 due to short-term oversupply, 2026 has entered a tightening phase as energy storage systems and mass-market EVs consume global inventories.

In addition, the supply chain is geographically concentrated. India still imports approximately

The EV revolution reflects both innovation and resource limits. Long-term sustainability depends on diversifying technologies, ensuring ethical sourcing, and building circular supply chains

70–80 per cent of its lithium-ion cells, largely from China. This dependence creates what can be called a ‘geopolitical tax’ on every EV sold. Trade tensions, export controls or disruptions can quickly raise prices, making EVs unaffordable for consumers. The promise of accessible green mobility becomes uncertain when mineral security is fragile.

While EVs are designed to reduce carbon emissions, the supply side of the industry carries ecological and social consequences. Lithium extraction, especially from brine in Chile’s Salar de Atacama, has been linked to severe water depletion. Producing one ton of lithium can require nearly half a million

litres of brine water, and groundwater levels in the region have fallen significantly over the past fifteen years. This has damaged vegetation, lagoons and ecosystems that local and indigenous communities depend on.

Cobalt supply presents another concern. A significant share of the world’s cobalt originates in the Democratic Republic of Congo, where artisanal mining is often associated with hazardous conditions and child labour. This reveals a contradiction as the ‘clean’ vehicle driven in one part of the world may rely on labour practices and environmental degradation elsewhere. A sustainable transition must account for both environmental and social justice.

Beyond ecological stress and the human costs, there are other concerns as well. High battery prices—accounting for 40–50 per cent of total vehicle cost—create a social affordability barrier. For example, in India, an electric Tata Nexon is priced at around Rs 16 lakh, compared to approximately Rs 9 lakh for its internal combustion engine version. For many middle-class families or small business owners, the upfront cost remains prohibitive. Supply shortages keep battery prices elevated, limiting green mobility largely to higher-income groups.

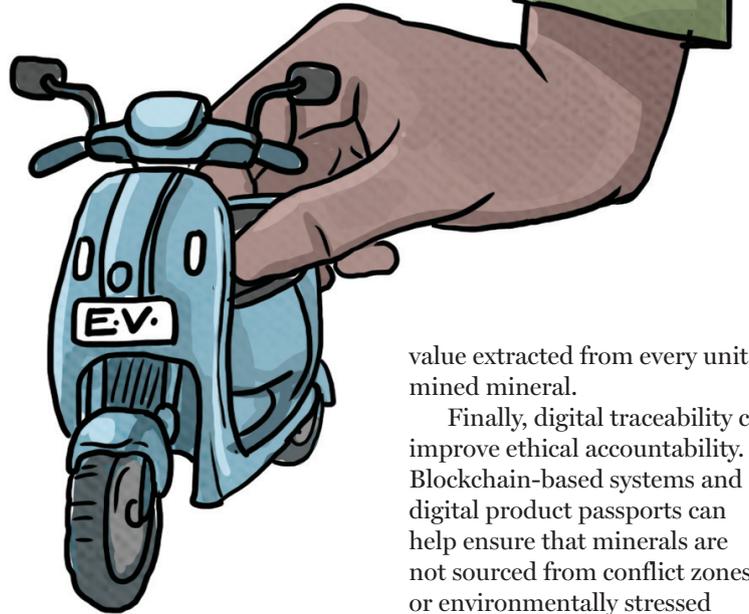
Governments have attempted to address these challenges, but most

policies focus on stimulating demand rather than strengthening supply chains. In India, the transition from FAME-II to the PM E-DRIVE scheme has reduced upfront costs for electric two-wheelers and buses. While this has increased adoption, it does not resolve mineral import dependency. Strict localization norms have also delayed subsidies because domestic manufacturers have begun to source some components locally, not raw materials.

Globally, new regulatory efforts are emerging. The European Union's 2026 Battery Regulation requires a 'battery passport' by 2027 to track the ethical and environmental footprint of battery cells. Such initiatives aim to improve transparency and accountability in mineral sourcing.

To ensure that electric mobility remains both sustainable and equitable, practical solutions are necessary. One promising alternative is the development of sodium-ion batteries. Sodium is far more abundant than lithium—approximately 450 times more plentiful—and can be sourced from common salt. Sodium-ion batteries are also projected to be 30–50 per cent cheaper per kilowatt-hour than lithium-ion batteries.

Shifting short-range vehicles such as two-wheelers and city cars to sodium-ion technology could reduce pressure on lithium supplies. Lithium could then be reserved for long-range transport and



heavy-duty applications. This would make EVs more affordable for working-class consumers, particularly in developing nations, while reducing exposure to fossil-fuel-related air pollution.

Another important approach is second-life battery use within a circular economy framework. When EV batteries degrade to about 70 per cent capacity, they may no longer be ideal for vehicles but are still valuable for applications with low performance demand. In 2026, such second-life systems are being used in rural areas to store solar power for nighttime use. This extends the life of each battery, lowers electricity costs for communities and maximises the

value extracted from every unit of mined mineral.

Finally, digital traceability can improve ethical accountability. Blockchain-based systems and digital product passports can help ensure that minerals are not sourced from conflict zones or environmentally stressed regions. Greater transparency can incentivise investment in more sustainable extraction methods, such as Direct Lithium Extraction, which uses less land than traditional evaporation methods.

The electric mobility revolution reflects both human ingenuity and the limits of natural resources. The transition cannot rely indefinitely on concentrated mineral supplies without addressing environmental and social impacts. A truly sustainable future requires investment in diversified technologies, ethical sourcing and circular resource use.

Electric vehicles represent progress, but that progress must not come at the expense of water-scarce ecosystems or vulnerable labour communities. By embracing sodium-ion alternatives, circular economy principles and transparent supply chains, it is possible to align rising demand with responsible resource management. Only then can electric mobility fulfil its promise as a solution that is not only environmentally efficient but also socially just.





Sauhard Kukreti

The Lithium Loop

Reimagining the Second Life of India's EV Batteries

India is undergoing an unprecedented transformation in its mobility landscape. Driven by FAME II subsidies and the PM E-Drive scheme, electric vehicle (EV) adoption is rising rapidly across the country, from two-wheelers to electric buses in city fleets. However, this transition is unfolding within a unique environmental and economic context. India remains resource-constrained, experiences high ambient temperatures, and continues to rely heavily on coal for electricity generation. While EVs promise cleaner urban mobility, they also introduce a new and urgent challenge: battery waste.

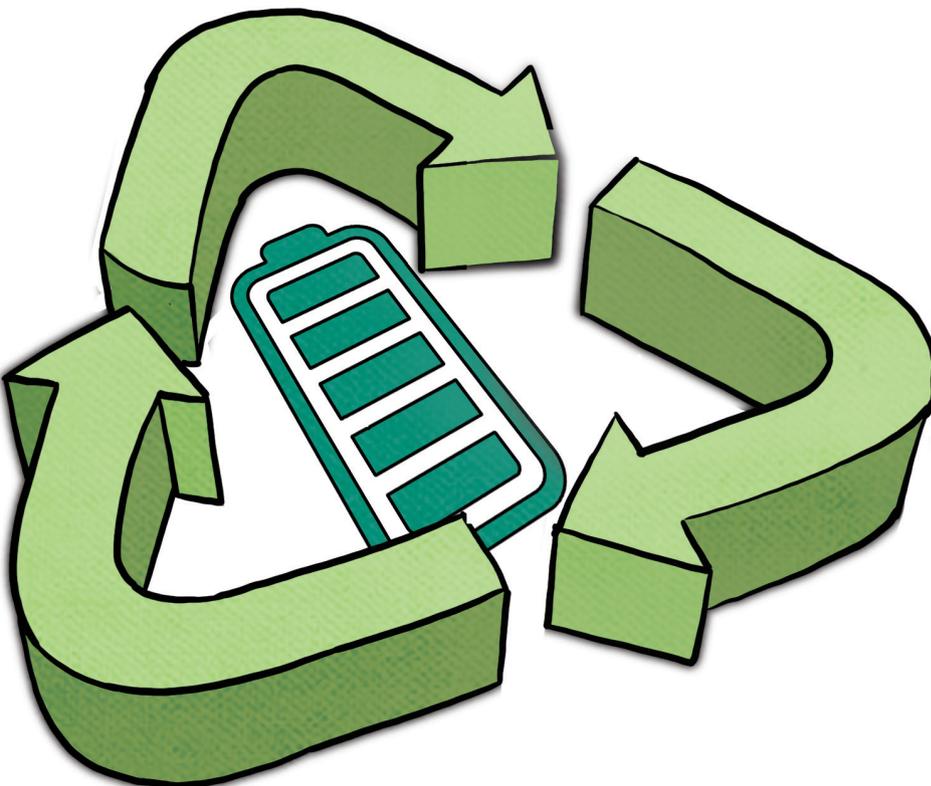
As the first generation of EVs begins to age, India faces the risk of a large-scale surge in lithium-ion battery disposal. India's rapid expansion in two- and three-wheeler segments means millions of battery packs may reach end-of-life within a couple of years. Without a robust formal recycling ecosystem, these batteries risk ending up in landfills, leaking toxic chemicals into soil and groundwater, or being processed in unsafe informal smelting units. The environmental implications are severe, particularly in a country already struggling with waste management.

The core issue lies in the absence of a robust system to manage this growing stream of lithium-ion battery waste.

According to NITI Aayog, India could generate over 128 GWh of battery waste by 2030. Historically, India's response to electronic waste has been reactive, relying heavily on informal recycling networks. This precedent raises concerns for the EV transition, as the informal sector will become the primary handler of high-voltage battery waste.

A key misconception surrounds the definition of a 'dead' EV battery. Batteries are considered retired when their capacity drops to around 70–80 per cent, as they can no longer deliver the peak power required for vehicle acceleration. However, they still retain significant energy capacity. This residual capacity makes them suitable for less demanding applications such as stationary energy storage for solar hubs, etc. Instead of opting for immediate disposal or crude recycling, which represents a loss of valuable energy and material, these batteries should first be channelled for reuse before being recycled.

Current informal recycling practices pose additional risks. Rudimentary smelting methods, particularly pyrometallurgy, burn batteries to extract base metals. This process destroys the cathode structure, often loses lithium entirely, and releases toxic emissions. Furthermore, India predominantly uses Lithium Ferrous Phosphate (LFP) batteries, which are safer and cheaper and do



not contain expensive metals such as cobalt and nickel. This increases the likelihood that they will be disposed of rather than responsibly processed, creating hazards such as chemical leaching and landfill fires.

The ecological consequences of mishandled EV batteries are significant. Lithium-ion batteries contain hazardous materials including heavy metals and flammable electrolytes. When disposed of in landfills, their protective casings degrade over time, allowing chemicals to seep into soil and groundwater. Contamination can persist for decades, affecting agricultural productivity and the food chain. Groundwater contamination threatens drinking water supplies and increases the risk of heavy metal poisoning. Damaged cells can also trigger fires that could be uncontrollable, releasing toxic gases into the atmosphere. Burning battery casings release particulate matter and harmful fumes, contributing to respiratory illnesses.

Unfortunately, the burden falls disproportionately on vulnerable populations. Communities living near landfills or informal recycling hubs face direct exposure to these risks.

Informal waste pickers and recyclers form the backbone of India's waste economy but operate without protection. Many dismantle batteries manually, exposing themselves to carcinogenic chemicals and electric shock hazards. Economically, they remain confined to low-value activities such as breaking and burning, earning minimal wages while facing high health risks. Child labour in informal battery waste environments furthers safety risk, particularly when dealing with heavy, high-voltage EV batteries.

The Government of India has

introduced the Battery Waste Management Rules, 2022, marking a significant policy shift. These rules establish Extended Producer Responsibility (EPR), making manufacturers legally and financially responsible for collecting and recycling batteries. Collection and recovery targets aim to encourage more efficient hydrometallurgical processes over crude smelting. However, implementation challenges remain. Reverse logistics for transporting heavy batteries to centralised facilities is costly. Informal scrap dealers often pay cash up front, making it difficult for compliant recyclers to compete. Additionally, the lack of standardised testing infrastructure limits certification for second-life use, discouraging financial investment in repurposing projects.

A viable solution lies in a structured 'cascade utilisation' model. Instead of direct recycling, retired batteries should first enter a mandatory second-life phase. Aggregated and repackaged into Battery Energy Storage Systems (BESS), they can power telecom towers, replace diesel generators, or store solar energy in rural microgrids. This approach extends battery life while reducing pressure on raw material extraction.

A digital battery passport system can further strengthen accountability. Blockchain-based tracking of battery health, chemistry and ownership history would ensure transparency and reduce leakage into informal channels. Establishing decentralised collection hubs at EV dealerships and service centres can ease reverse logistics and improve compliance.

