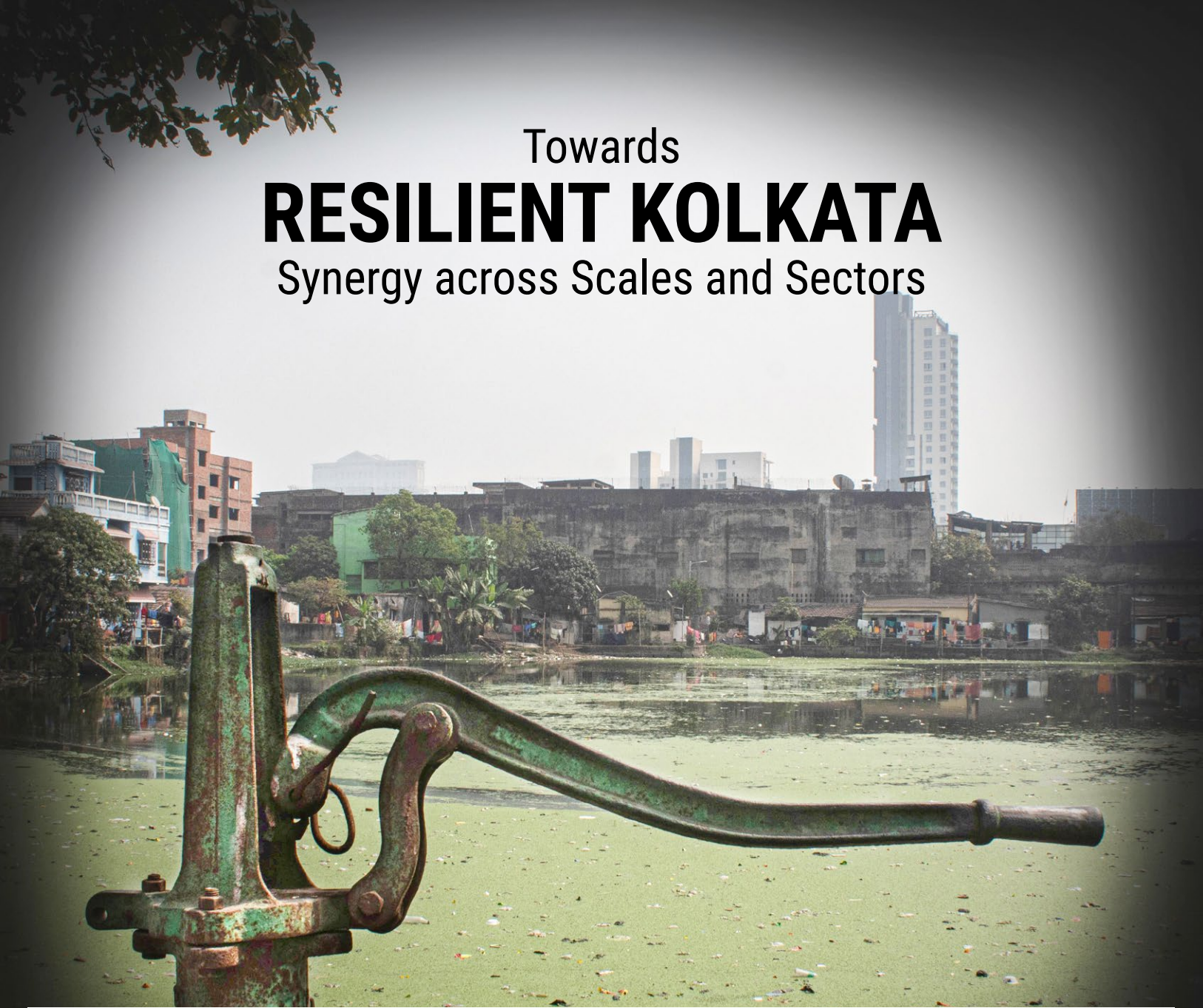
Towards

RESILIENT KOLKATA

Synergy across Scales and Sectors



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ADB

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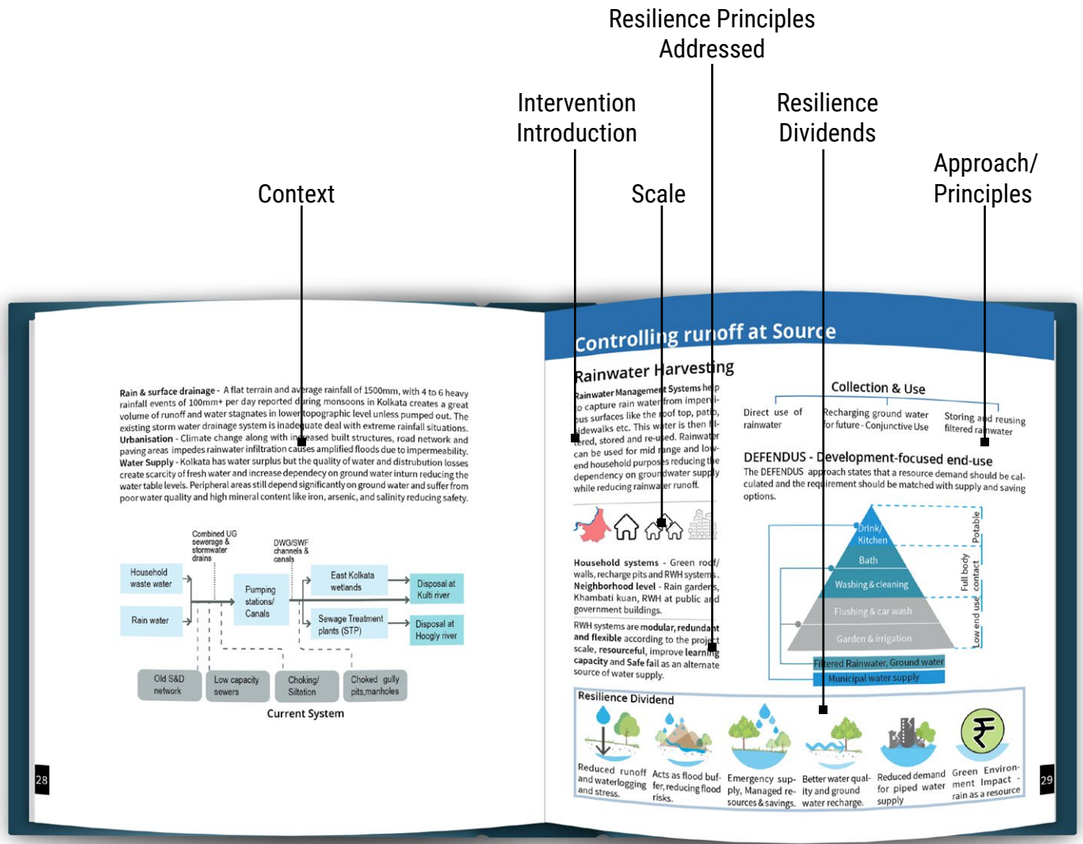
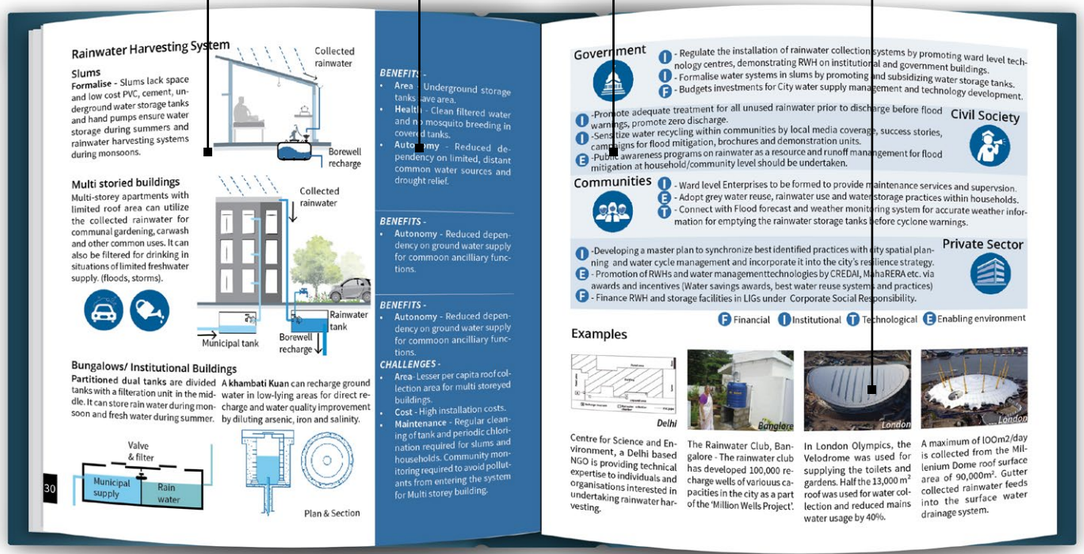
HOW TO USE THE BOOK