Importantly, the transition must integrate, and not exclude, the informal sector. Training programs can equip waste pickers

India's rapid EV transition is expected to create a surge in lithium-ion battery waste. India must strengthen its reuse and recycle ecosystems to prevent an environmental crisis and to support energy security

with safe dismantling skills. Recognising them as official last-mile collection agents, with payments of fair premiums for depositing batteries at authorised centres, can protect livelihoods while ensuring environmental safety. Urban local bodies must enforce bans on landfill disposal and designate safe drop-off points, while NGOs can bridge gaps through awareness campaigns, health camps and advocacy.

If implemented effectively, such a framework can reduce dependence on lithium imports, enhance grid stability through affordable storage, and formalise thousands of jobs within a safer system. India's EV revolution must therefore move beyond mobility alone and address the full lifecycle of batteries. By shifting from only disposal to reuse, and from informality to integration, can the country ensure that its green transition does not create new environmental crises.



Chahat

Holding the Coast

Building Urban Resilience in Coastal Kerala

Kerala, located along the western coast of India, presents a geographically narrow yet ecologically diverse landscape. Though it accounts for only about 1.3 per cent of India's total land area, it supports a population of 3.34 crore (2011 Census) and contributes nearly 3.65 per cent to the national GDP. However, the 2018 Kerala floods and the 2024 Wayanad landslides highlight concerning challenges in keeping the state secure from adverse climatic extremes.

Kerala is ranked as the second most urbanised state in India, with nine of its fourteen districts having significant coastlines, including the capital city, Thiruvananthapuram. Major cities such as Kochi, Kozhikode and Malappuram are located along the coast, placing dense populations and infrastructure directly within zones of climatic exposure. Floods, erosion, landslides and seasonal water scarcity have emerged as interconnected challenges. Reliable infrastructure that can withstand inundation, shoreline retreat and landslides, while also ensuring water security during dry periods, has become essential.

Although Kerala has recorded an overall decreasing trend in average rainfall with high interannual variability, deeper analysis offers two key observations. Indian southwest monsoon rainfall and northeast monsoon rainfall have shown relative stability and a decline in variability. However, monthly

patterns indicate increased variability during winter and pre-monsoon summer periods. Pre-monsoon and southwest monsoon phases now show higher outlier distribution, intensified rainfall cycles and thermal disturbances, pointing to increased cyclonic activity. Irregular deluges during May, June, July and September have become more pronounced. Anomalies in Arabian Sea upwelling and sea surface temperatures have further amplified the frequency and duration of extreme events.

Kerala's topography intensifies these impacts. The steep slopes of the Western Ghats, which cover nearly half the state, are highly susceptible to landslides. Transported sediments, rising water volumes and structural debris become major concerns for downstream towns during torrential episodes, as highland

runoff increases regional discharge and renders water unsuitable for regular use. Spatial data also show inverse trends between northern and southern Kerala, with recent decades recording a positive rainfall trend in the north and a negative trend in the south, creating a sharp contrast where some regions face flooding while others confront scarcity. Temporal rainfall deviations combined with shallow, porous aquifers intensify monsoon floods and landslides and lead to water shortages during dry seasons. These events can cause astronomical damage to life and property and endanger the state's delicate natural environment.

Coastal plains and midlands, composed largely of lateritic and sandy soils, experience high porosity and drainage, resulting in water shortages despite intense rainfall episodes. Studies suggest that nearly 45 per cent of Kerala's coastline is undergoing erosion, placing coastal settlements at risk of shoreline retreat and habitat loss. Collectively, these lead to forced migration, lost livelihood, a ruptured economy, and a destabilised ecosystem. The growing coastal population will bear the consequences of unplanned and environmentally incompatible development, particularly those dependent on natural resources for their livelihoods.

Coastal populations are often least equipped to tackle and rebuild after a disruptive event with middle and lower socio-

With 9 out of 14 districts placed along the coast and nearly half of its population urbanised, Kerala's climate risk is spatially embedded in its cities, requiring resilient urban planning

economic groups in hazard-prone areas bearing a disproportionate share of the damage. In response, Kerala launched the Resilient Kerala Program under the Rebuild Kerala Initiative, backed by the World Bank, aiming to establish adaptive and resilient safety standards for thirty critical coastal stretches. Temporary measures such as sand-filled geo bags in Chellanam have also been effective. However, short-term interventions must evolve into durable and integrated solutions.

Several cross-cutting measures are needed to protect coastal populations from climatic variability. Mapping and evaluation of vulnerable coastal stretches are essential to identify priority zones. Quarterly and annual assessments can guide conservation efforts and resource allocation. Central agencies such as NCCR and INCOIS, in coordination with local authorities including KWA and KCZMA, must work alongside IMD systems to strengthen early warning mechanisms. Flooding and erosion need hybrid innovations that integrate built infrastructure with nature-based solutions

Offshore reef amplification paired with sea walls can reduce tidal energy while preserving marine ecosystems. Salt marshes and surge barriers can mitigate sudden sea level surges. Dunes and living shorelines reduce wind intensity and prevent aeolian erosion and saline intrusion. At the urban scale, expanded drainage systems are necessary to accommodate heavy runoff. Constructing water squares along runoff routes toward backwaters can store excess water for reuse, addressing both flooding and scarcity.

The sponge city model presents another viable approach. Given Kerala's natural slope toward the coast, water banks can be



developed to channel and store runoff. These can integrate with existing drought mitigation initiatives. The Mazhapolima programme in Thrissur district, which revived and recharged aquifers through participatory well recharge and hyperlocal open dug wells, offers a replicable model for other districts. Expanding infiltration and drainage extensions across coastal regions would strengthen groundwater resilience.

Traditional agricultural practices also form a critical component of climate adaptation. Pokkali farming, practised in districts such as Alappuzha, Kottayam, Thrissur and Ernakulam, is a saline-resistant paddy cultivation system rotated with prawns and shrimps. Despite its resilience to saline and alkaline water, pokkali farming faces decline due to labour shortages, limited mechanisation and insufficient policy support. Integrating pokkali cultivation into flood-prone zones can serve as a natural reservoir for excess water while strengthening food and livelihood security. Preserving

pokkali as an intangible cultural heritage reflects a commitment to climate-responsive agro-practices.

International models also provide useful insights. Copenhagen's Cloudburst Management Plan demonstrates how blue-green infrastructure and multi-functional urban design can manage extreme rainfall. Adapting such models to Kerala's ecological context, in partnership with local communities and civil society organisations, can enhance urban reliability during climatic shocks. Proactive governance, regular post-implementation assessments and climate accounting are essential to ensure accountability and sustained impact.

Failure to address flooding, erosion and water scarcity risks undermining Kerala's social and economic foundations. Climatic challenges are no longer episodic disruptions but structural realities. Securing Kerala's coastal cities demands immediate, coordinated and ecologically sensitive action to safeguard its financial, environmental and social fabric.

*Ruchita Patil*

Facing the Heat

Ozar's Rising Thermal Challenge

Indian cities are heating up at an unpredictable rate. Rapid urbanisation, concretisation and declining green cover have intensified the Urban Heat Island effect, where developed urban zones experience significantly higher temperatures than surrounding peri urban and rural areas. Ozar, a Census town about 20 kilometres from Nashik in Maharashtra, reflects this transformation. Traditionally known for moderately high summers, the town has been recently witnessing rising temperatures and increasing heatwave conditions.

Ozar's growth has been driven by the presence of Hindustan Aeronautics Limited, the Air Force, and other industries. Residential colonies and commercial structures have expanded, largely constructed with reinforced cement concrete roofs or metal sheets. Tree cover within residential areas remains limited, and open plots are steadily being converted into buildings. Combined with declining vegetation and high heat exposure, these conditions have created a microclimate that is vulnerable to elevated surface temperatures.

Rooftop temperature and albedo, which refers to how much sunlight a surface reflects, are critical in understanding urban heat accumulation. Materials with low reflectivity such as dark concrete or asbestos sheets absorb and retain more solar heat, warming surrounding areas.

As Ozar expands with concrete and industry, rising rooftop heat is quietly transforming this small town's climate, energy demand and social vulnerability

In Ozar, summer temperatures exceed 40°C. These rooftop surfaces store heat during the day and release it slowly at night, preventing natural cooling and prolonging discomfort.

The objectives of this study are to examine rooftop surface temperature patterns in Ozar and understand their contribution to localised heat stress, ecological disruption, and community vulnerability. It seeks to identify causes, impacts and practical mitigation strategies that can enhance thermal comfort, reduce energy demand and protect vulnerable populations.

Urban expansion has steadily replaced natural land cover with impervious built surfaces. Traditional clay-tiled roofs and shaded courtyards are increasingly being replaced by reinforced cement concrete slabs, metal sheets and dark waterproofing

coatings. This transition intensifies heat absorption and reduces passive cooling practices embedded in earlier architecture.

Rooftop heat connects closely with several broader concerns. Higher indoor temperatures increase reliance on air conditioning. In cities such as Delhi, peak electricity demand now regularly surpasses 7,000 MW during summer. Increased electricity demand often depends on fossil fuel-based generation, contributing to air pollution and greenhouse gas emissions. Heat stress aggravates dehydration, cardiovascular disorders and respiratory illnesses. The lack of rooftop regulation reflects wider gaps in climate sensitive urban planning. Socio economic inequality becomes more visible as wealthier households can afford cooling systems while poorer residents endure greater exposure.

Potential causes include the dominance of low albedo roofing materials, lack of awareness about cool roof technologies, absence of building codes mandating reflective surfaces, rapid unplanned urban growth, reduced vegetation, and economic constraints limiting retrofitting options.

The impacts extend beyond indoor discomfort. Increased heat absorption alters near surface air temperature and humidity, affecting microhabitats for urban flora and fauna. Accelerated soil moisture loss in adjacent areas stresses vegetation and reduces biodiversity. Elevated

thermal radiation can influence insect populations and disrupt pollination cycles that support agriculture.

Heat exposure disproportionately affects residents living under poorly insulated roofs. Low-income households in informal settlements often rely on metal sheet roofing that can reach surface temperatures above 60°C under direct sunlight. Indoor temperatures become dangerously high, increasing risks of dehydration, heat exhaustion and sleep disruption. Outdoor workers including industrial labourers, street vendors and agricultural workers face rising heat stress as ambient temperatures increase and built surfaces radiate heat. Elderly individuals, children and those with chronic illnesses face heightened vulnerability, particularly in homes lacking ventilation or cooling access. Increased cooling demand also raises electricity costs, placing financial strain on economically weaker households.

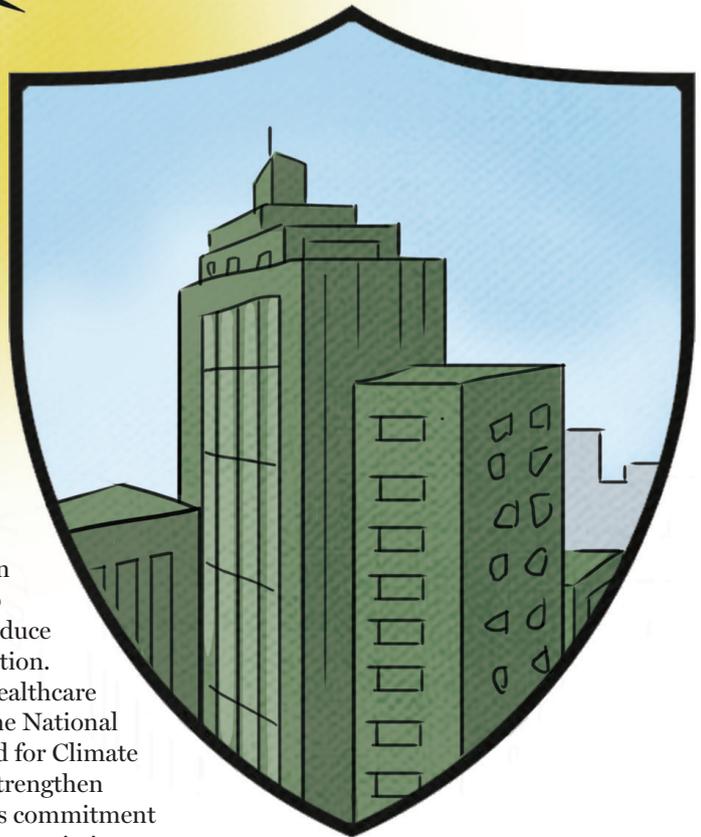
India has introduced several frameworks addressing urban heat mitigation. The National Solar Mission promotes renewable energy adoption. The Perform, Achieve and Trade scheme regulates industrial energy consumption. The National Mission on Sustainable Habitat focuses on energy efficient buildings, waste management and public transport. The Green India Mission aims to increase forest cover and restore ecosystems. Agriculture and water missions support climate resilient farming and conservation. The 2022 amendment to the Energy Conservation Act introduces a carbon trading market, mandates non fossil fuel use and sets efficiency standards for vehicles and vessels. Heat Action Plans have been prepared in several



regions. Revised air conditioning standards restrict operation within a 20°C to 28°C range to reduce energy consumption. Climate smart healthcare initiatives and the National Adaptation Fund for Climate Change aim to strengthen resilience. India's commitment to achieve net zero emissions by 2070 emphasises green hydrogen and industrial transition strategies.

Despite these measures, rooftop heat remains insufficiently addressed at the local scale. Practical solutions are required. For vulnerable groups, subsidised reflective coatings and community-based roofing improvement programmes can significantly reduce indoor heat exposure. Low-cost lime wash treatments with high reflectivity offer accessible relief for low-income households. Rooftop vegetation and shading structures can further reduce heat absorption while enhancing air quality.

Urban local bodies can integrate albedo guidelines into building permissions and retrofit schemes. Community



participation is essential. Local residents can be trained in applying reflective coatings and maintaining rooftop vegetation systems. Non-governmental organisations can facilitate awareness campaigns, technical training and financial support mechanisms such as micro grants or cooperative procurement of materials.

Ozar's experience demonstrates that small towns are equally vulnerable to rising urban heat. Material choices, planning decisions and community awareness will shape future thermal comfort and resilience. Addressing rooftop albedo and surface temperature can help in protecting health, reducing energy demand and ensuring equitable climate adaptation.



Tamaghna Banerjee

Fragile Frontiers

Ecology and Survival in the Sundarbans

The Sundarbans mangroves in South 24 Parganas, West Bengal, form one of the world's most fragile yet productive ecosystems. Recognised as a Ramsar Wetland of International Importance (2019) and a UNESCO World Heritage Site, this delta at the confluence of the Ganges and Brahmaputra spans hundreds of riverine islands across India and Bangladesh. Accounting for nearly 60 per cent of India's mangrove cover, it supports endangered species such as the Royal Bengal Tiger, estuarine crocodile, and

Irrawaddy dolphin.

This essay examines how climate change affects the biodiversity and communities of the Sundarbans, particularly farmers' access to clean water and the declining soil fertility caused by cyclones and floods, raising urgent questions about livelihood and survival in an increasingly fragile landscape.

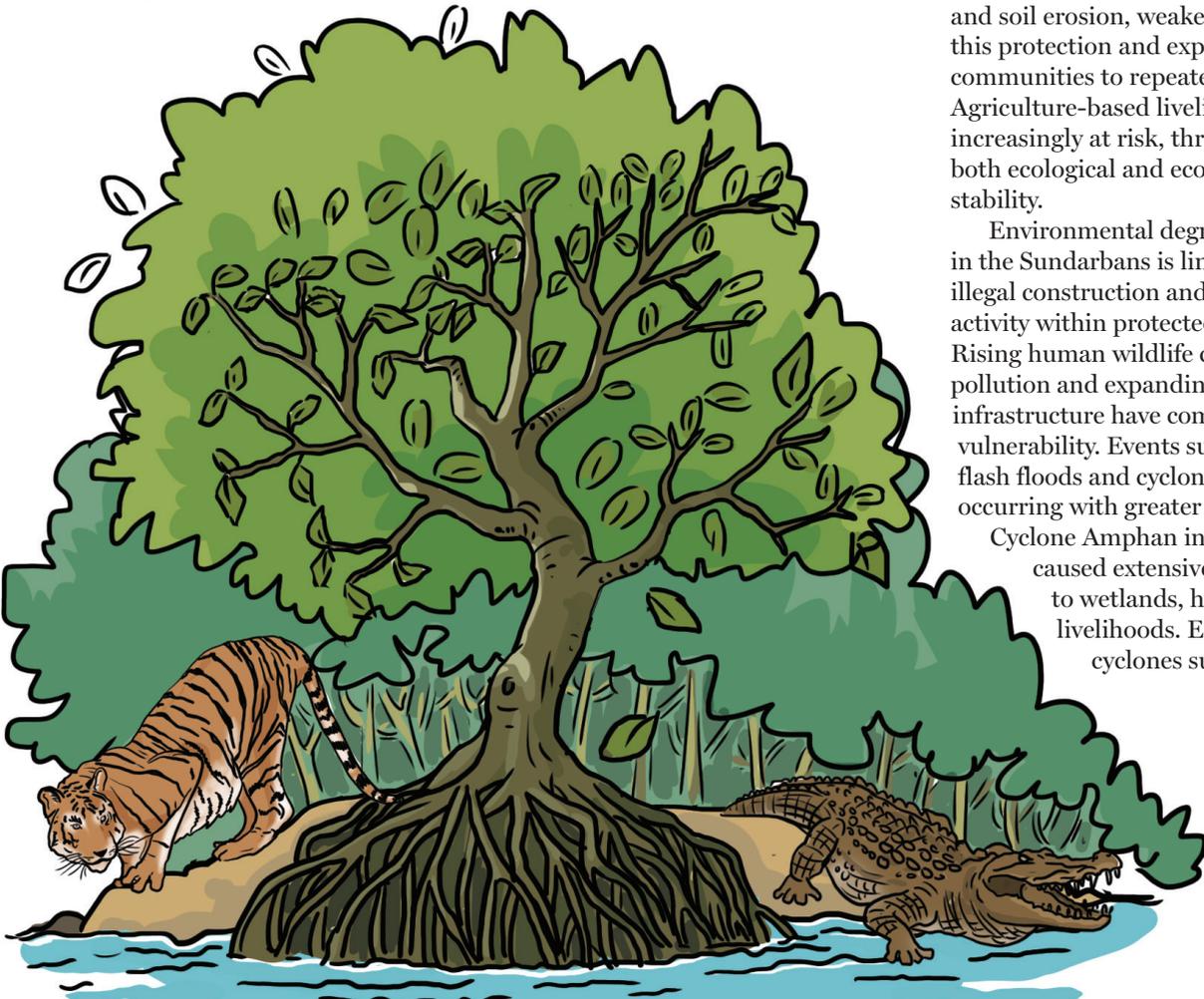
This fragile ecosystem sustains both biodiversity and community life. Its mangroves function as natural storm barriers, stabilise shorelines, trap sediments and nutrients, and provide

timber, honey and other natural resources. For local communities, the forest is a sacred landscape. Traditions of tree worship help protect habitats, and local belief systems centre around deities such as Bonobibi, the Queen of the Jungles, and Dakshin Ray, the protector who tames tigers. Culture and conservation have historically coexisted in this region.

For generations, the Sundarbans has acted as a biological shield against cyclones and tidal surges. Climate change has intensified cyclones, floods, and soil erosion, weakening this protection and exposing communities to repeated loss. Agriculture-based livelihoods are increasingly at risk, threatening both ecological and economic stability.

Environmental degradation in the Sundarbans is linked to illegal construction and industrial activity within protected zones. Rising human wildlife conflict, pollution and expanding infrastructure have compounded vulnerability. Events such as flash floods and cyclones are occurring with greater intensity.

Cyclone Amphan in 2020 caused extensive damage to wetlands, homes and livelihoods. Earlier cyclones such as Aila,



Bulbul and Sidr had already left deep scars across the region. Rising sea levels associated with global warming have worsened saline intrusion, reducing access to fresh water.

Fresh water has historically been scarce in the Sundarbans. Rainwater harvesting through household ponds has long served as the primary source of drinking and irrigation water, reflecting traditional resilience in a saline landscape. However, there is no comprehensive, regional-scale water management system. Cyclones frequently inundate agricultural land with saline water, contaminating freshwater sources and reducing soil fertility through waterlogging and salt deposition. As agricultural productivity declines, farmers lose their principal source of income.

Farmers are highly exposed, while women and children often suffer disproportionately when homes are destroyed and shelter becomes uncertain. Cyclones can push families into extreme poverty, affecting even middle-income households. Accounts from Kakdwip town in the Ganges Delta show how Cyclone Amphan damaged homes and rooftops, reflecting the widespread nature of loss. Repeated crop failure and infrastructure damage weaken both economic stability and social cohesion.

Several policy frameworks govern conservation and development in the Sundarbans. Domestically, measures such as the Sundarbans Biosphere Reserve Rules and the West Bengal Coastal Zone Management Plan, 2019 seek to regulate land use and protect biodiversity. Internationally, the region falls under instruments including the Ramsar Convention, the UNESCO World Heritage Convention, the Convention on Biological Diversity, the United Nations

Known as protective barriers, the Sundarbans today are grappling with saline tides, repeated cyclones, and eroding mangroves that are steadily reshaping both farmland and fragile livelihoods that depend on it

Framework Convention on Climate Change and frameworks of the International Maritime Organization.

The Government of West Bengal established the Sundarbans Development Board in 1972 under the Department of Sundarban Affairs to support both conservation and development. At the time, the region lacked roads, healthcare, and basic connectivity, relying largely on boats for transport between islands. Although infrastructure has improved over five decades, chronic vulnerabilities remain.

A central weakness in existing policy lies in enforcement. There is no dedicated enforcement agency to address violations, and illegal construction continues due to corruption and weak oversight. Judicial interventions have highlighted these gaps. In *Subhas Dutta v. State of West Bengal*, the court expressed concern over inaction against illegal infrastructure. Similarly,

in *Re Sunderbans Forests v. Union of India*, the National Green Tribunal emphasised the need for strict compliance with environmental laws and acknowledged the degradation driven by climate change.

Addressing the climate crisis in the Sundarbans requires both long term policy reform and immediate community engagement. The government must formulate a comprehensive land use policy tailored to the region's ecological fragility. Planned and scaled up water harvesting initiatives are essential to secure year-round access to fresh water for agriculture and domestic use. Equally important is the creation of a dedicated enforcement agency to ensure compliance with conservation laws. Policy declarations alone are insufficient without institutional capacity to act.

Community-led initiatives can complement formal governance. The formation of Sundarbans Suraksha Committees at block or tehsil level could mobilise local participation. Women and children can serve as climate change advocates, raising awareness about sustainable practices and resisting activities such as illegal embankment construction that contribute to human-induced flooding. Environmental non-governmental organisations can support these committees through capacity building, training and knowledge dissemination, transforming residents into informed stakeholders.

The Sundarbans lies between ecological fragility and human resilience. As mangrove protection weakens, farmers confront saline soils and recurring cyclones, making stronger governance, water security, and community empowerment essential to protect both ecosystems and livelihoods.

*Vaishnavi Mandangi*

Too Ripe for the Road

Climate Vulnerability in Andhra's Tomato Economy

Coastal Andhra Pradesh is recognised as an important horticultural zone with high vegetable production, particularly tomatoes. The region experiences a warm tropical climate where temperatures frequently rise above 40°C and humidity levels often exceed 70 per cent during summer. These environmental conditions create a challenging setting for handling perishable produce. Tomato cultivation has expanded over the years due to irrigation development and market demand. However, rising temperatures, heatwaves, cyclones and prolonged humid conditions have increased the risk of post-harvest deterioration. Perishable produce such as tomatoes is now more vulnerable to early spoilage and microbial decay even before reaching markets.

Climate change is turning food abundance into waste before it reaches people, exposing gaps in food security planning. Pre-consumer losses reduce availability, waste cultivation resources and weaken the livelihoods of smallholders and women workers. This study examines climate-driven tomato losses in coastal Andhra Pradesh's humid supply chain and proposes packaging-led solutions such as modified atmosphere packaging and improved handling, aiming to reduce waste by up to 60 per cent through scalable, locally appropriate interventions.

During peak summer months, tomatoes are harvested

Up to 25 per cent of transported tomatoes spoil in humid gluts, destabilising incomes and exposing a hidden climate vulnerability in coastal Andhra's food system

at early ripening stages under rising temperatures. Heat accelerates respiration and ethylene production, causing rapid softening, while coastal humidity encourages microbial growth before sorting or grading. Production in coastal regions has expanded over the past decade due to improved irrigation and market access, even as cyclones and heatwaves have intensified. Market gluts, damaged storage, and transport delays increase losses, with excess supply often discarded due to rapid spoilage and falling prices.

Pre-consumer tomato waste in coastal Andhra Pradesh has ecological, economic and social consequences. Ecologically, decomposition of an estimated 20,000 tonnes of wasted tomatoes in humid field dumps releases methane and contributes

to rising temperatures. In delta regions exposed to cyclones, repeated cultivation and replanting to compensate for losses further degrade soil quality. Economically, up to 25 per cent of transport loads can spoil during humid periods or gluts, causing significant financial losses for small vendors and producer groups. Farmer Producer Organisations (FPOs) face income instability during oversupply seasons, limiting their capacity to invest in processing and storage infrastructure. From a food security perspective, edible produce is lost before consumption, creating a mismatch between production and distribution. Coastal cities may experience price spikes during shortages, yet food is wasted during gluts.



Certain groups are particularly affected. Women sorters, who constitute more than half of the workforce, experience wage reductions when rejection rates rise due to climate damage. Smallholder farmers with limited land and resources struggle to recover from repeated losses. Women-led self-help groups engaged in processing face declining revenues when humid storage conditions cause early spoilage. Migrant workers displaced by cyclones lose seasonal employment opportunities.

Although national and state-level programmes exist to reduce food losses, most focus on retail or post-market stages rather than climate-induced pre-consumer rejection. Under the Pradhan Mantri Kisan Sampada Yojana, 1,601 cold chain projects with a combined capacity of 255 million metric tonnes have

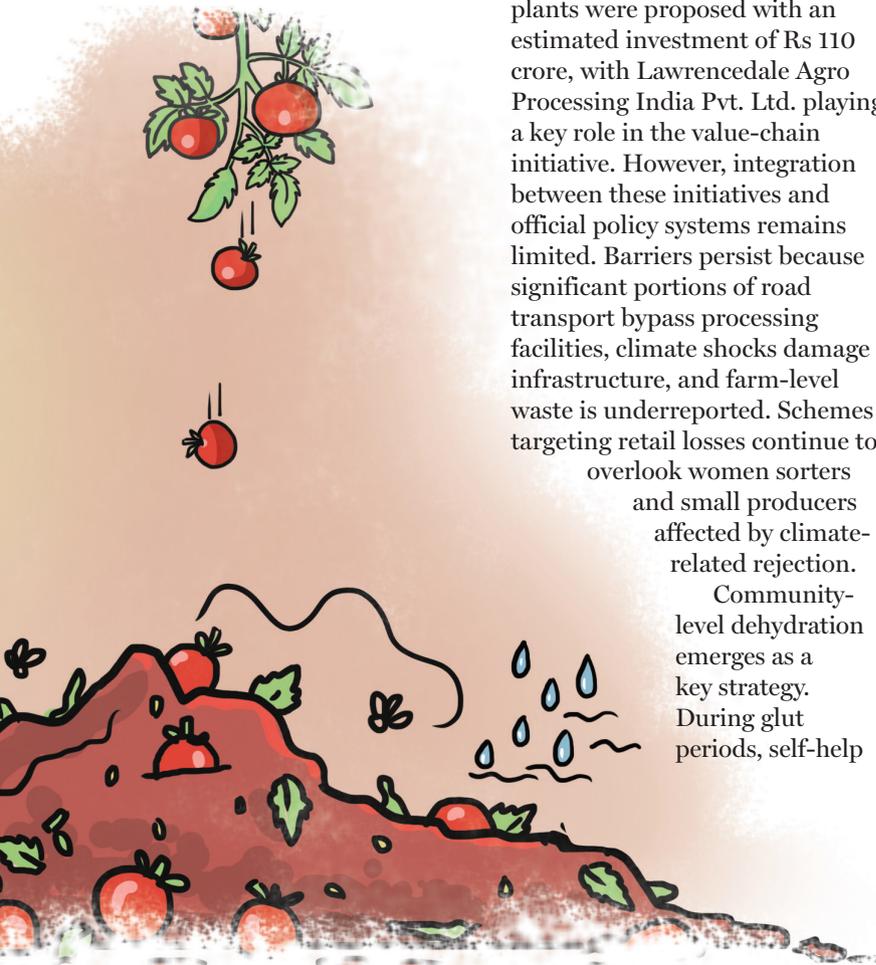
been supported nationwide, yet coverage in coastal districts remains limited and cyclone-resilient infrastructure is lacking in areas such as Visakhapatnam. Operation Greens has allocated Rs 500 crore to stabilise tomato supply, but infrastructure gaps and rural power outages restrict effective implementation. At the state level, Andhra Pradesh's Food Processing Policy 4.0 offers a 35 per cent capital subsidy of up to Rs 35 lakh for micro-units engaged in secondary and tertiary processing activities, such as dehydration. Rythu bazaar (government-initiated farmer's market) procurement has supported nearly 20,000 farmers during gluts with prices ranging from Rs 6 to Rs 13 per kilogram. Civil society initiatives complement these measures. Under an MoU with the Government of Andhra Pradesh, 20 primary tomato processing plants were proposed with an estimated investment of Rs 110 crore, with Lawrence Dale Agro Processing India Pvt. Ltd. playing a key role in the value-chain initiative. However, integration between these initiatives and official policy systems remains limited. Barriers persist because significant portions of road transport bypass processing facilities, climate shocks damage infrastructure, and farm-level waste is underreported. Schemes targeting retail losses continue to overlook women sorters and small producers affected by climate-related rejection.

Community-level dehydration emerges as a key strategy. During glut periods, self-help

groups in coastal districts can use subsidised solar dryers to convert surplus or rejected tomatoes into stable products such as powder and dried slices. This approach reduces immediate spoilage pressure, extends shelf life, preserves nutritional value and creates additional income streams. Improved post-harvest handling and SHG-led processing can retain value before climate-induced spoilage reduces quality. Low-cost evaporative cooling methods such as zeer pots (pot-in-pot earthenware refrigerators) can reduce field temperatures and delay deterioration. Simple sanitation and sorting techniques help minimise microbial contamination prior to processing. Harvesting during cooler hours and using padded crates can reduce mechanical damage during transport.

Strengthening livelihoods is integral to this approach. Women engaged in sorting and handling can transition into processing roles within self-help groups, stabilising incomes. Smallholders and migrant workers affected by climate disruptions can participate in value addition and drying activities linked to farmer-producer organisations. An effective implementation ecosystem requires coordination among FPOs, local governments and non-governmental organisations to connect surplus produce to community processing facilities through training, equipment access and storage systems.

What was once discarded as waste can become a pathway for rural adaptation by reducing early market losses, protecting incomes and lowering emissions. Community-based processing strengthens women's participation and offers a replicable model for other humid coastal regions facing similar cycles of surplus and loss.





Ankita Rai

Mangrove Under Siege

Pichavaram's Weakening Coastal Armor

Pichavaram is a small coastal village in the Cuddalore district of Tamil Nadu, located between the Vellar and Coleroon estuaries along the Bay of Bengal. The Pichavaram mangrove forest, one of India's largest mangrove ecosystems and a designated Ramsar site, spreads across a complex network of tidal channels, mudflats and dense vegetation. This biotope supports remarkable biodiversity, including around 177 species of resident and migratory birds, and sustains local fishing communities who depend on its

waters for livelihood.

Ecologically, the mangroves form a vital buffer between land and sea. They protect inland settlements from cyclones, storm surges and tidal flooding. Their importance became especially clear during the 2004 Indian Ocean tsunami, when areas shielded by dense mangrove cover experienced comparatively less damage. Mangroves are more than forests; they are living coastal defenses.

Globally, mangroves cover about 15 per cent of the world's coastlines. However, nearly half of all mangrove ecosystems are at risk of collapse due to coastal development, aquaculture expansion and pollution. Of the 36 mangrove ecosystems

assessed in the IUCN Red List, Pichavaram is among the critically endangered zones.

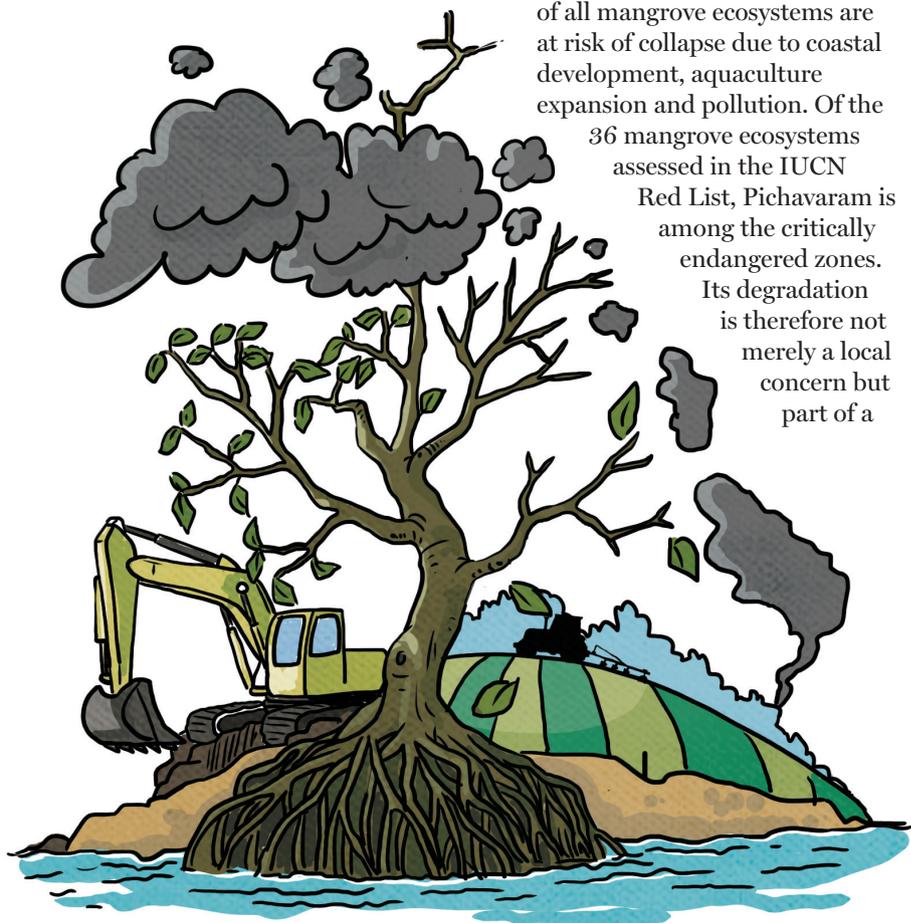
Its degradation is therefore not merely a local concern but part of a

broader global environmental crisis.

Mangroves function like natural coastal kidneys. The unique structure of mangrove roots, known as pneumatophores, slows tidal currents and traps organic matter, debris and sediments. This makes them highly efficient filters but it also means plastic debris and microplastics settle within their root systems. Plastics from nearby settlements enter estuarine waters, move through mangrove channels and become embedded in sediments. They accumulate, absorb heavy metals and enter fragile aquatic nurseries. As plastic pollution weakens mangroves, fisheries, shoreline stability, health and local livelihoods are all placed at risk.

Historically, Pichavaram's mangroves served as nurseries for fish, prawns and crabs while protecting the coastline from storms. However, in recent decades, the ecosystem has faced mounting pressures from shrimp farming, land conversion, unregulated tourism and rising plastic waste. When mangroves are degraded due to cutting, pollution or reduced freshwater inflow, their ability to stabilise sediments weakens, creating a feedback loop: increased plastic inflow raises contamination, while stressed mangroves lose resilience

Recent research found significant seasonal microplastic contamination in Pichavaram's aquatic species. Microplastics,



defined as plastic particles smaller than five millimetres, originate from the breakdown of larger plastic waste or from synthetic textiles, packaging and fishing gear. The monsoon season recorded the highest levels, largely due to runoff from nearby settlements. Species such as *Liza tade* showed notable particle ingestion, and shellfish including *Scylla serrata* and *Portunus sanguinolentus*, were also affected. A substantial proportion of particles were below one millimetre, with blue fibres dominant. Common polymers included polypropylene, polyethylene and PET, confirming that contamination is systemic and widespread.

The ecological consequences are serious. Microplastics alter sediment composition and may interfere with nutrient exchange, affecting mangrove seedling growth. Benthic organisms such as worms and crustaceans, which maintain soil health, are also disrupted. Gradually, the forest's regenerative capacity weakens.

Through bioaccumulation and biomagnification, microplastics and associated toxins build up along trophic levels. Larger fish that consume contaminated prey accumulate higher toxin levels, which eventually reach humans. For local communities, especially fisherfolk, the impacts are immediate. Fish and shellfish that ingest microplastics often exhibit reduced growth, reproductive disorders and increased mortality.

Since many families depend almost entirely on small-scale fishing, even minor declines in stock threaten economic security. There is also the risk of reduced consumer confidence if seafood is perceived as contaminated. Women engaged in fish cleaning and processing face prolonged exposure, while children may be particularly vulnerable to

Mangroves are natural coastal kidneys, with roots that slow tidal currents, trapping sediments and organic matter. However, it also causes plastic debris and microplastics to accumulate within their root systems

long-term health risks. Studies increasingly link microplastic exposure to inflammation, hormonal disruption and toxicity. Thus, in Pichavaram, ecological degradation directly intersects with public health and livelihood concerns.

Geospatial research by the Symbiosis Institute of Geoinformatics shows that while about 610 hectares of mangroves remain stable, 238 hectares are degraded and nearly 369 hectares are regenerating. These figures reflect both ecological stress and potential for recovery under strong human pressure.

Government initiatives have begun addressing restoration. Under the Tamil Nadu Coastal Restoration Mission (TN-SHORE), launched in 2025 with World Bank support, large-scale mangrove restoration efforts are underway. A significant innovation is the tidal mangrove nursery established at Killai, where saplings of native species are raised on floating platforms under

natural tidal conditions before transplantation. This improves survival and resilience once the saplings start taking root.

However, enforcement of plastic regulations remains inconsistent. Waste segregation systems are weak in rural areas, and livelihood pressures often drive short-term economic decisions that harm the ecosystem. Scientific monitoring of microplastic levels is also limited.

A comprehensive response must therefore combine restoration with pollution control. Mangrove reforestation alone cannot succeed if contamination continues. An integrated microplastic monitoring system, in collaboration with local universities, should regularly test water, sediment and seafood. Waste management infrastructure in nearby towns must be strengthened through decentralised segregation units, stricter regulation of single-use plastics and incentives for recycling. Women's self-help groups can be engaged in collection and recycling efforts, linking environmental protection with income generation.

Community participation is essential. Fishing communities should be involved as custodians of restoration projects, trained in nursery management and eco-tourism. Health awareness programmes and financial support during lean fishing seasons can reduce vulnerability.

Protecting Pichavaram's mangroves is not simply about conserving trees; it is about preserving coastal resilience, public health and livelihood security. If pollution and degradation continue unchecked, the natural armor that once shielded the coast may slowly weaken. But with integrated action and community engagement, recovery remains possible.

**Vaishal Dsouza**

The Unseen Current

Plastic Pollution in Mangalore's Rivers and Coast

Water shapes everything when one spends their childhood in Mangalore. The Arabian Sea lies close by and the Nethravati and Gurupura rivers twist their way across the town, meeting the tide at estuaries and sand-lined edges where boats return to their docks. When heavy rains pour, streets fill up with water quickly. Water runs off rooftops into gutters and then into the channels below. What moves through our drains eventually reaches the sea. Today, more than ever, plastic travels through these waters.

Recent scientific studies have documented significant microplastic contamination in the sediments of the Gurupura estuary and the Nethravati river basin. Researchers have identified particles composed of polyethylene, polypropylene, polystyrene, and polyamide, materials commonly found in packaging, bags, and synthetic fabrics. These findings are not isolated incidents. They reflect everyday waste, poor segregation practices, monsoon runoff, and coastal activities. Larger plastics break down into fragments smaller than five millimetres. They are invisible to the eye but increasingly difficult to ignore. Global scientific reviews, including those cited by IEEE, show that microplastics can enter the human body through water, seafood, and air. Potential effects range from inflammation and oxidative stress to immune and metabolic disruptions. Although

Studies show that Mangalore's rivers carry microplastics into the Arabian Sea, embedding them in coastal sediments and marine life, eventually reaching the human food chain

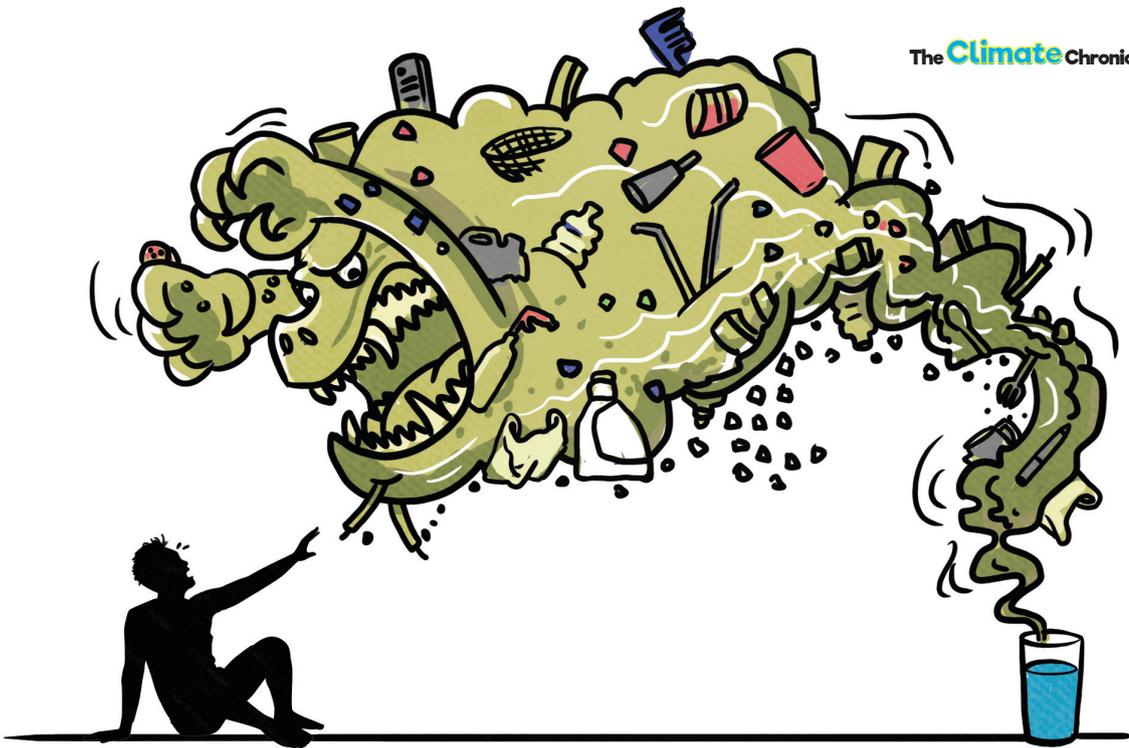
local human data remains limited, the signals are strong enough to demand attention. This project examines how plastic pollution in Mangalore's rivers and coastlines intersects with public health, especially among vulnerable communities.

Understanding this link requires examining how microplastics move through local ecosystems, travelling across water and soil into spaces where families live, work, and obtain food. Children, fisherfolk, and low-income households face higher exposure risks. The data reveal patterns of contamination as well as underlying waste and consumption practices. Addressing the issue requires recognising its disproportionate impact on vulnerable groups and developing solutions suited to

coastal contexts.

Plastic enters rivers through daily consumption, poor waste segregation, beach littering, and monsoon-overflowing drains. Studies of the Gurupura and Nethravati estuaries have found microplastics in sediments, primarily fibres and fragments, indicating a systemic rather than isolated contamination process. Each monsoon downpour carries new plastic loads into the river system, with the Nethravati estimated to transport hundreds of millions of microplastic particles into the Arabian Sea daily. In effect, every heavy rain flushes urban plastic downstream.

Marine organisms often mistake these particles for food. Plastics also act as carriers for chemical pollutants. In a coastal city where seafood forms part of daily life, the pathway to human exposure becomes uncomfortably direct. Globally, researchers have detected microplastics and nano plastics in water, air, food, and sediments. Reviews report their presence in human tissues and associations with oxidative stress, immune dysfunction, reproductive effects, and potential liver and neurological impacts. Long-term human studies are still developing, but laboratory findings confirm inflammatory and metabolic disruptions. The most unsettling aspect here is invisibility. Bottles and bags on the beach are visible; microscopic fragments in water and air are not. Yet those fragments may



accumulate slowly in the body over time.

Ecologically, microplastics disrupt marine ecosystems. Around Mangalore's shores and river mouths, fragments and fibres threaten aquatic organisms and disturb food chains. As rivers carry plastics into the sea, ingestion reshapes feeding behaviour and introduces synthetic particles into biological systems. For a coastal city dependent on marine health, this transformation is significant.

The impact extends to local communities, especially fisherfolk. For communities dependent on the sea for livelihood plastic pollution is both ecological and economic. Declining marine health and contamination concerns affect livelihoods directly. Global findings suggest that tiny plastics cause cellular stress, tissue inflammation, immune shifts, and metabolic disruptions. Inhalable microplastics have also been detected as part of urban particulate matter, contributing to respiratory risks.

Certain groups face higher exposure. Fisher communities are affected by occupational and dietary pathways. Children

and the elderly face risks due to developing or weakened immune systems. Waste workers and informal pickers handle plastic debris daily, often without protection. Residents of low-income settlements near drains and estuaries face additional risks during floods. For these groups, cumulative exposure may increase respiratory, inflammatory, and metabolic risks.

Mangalore operates under Karnataka's plastic waste management rules, including bans on certain single-use plastics and segregation mandates. Coastal cleanup drives and awareness campaigns have increased public participation. However, implementation remains inconsistent. Monitoring efforts rarely include microplastics, and policies focus primarily on visible waste rather than fragmented particles. Civil society engagement is growing, but challenges persist, including limited health data, inadequate processing infrastructure, and weak enforcement of Extended Producer Responsibility.

Solutions must begin at the source. Waste segregation should

become routine, supported by incentives. Expanding Material Recovery Facilities would reduce leakage into waterways. Producers should adopt circular economy practices and reduce single-use packaging. Local research institutions can lead regular monitoring of microplastics in water, sediment, seafood, and air. Protecting vulnerable groups requires protective equipment for waste workers, awareness support for fishing communities, and school-level education initiatives. Behavioural change campaigns promoting reusable alternatives and plastic-free markets can gradually reshape consumption patterns. Regulations must also consider microplastic risk assessments, and businesses adopting eco-friendly packaging should receive incentives.

Plastic pollution in Mangalore is no longer confined to visible debris on beaches. It now concerns what enters rivers, seafood, air, and potentially human bodies. Recognising this shift reframes the issue from waste management alone to a broader question of environmental health and community protection.



Adiba Saifi

Outsourcing Risk

The Burden of India's E-Waste in Seelampur

In the narrow, soot-stained lanes of Northeast Delhi, Seelampur stands as the ground zero of India's e-waste crisis. While India ranks third globally, generating 2.2 million metric tonnes of digital trash annually as of 2025, our official infrastructure is largely a facade. Despite the existence of 500 licensed recyclers, nearly 95 per cent of this hazardous waste flows into the informal sector. Seelampur and neighbouring hubs like Loni have become 'urban mines' where workers extract gold and copper using toxic, backyard methods. This isn't just a scrapyards; it is a vital, illicit junction in a global supply chain, absorbing the digital detritus of both the Global North and India's tech-hungry middle class.

This essay examines

Seelampur's informal dominance and how formal producers and authorised recyclers exploit it to evade compliance costs, shifting environmental damage and human suffering onto marginalised families in its polluted lanes.

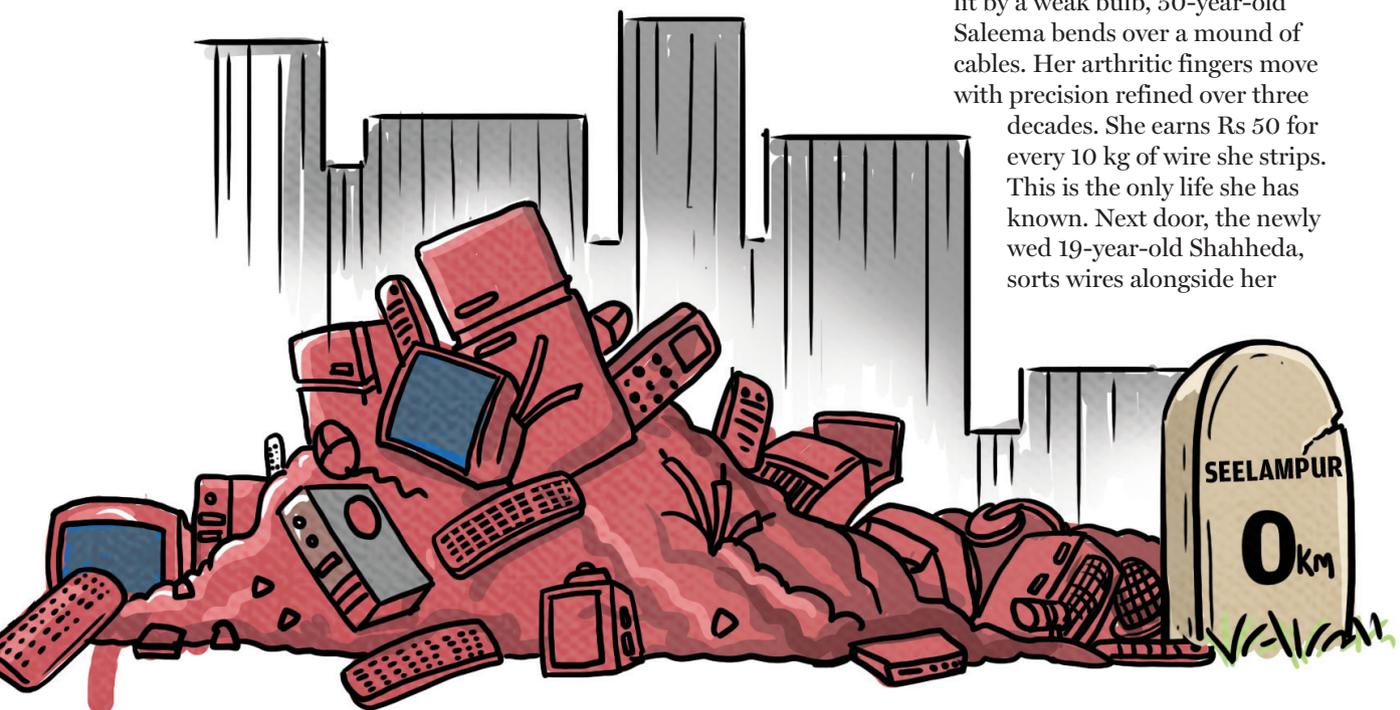
The crisis in Seelampur is not just informality, but the formal sector's dependence on it. The E-Waste (Management) Rules, 2022 require manufacturers to take Extended Producer Responsibility and recycle their products. In practice, large volumes leak into unregulated channels because it is far cheaper to burn and strip cables in backyard units than to process them in compliant, high-tech facilities.

Seelampur was once a general scrap market for metal and

paper, but the technology boom turned it into a graveyard for the digital age. Smuggled electronics arrive daily, straining the area, while backyard burning and acid baths release toxic fumes and heavy metals into soil and water. Environmental, urban and public health crises converge in these lanes.

A ground report from June 2025 captures a soundscape far removed from the modern city, the snapping of plastic casings and the rustle of copper wires replacing traffic noise. Nearly every doorway houses a family tied to this trade. Under regulatory pressure, the hub, though strained, has not disappeared but splintered into smaller, harder-to-track units in places like Muradabad and Meerut.

Inside a cramped 6x6 room lit by a weak bulb, 50-year-old Saleema bends over a mound of cables. Her arthritic fingers move with precision refined over three decades. She earns Rs 50 for every 10 kg of wire she strips. This is the only life she has known. Next door, the newly wed 19-year-old Shahheda, sorts wires alongside her



in-laws. The copper strands determine whether the family eats that night. Nearby, Sajid Khan watches his 12-year-old daughter Sharmila strip mobile chargers after school. She dreams of becoming a doctor to treat the respiratory illnesses she sees around her.

Formal recycling is costly, with expenses for safety systems, labour compliance, pollution control and taxes. Informal units operate without permits or overheads. Producers and even authorised recyclers quietly divert waste to these channels while maintaining paper compliance. A shadow market for fake EPR certificates allows them to buy proof of recycling without actual processing. Regulators see clean paperwork, while the ground remains contaminated.

A 2023 study by researchers at Jawaharlal Nehru University found that surface dust in Delhi's e-waste clusters contains dangerously elevated levels of lead, copper and zinc. These contaminants arise from open burning and acid leaching and do not remain confined to dust. They seep into groundwater and threaten the Yamuna basin. Soil fertility declines. Water becomes unsafe for consumption and agriculture, and leads to a slow degradation of the whole ecosystem.

For residents, the crisis manifests as a syndemic where poverty and toxic exposure reinforce each other. A 2025 study reported that 80 per cent of workers in such clusters suffer from chronic respiratory diseases. Burning insulation releases dioxins that settle in homes and lungs. Persistent coughs, weakened immunity and suspected cancer clusters shape daily life. Families cannot exit the trade easily because it remains their only livelihood.

Women and children bear the greatest burden. Women like Saleema and Shahheda perform intricate dismantling within their homes, exposing themselves and their families to fine lead dust. Lead exposure results in reproductive complications among the women. Children such as Sharmila are valued for their small fingers, suited to picking apart tiny components. Yet their developing brains are highly vulnerable to lead toxicity. Exposure can cause irreversible cognitive decline and learning disorders.

Policy interventions have

Seelampur demonstrates how India's e-waste regime sustains itself by relocating risks to informal labour and urban fringes.

attempted to address these distortions. The E-Waste Rules of 2022 and updated guidelines from the Central Pollution Control Board in 2024 standardised penalties and certificate pricing. Civil society groups such as Toxics Link have pushed for stricter enforcement. The National Green Tribunal ordered crackdowns, including power disconnections to illegal units between 2024 and 2025. Initial action suggested progress.

Yet the system exhibits a hydra effect—closing one cluster in Seelampur often results in others emerging on the outskirts. The formal sector cannot compete with an informal system that pays cash instantly and operates without the

burden of safety rules, taxes and equipment costs. Enforcement is difficult in dense areas, and poverty draws workers back, allowing the system to continue leaking.

A more viable approach lies in recognising, not denying, the informal sector's role. A hybrid hub-and-spoke model, inspired by Delhi's Eco-Park in Holambi Kalan, offers direction. Informal workers could be integrated into authorised collection and initial dismantling stages where their expertise already lies. Hazardous chemical extraction and advanced processing should be shifted to regulated facilities equipped with pollution controls.

Such integration directly addresses vulnerable groups. Street collectors and women dismantlers should be recognised as authorised collectors and paid transparent rates at designated centres. Work would then move out of bedrooms and into safer spaces. Urban local bodies such as the Municipal Corporation of Delhi should establish neighbourhood collection points feeding into formal facilities. Non-governmental organisations should help form cooperatives, ensuring workers receive payments directly from producers rather than losing income to middlemen.

If the first mile of collection and dismantling is formalised, the incentive for illegal acid processing declines. Toxic work shifts away from homes and into monitored facilities. Health outcomes improve gradually, and environmental contamination slows. The circular economy cannot remain credible if it externalises its costs onto the poorest citizens. In Seelampur's lanes, the promise of circularity remains shadowed. Bringing those shadows into the open is essential for genuine reform.



Akshata Vispute

Integrating Solar into Structure

Assessing the Feasibility of BIPV in Maharashtra

Building-Integrated Photovoltaics (BIPV) represents an emerging shift in how solar energy is integrated into the built environment. Unlike traditional rooftop solar panels that are mounted onto completed structures, BIPV replaces conventional building materials such as roofs, facades, windows, skylights, and balustrades with photovoltaic components. These systems serve a dual purpose; they function as structural elements of the building while simultaneously generating electricity. This integration makes buildings more energy-efficient, aesthetically cohesive, and environmentally sustainable.

India lies within the equatorial sunbelt and receives over 300 sunny days annually, making it highly suitable for solar deployment. With projections indicating that India will add 5.7 billion square metres of building stock by 2030 and 21.5 billion square metres by 2040, integrating renewable energy into new construction is both practical and urgent. In fast-growing cities, BIPV offers a pathway toward decentralised, cleaner energy infrastructure. Rather than treating energy generation as an afterthought, it embeds it directly within architectural design.

This project assesses the feasibility of implementing BIPV in Maharashtra's residential and industrial sectors by examining solar potential, technical

BIPVs have the potential to integrate solar energy into Maharashtra's built environment, aligning architecture and industry with climate goals

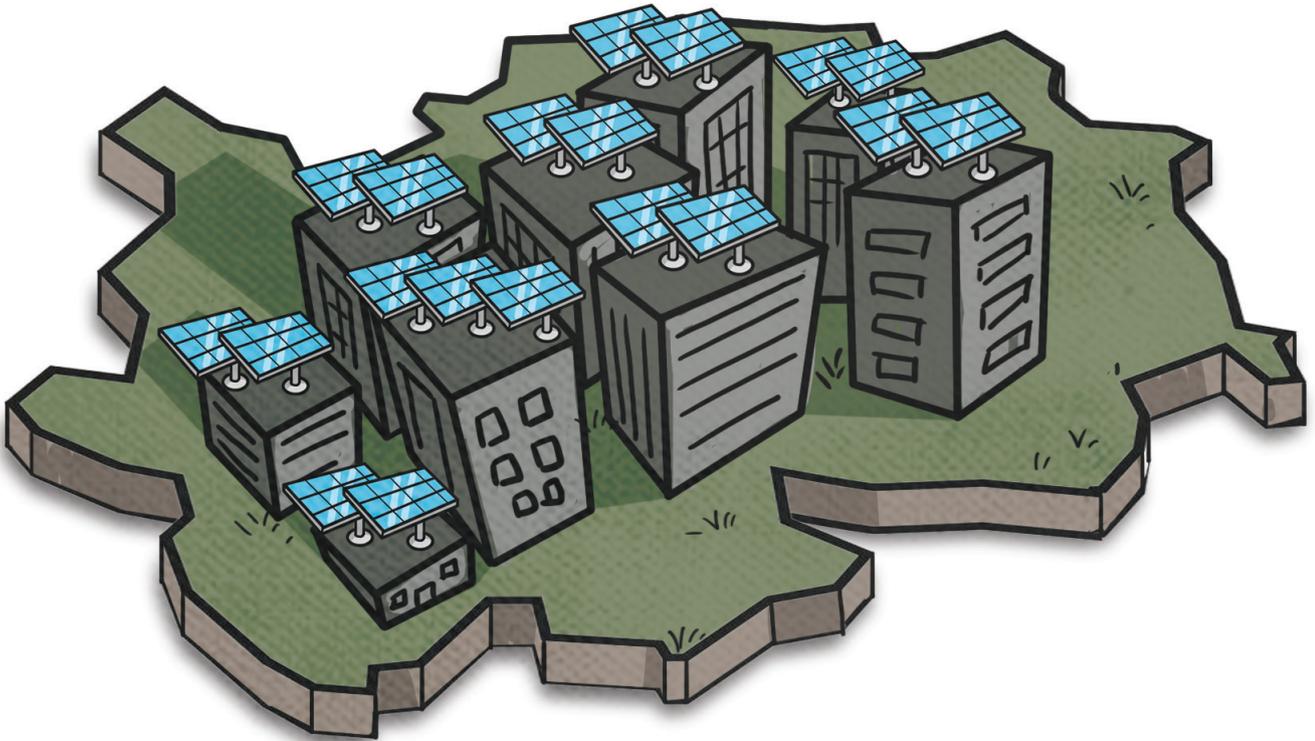
constraints, and socio-economic barriers, in alignment with India's 2070 net-zero emissions goals.

The potential impacts of BIPV deployment in Maharashtra are multi-dimensional. Ecologically, BIPV utilises existing building surfaces, reducing the need for additional land while lowering CO₂ emissions without additional infrastructure footprint.

Industrial zones in Maharashtra have high daytime energy demand that aligns closely with peak solar generation hours, reducing electricity costs significantly. Socially, BIPV applications such as balcony railings, solar windows, and facade panels enable residents without exclusive rooftop access to participate in energy generation. However, security considerations are important, particularly in dense neighbourhoods where high-value modules may require additional protective measures.

Solar irradiance data further strengthens the case for BIPV in Maharashtra. PVWatts-based analysis across key industrial zones such as Ambad MIDC, Satpur, and the Jaulke-Dindori area indicates strong and consistent solar potential throughout the year. Annual average solar radiation stands at 5.90 kWh per square metre per day in Ambad MIDC and 5.99 kWh per square metre per day in Jaulke-Dindori. Peak generation occurs in March, with values exceeding 7.2 kWh per square metre per day in both zones. Even during monsoon months, radiation remains above 4 kWh per square metre per day, ensuring year-round generation. A 4-kW system can generate approximately 6,249 kWh annually in Ambad MIDC and 6,351 kWh in Jaulke-Dindori. Such output is sufficient to meet office loads, lighting requirements, and supplementary industrial energy needs. These figures confirm that Maharashtra's solar resource base comfortably exceeds minimum thresholds for BIPV viability.

Government policies and market trends provide additional momentum. India's construction sector is projected to expand significantly by 2060, with residential buildings accounting for over 80 per cent of new floor area. Initiatives such as the PM Surya Ghar Yojana, the Smart Cities Mission, and the National Mission on Sustainable



Habitat create a supportive policy foundation for solar-integrated construction. Subsidies and green building incentives are gradually reducing the financial premium associated with BIPV adoption. Furthermore, aggregated residential and industrial BIPV installations may generate tradable carbon credits under India's evolving carbon market, following models operational in the European Union, South Korea, and the United States. With national targets of achieving 500 GW of non-fossil energy by 2030 and net-zero emissions by 2070, BIPV is positioned for wider expansion in commercial and public buildings.

When compared with traditional rooftop solar panels, BIPV presents distinct characteristics. It is integrated into the building fabric rather than mounted externally. Aesthetically, it offers a seamless and modern appearance, while traditional panels remain visibly separate structures. Functionally, BIPV performs a

dual role, combining structural support with energy generation, whereas conventional panels generate energy alone. Although BIPV involves higher upfront costs, it can offset expenses related to cladding and roofing over time, creating long-term value beyond electricity savings.

Despite its advantages, several barriers limit adoption. High installation costs remain a primary concern. There is also a shortage of skilled professionals trained in BIPV installation and maintenance. Vertical facades may experience efficiency losses due to suboptimal tilt angles. Security risks, particularly module theft, must be addressed in dense residential areas. Proposed solutions include targeted government subsidies, community-based financing models, and upskilling programs to train youth in installation and maintenance. Advances in module encapsulation, such as glass-glass photovoltaic technology, can improve durability

and performance. Regular maintenance is equally important, as dust and pollution reduce panel efficiency. Cooperative housing associations can implement structured cleaning protocols to sustain performance over time.

BIPV represents a convergence of architecture and renewable energy that responds directly to India's developmental trajectory. In Maharashtra, strong solar irradiance, expanding industrial corridors, and supportive policy frameworks create favourable conditions for adoption. While cost and technical constraints persist, collaborative public-private investment and sustained policy support can narrow these gaps. The transition toward BIPV is not simply an architectural upgrade but a structural step toward aligning buildings with national climate goals. Each installation integrates energy production into everyday infrastructure, contributing incrementally to a cleaner and more resilient future.



Siddhartha

Policy vs Practice

An Exploratory Study on Delhi's Solar Transition

It is scientifically acknowledged that the climate crisis poses existential threats to the living world. Global warming, driven largely by increased carbon emissions from human activities, is closely linked to fossil fuel-based electricity generation. Recognising this, there has been a global push toward renewable energy under international commitments such as the Paris Agreement and the Sustainable Development Goals. Power generation accounts for 54 per cent of India's CO₂ emissions, making the sector central to the country's climate strategy. As the world's fourth-largest economy and third-largest electricity producer, India has committed to ambitious Nationally Determined Contributions.

Among renewable sources, solar energy holds strong promise in India due to its vast geographical potential, declining costs and modularity. As of March 2024, India's estimated solar potential stands at nearly

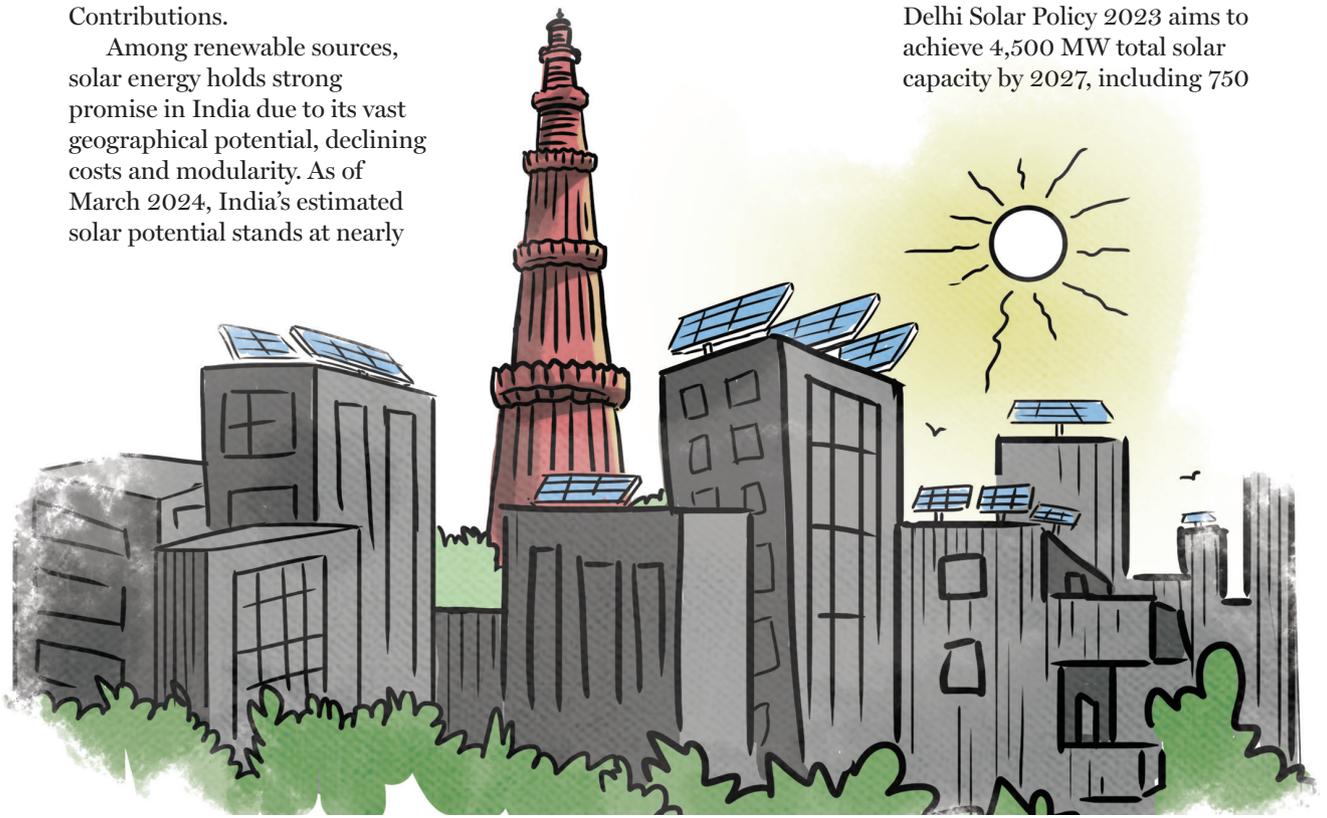
748,990 MW. Solar installations are broadly categorised into large-scale centralised parks and small-scale decentralised systems. While large solar parks are often criticised for land acquisition and centralised ownership patterns, rooftop solar offers a decentralised and less conflict-prone alternative. Residential rooftop solar potential is estimated at 637 GW across approximately 25 crore households.

Urban areas like Delhi present a compelling case for rooftop solar due to high electricity demand and emissions. Delhi's per capita electricity consumption is significantly higher than the national average. With ambitious policy targets but limited visible

adoption, Delhi becomes a relevant case for study.

This study aims first to examine the policy approach toward rooftop solar in Delhi, and second to explore household-level perceptions and constraints affecting adoption in a specific locality. The goal is to generate grounded insights into the transition toward sustainable energy.

India's solar transition is central to its 2030 and 2070 climate goals. Following the National Solar Mission and schemes such as PM-KUSUM, the central government launched PM Surya Ghar–Muft Bijli Yojana in 2024 with an outlay of Rs 75,021 crore to solarise one crore households. At the state level, Delhi Solar Policy 2023 aims to achieve 4,500 MW total solar capacity by 2027, including 750



MW from rooftop installations. The policy promises accessibility and affordability through targeted incentives.

However, Delhi's technical rooftop solar potential is estimated at 2.5 GW, while installed capacity as of January 2026 stands at only 392 MW—about 15.7 per cent of its technical potential and roughly 52 per cent of its 2027 rooftop target of 750 MW. Although installations have grown since 2022, a substantial gap persists between policy ambition and on-ground deployment. Household-level adoption could be transformative for scaling rooftop solar in the city, yet a clear understanding of consumer-level constraints and barriers remains limited.

To explore these realities, a household survey was conducted in residential areas around Dheerpur village and Nirankari Colony in North Delhi. The household was chosen as the unit of analysis. A total of 27 surveys were conducted physically using primarily close-ended questions, with some open-ended responses. Respondents were categorised into low- and high-income groups using a Rs 1 lakh monthly household income threshold.

The survey did not find a single adopter in the locality. Although nearly 80 per cent of respondents had basic awareness of solar energy, awareness did not translate into adoption. This suggests that structural and economic barriers outweigh informational gaps.

Affordability emerged as a major concern. High upfront cost was cited frequently as the primary barrier. Among low-income respondents, 92 per cent indicated willingness to adopt solar if EMI or subsidised models were available. Some perceived solar as 'only for high-income households.' Higher-income respondents also cited cost but were more

concerned about maintenance guarantees and clarity of benefits.

A unique factor in Delhi is the free electricity provision up to 200 units per month. Several respondents stated they did not consider solar necessary because electricity is free and supply is reliable. This welfare provision, while beneficial for consumers, may reduce financial incentives for rooftop solar adoption.

Structural constraints were equally significant. Roof access is essential, yet 33 per cent of all respondents reported having no access. Among low-income households, 69 per cent lacked rooftop control. Additionally, 54 per cent of low-income respondents lived in rented or shared housing. These findings align with broader assessments indicating that only about 30 per cent of roofs in Delhi are structurally viable for solar installations.

Beyond economic and structural barriers, perceptions of exclusion were notable. A majority of respondents felt either completely or partially excluded from policy processes. Tenants, low-income households and residents of informal settlements were repeatedly identified as groups left out of Delhi's rooftop solar transition.

Procedural awareness was also weak. When asked about the ease of accessing subsidies, 67 per cent cited a lack of awareness, and only 11 per cent found the process very easy. Complaints included bureaucratic hurdles and distrust regarding subsidy implementation.

The findings indicate that rooftop solar adoption in Delhi is shaped not just by technical feasibility but by structural ownership patterns, welfare policies, affordability constraints and perceptions of exclusion. Policy success therefore depends not only on targets and subsidies

Delhi shows that the energy transition is as much social and institutional as it is technical. Closing the gap between policy ambition and ground realities will determine rooftop solar's success

but on addressing these grounded realities.

The solar transition is imperative in the context of climate change, and rooftop solar has significant potential. However, it requires a multipronged strategy grounded in local realities. Awareness remains a bottleneck. Respondents highlighted the need for better information, awareness campaigns, peer examples, and a simplified subsidy process. Clearer procedures can improve accessibility.

Households prioritise cost and feasibility over environmental concerns. High upfront costs remain a key barrier, and targeted subsidies are essential. Notably, 92 per cent of low-income respondents indicated that EMI or subsidised models would encourage adoption.

Given the perception of exclusion, policies must be more inclusive. Community and shared solar schemes can address rooftop constraints, while public consultations and local facilitation efforts can incorporate marginalised voices and improve trust in the transition.



Tanya Bhati

Rethinking Urban Energy

Rooftop Solar Potential in Greater Noida

Greater Noida, located in Uttar Pradesh, is a rapidly urbanising region with a growing number of residential societies, apartment complexes and semi-urban neighbourhoods. As urban development expands, electricity consumption has increased significantly. Air conditioners, elevators, lighting systems and household appliances all contribute to rising energy demand. At the same time, climate change and environmental degradation have made the need for sustainable energy solutions more urgent than ever.

Residential societies in Greater Noida largely depend on conventional grid electricity, much of which is still generated through coal and other fossil fuels. This contributes to greenhouse gas emissions and worsens climate change. Increasing heatwaves and changing climate patterns further raise energy needs, especially for cooling during the summer months.

One promising solution is rooftop solar energy. Rooftop solar systems convert unused rooftop spaces into sources of clean and renewable electricity. India receives abundant sunlight throughout the year, making solar power especially suitable for cities like Greater Noida. By adopting rooftop solar, residential societies can reduce their dependence on fossil-fuel-based electricity, lower carbon emissions and become more energy resilient. Exploring the potential of rooftop solar systems

is therefore highly relevant for sustainable urban living.

However, several barriers limit widespread adoption. Despite abundant sunlight and suitable rooftop space, uptake of rooftop solar in many housing societies remains low. High upfront installation costs discourage households from investing, while shared rooftop ownership in apartment societies complicates decision-making. Installing solar panels requires collective approval and cooperation among residents, often leading to delays.

Another challenge is the lack of awareness and technical understanding. While many residents have heard about

rooftop solar, not all are aware of government subsidies, installation procedures or long-term financial benefits. Maintenance concerns, misinformation and complicated paperwork processes also reduce interest. As Greater Noida continues to expand, the absence of decentralised renewable energy solutions may increase pressure on the electricity grid and deepen environmental impacts.

To better understand local awareness and interest, informal discussions and a small survey were conducted among residents of a few housing societies in Greater Noida. The responses showed that most people are familiar with the idea of rooftop solar systems, but only some understand how subsidies work or how to apply for installation. Many residents expressed willingness to adopt solar energy mainly to reduce electricity bills and improve power reliability. However, high upfront costs, limited information and the need for society-level approval were identified as major barriers.

The continued dependence on fossil-fuel-based electricity has serious environmental and social consequences. Coal-based power generation contributes to air pollution, carbon emissions and global warming. Climate change increases the frequency of extreme heat events, water stress and unpredictable weather patterns. Transitioning to renewable energy sources like solar power is essential to reduce these risks.

At the community level, rising

Increasing rooftop solar adoption in Greater Noida will require a blend of strong policy support and active community engagement. One promising strategy is to promote community-owned rooftop solar initiatives

electricity costs and occasional power shortages affect the quality of life in residential societies. Rooftop solar systems can reduce monthly electricity bills and provide more reliable energy supply, especially during peak summer demand. They can also help reduce strain on the central grid.

While adopting rooftop solar would alleviate most of these issues, it is most effective in addressing the concern of vulnerable groups. For e.g. low-income households are more affected by rising electricity tariffs because energy expenses take up a larger share of their income. Elderly people and individuals with health conditions are especially vulnerable during heatwaves, as they require uninterrupted electricity for cooling and medical support. Informal workers and daily wage earners may also face indirect impacts when rising energy costs contribute to overall inflation and economic stress. Rooftop solar adoption can therefore improve not only environmental sustainability but also energy equity and resilience.

Several government initiatives support rooftop solar adoption in India. The Ministry of New and Renewable Energy (MNRE) provides subsidies and financial assistance for households and residential societies installing rooftop solar panels. The PM Surya Ghar Muft Bijli Yojana is a recent national scheme aimed at making rooftop solar more affordable and promoting clean household energy. The net metering policy allows residents to export surplus solar electricity back to the grid, reducing their overall electricity bills. In addition, NGOs and civil society organisations contribute through awareness campaigns, workshops and community mobilisation.

However, barriers to

implementation remain. These include lack of awareness about subsidies, high upfront costs, complex paperwork, approval delays, maintenance concerns and difficulties in collective decision-making within housing societies.

To increase rooftop solar adoption in Greater Noida, a combination of policy support and community engagement is required. One effective approach is promoting community-owned rooftop solar projects. Societies can collectively install solar panels to power common facilities such as elevators, lighting and water pumps. This reduces individual financial burden and ensures shared benefits.

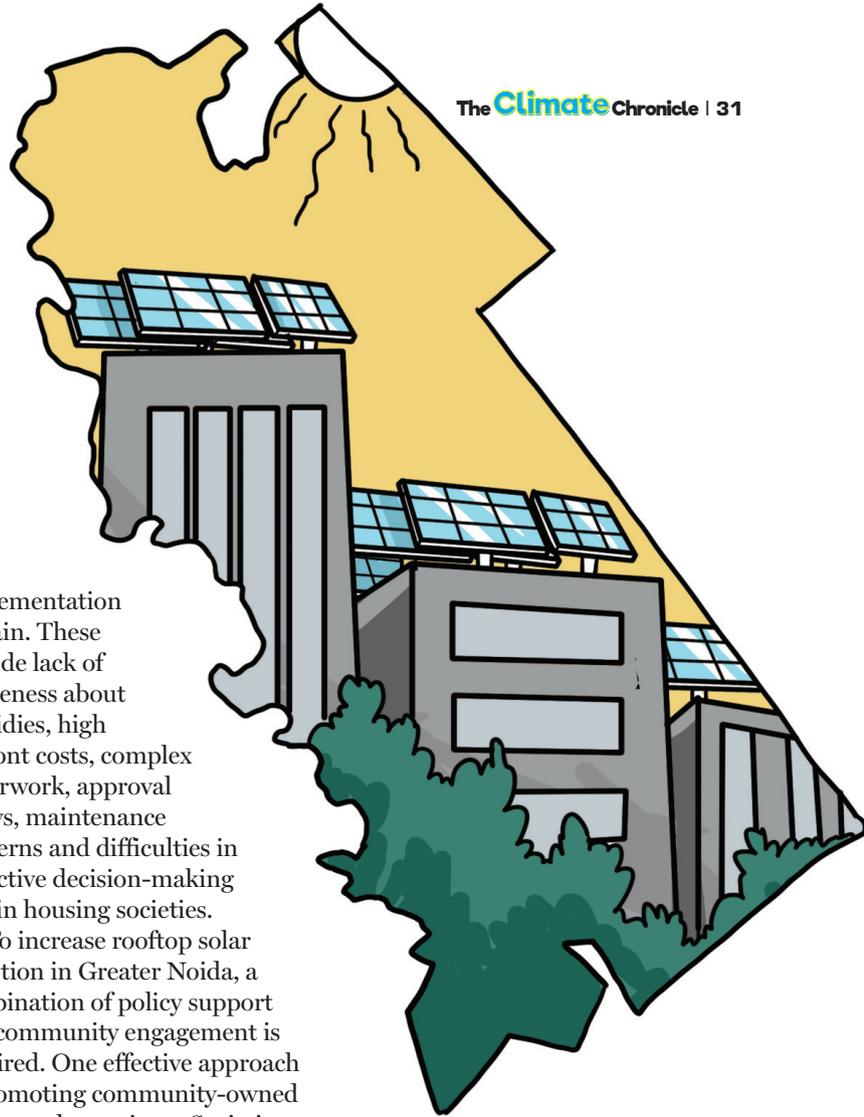
Financial barriers can be addressed through easier access to subsidies, low-interest loans and instalment-based payment options. Government agencies and electricity distribution companies should simplify paperwork and provide technical support for installation and maintenance.

Resident Welfare Associations (RWAs) can play an important role by organising awareness drives, inviting experts for discussions and encouraging informed collective decisions. NGOs can support by helping residents understand the long-term economic and environmental advantages of solar

energy.

Special attention should be given to ensuring that low-income households benefit from reduced electricity costs through shared solar systems. Rooftop solar adoption can enhance energy security during heatwaves and reduce dependence on unclean energy sources.

Rooftop solar offers a practical and sustainable solution for residential societies in Greater Noida. Despite challenges related to cost, awareness, and collective decision-making, its long-term environmental, economic, and social benefits make it a valuable investment. With government support, community participation, and informed action, rooftop solar can become an important pillar of sustainable development in urban and semi-urban neighbourhoods.





Umesh Sharma

Solar on the Rooftops

A Tale of Two Societies in Greater Noida

Greater Noida, a planned city in the National Capital Region, has urbanised rapidly over the past two decades, increasing pressure on energy resources. With long summers and nearly 300 days of high solar radiation annually, the city is well suited for solar generation. Yet electricity supply remains largely coal-based, contributing to emissions and air pollution. Residential societies, with large rooftops and collective demand, offer strong potential for decentralised solar, but adoption remains limited due to high installation costs, uneven uptake, maintenance and storage challenges, and reliance on private vendors.

This study examines rooftop solar adoption through case studies of Jaypee Greens and Senior Citizen Housing Society in Greater Noida, assessing installed capacity, energy generation, operational challenges, and their potential as sustainable urban energy solutions. It also identifies policy and coordination gaps between residential societies and urban governance institutions.

India's electricity system has long relied on centralised coal-based generation. Rapid urbanisation and rising living standards have increased electricity demand in cities like Greater Noida, particularly during peak summer months, placing pressure on the grid and increasing environmental costs.

Despite national and state promotion, rooftop solar adoption

in urban residential societies remains uneven, with significant rooftop potential underutilised. High-income societies face procedural delays, weak collective decision-making, and limited awareness of long-term benefits, while semi-urban or specialised housing societies encounter financial constraints and limited technical support.

The issue is multidimensional and closely linked to climate change, air pollution, and urban sustainability. Continued dependence on coal-based power worsens carbon emissions and air quality. Cities in the NCR region, including Noida and Greater Noida, frequently record severe

pollution levels. Low rooftop solar adoption can be attributed to high perceived installation costs, lack of technical knowledge, complex approval processes, and weak engagement by distribution companies.

This study adopts a case-based and empirical approach to understand real-life conditions rather than relying solely on secondary sources. Two contrasting residential societies were selected to analyse capacity, panel type, efficiency, and practical outcomes.

The Senior Citizen Home Complex Society consists of low-rise residential blocks with 845 flats, primarily inhabited by elderly residents. Many depend on fixed incomes, making affordability and reliability key concerns.

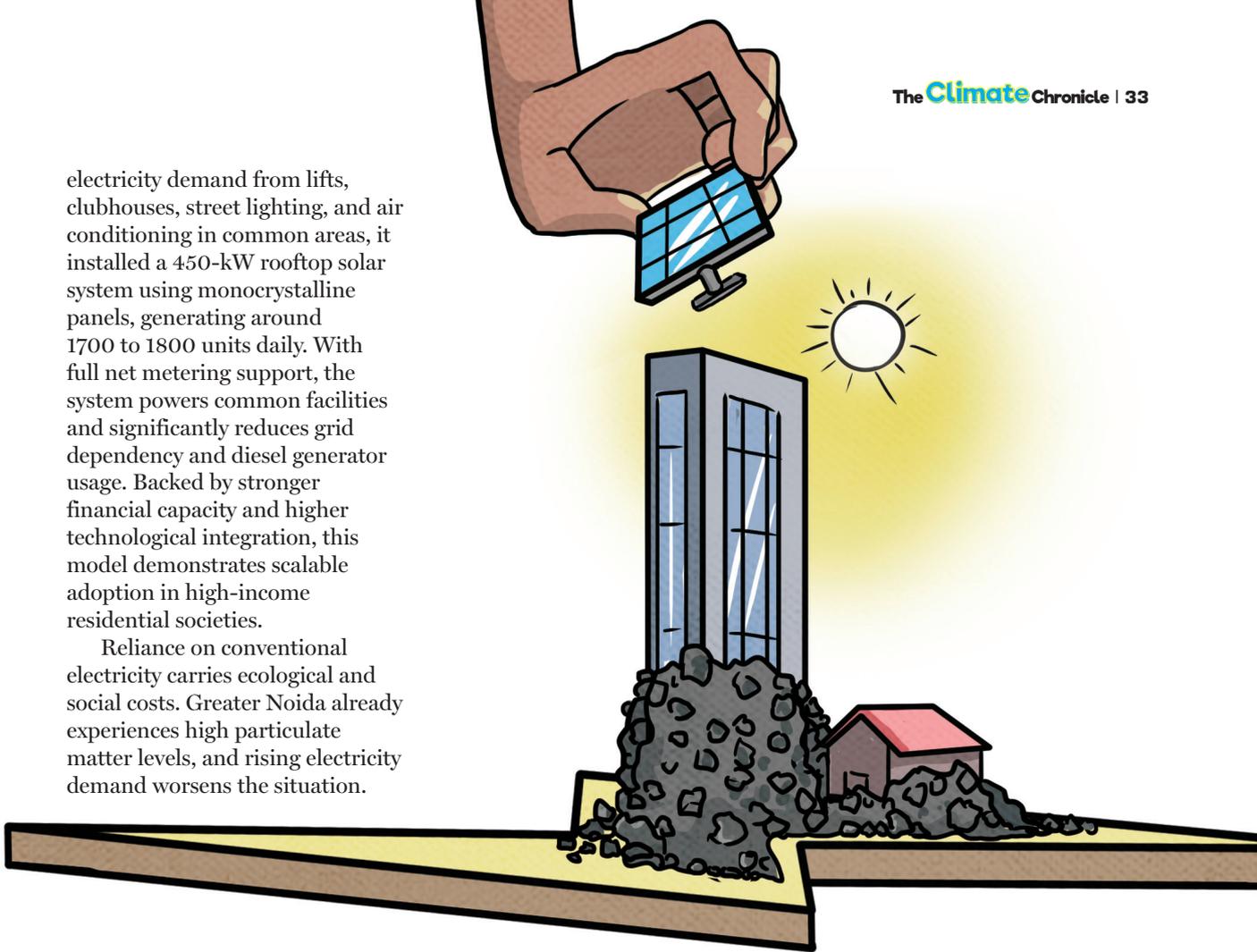
The society installed a 120-kW rooftop solar system using polycrystalline panels, generating about 450 to 500 units per day. With partial net metering support, the system powers lifts, corridor lighting, water pumps, and other essential services. The cost-sensitive installation prioritised reliability over automation and reduces electricity bills for common services, especially benefiting residents during peak summer months. This model reflects an inclusive renewable energy approach suited to vulnerable groups.

In contrast, Jaypee Greens is a premium gated society with high-rise towers and advanced infrastructure. Due to higher

The study shows that while financially robust societies can benefit from solar faster, inclusive and cost-sensitive models can also benefit vulnerable communities who face the strain of rising power consumption

electricity demand from lifts, clubhouses, street lighting, and air conditioning in common areas, it installed a 450-kW rooftop solar system using monocrystalline panels, generating around 1700 to 1800 units daily. With full net metering support, the system powers common facilities and significantly reduces grid dependency and diesel generator usage. Backed by stronger financial capacity and higher technological integration, this model demonstrates scalable adoption in high-income residential societies.

Reliance on conventional electricity carries ecological and social costs. Greater Noida already experiences high particulate matter levels, and rising electricity demand worsens the situation.



Residents face higher bills, peak-hour load stress, and dependence on diesel generators during outages, affecting quality of life and increasing household expenditure, though impacts vary across households.

Elderly residents are especially vulnerable to heat stress and power disruptions during extreme summers, with fixed incomes making them more sensitive to rising electricity costs. Lower-income residents, tenants, and support staff are also indirectly affected when higher operational costs lead to increased charges or reduced services. Rooftop solar systems, such as those in Jaypee Greens, can reduce electricity bills, lower grid dependence, and minimise such vulnerabilities.

The Government of India has introduced several initiatives to promote rooftop solar energy under the Ministry of New and

Renewable Energy. Schemes such as PM Surya Ghar Yojana aim to solarise one crore households with subsidies up to Rs 78,000 and an investment of over Rs 75,000 crore. The PM KUSUM scheme supports solar adoption in agriculture through subsidies and grid connectivity. However, implementation faces barriers including procedural complexities, delayed approvals, limited awareness, and inadequate technical support.

Community-based shared rooftop systems for common areas, supported by effective net metering, can help address these challenges. Improved coordination between Resident Welfare Associations and government authorities can enhance awareness and access. Such measures can reduce grid dependence and emissions, lower electricity bills by Rs 1,500–1,800

per household, and improve reliability during peak summer months.

Expected outcomes include lower carbon emissions, improved energy security, and a replicable model for sustainable urban neighbourhoods. Urban local bodies and NGOs can promote adoption through awareness, policy support, logistical assistance, and government schemes.

This comparative study shows that rooftop solar adoption in Greater Noida depends on socio-economic capacity, governance coordination, and awareness, in addition to technical feasibility. The cases of Senior Citizen Housing Society and Jaypee Greens illustrate that although financial strength shapes scale and efficiency, inclusive and cost-sensitive models can still deliver meaningful benefits.



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