The book suggests interventions across six sectors:
Water, Energy, Waste, Food & Land Use, Mobility, and Urban Monitoring. Each section comprises of the following.





INTRODUCTION TO ICONS

Sectors


Water

Energy


Waste


Food and Land Use


Mobility


Urban Monitoring Systems

Scales


Household Level


Neighbourhood Level


City Level


City Core Area


City Periphery


KMC Region

Stakeholders


Government (G)


Civil Society (Cs)


Community (C)


Private Sector (P)

ABBREVIATIONS

AMC	Annual Maintenance Contract
BNCCI	Bengal National Chamber of Commerce and Industry
CBO	Community Based Organization
CSR	Corporate Social Responsibility
DEFENDUS	Development Focused End Use
DM	Disaster Management
DRR	Disaster Risk Reduction
EKW	East Kolkata Wetlands
FFEWS	Flood Forecasting and Early Warning System
Ha	Hectare
IoT	Internet of Things
IWEX	Integrated Waste Exchange
JICA	Japan International Cooperation Agency
KSWMIP	Kolkata Solid Waste Management Improvement Project
KMC	Kolkata Municipal Corporation
LED	Light Emitting Diode
LID	Low Impact Development
LPCD	Litres Per Capita per Day
LPG	Liquified Petroleum Gas
mcum	Million Cubic Meters
mld	Million litres per day
NGO	Non-Governmental Organisation
OSRT	Off-Site Real-Time Monitoring
PV	Photovoltaic
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Public Private Partnership
RO	Reverse Osmosis
RTPC	Resilience Technology Promotion Centre
RWH	Rain Water Harvesting
Sq.m	Square Meter
SuDS	Sustainable Urban Drainage Systems
S&D	Sewerage & Drainage
TPD	Tonnes Per Day
UNFCCC	United Nations Framework Convention on Climate Change

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We thank the Kolkata Environmental Infrastructure Investment Project officials for providing knowledge support. We are grateful to Mr. Soumya Ganguly, DG KEIIP for his valuable insights about Kolkata's municipal infrastructure.

This book is the outcome of experiences we gained from observing the functioning of, and challenges faced, by various departments providing lifeline services to the city. The infrastructure history of Kolkata spans three centuries and collecting data was difficult. We particularly thank all the officials of Kolkata Municipal Corporation who provided invaluable assistance, explaining the history and providing data. We would like to express our sincere thanks to Mr. Amit Kumar Roy (DG S&D) and Mr. Supriyo Sengupta Executive Engineer, for providing support in installing and running the Flood forecasting and early warning system (FFEWS) as well as providing information on the sewerage and drainage system.

PREFACE

Coastal areas are the confluence of land, freshwater, and sea. The daily and seasonally changing boundaries between the land, the freshwater and the sea are also subjected to fast processes such as floods and cyclones. Slow processes such as erosion and deposition also shift these boundaries over time. These areas are known for recurrent shocks such as floods, cyclones, and stresses from endemic water-borne and vector-borne diseases. Unique ecosystems such as mangroves and marshes develop in these areas, which can adapt to the continuous changes in physical environment.

Since 1690, Kolkata has grown from a small port located on a relatively safe natural levee of the Hooghly into a 4.5 million city, expanding into more flood prone peripheries. The conventional urban infrastructure and services including water supply, drainage and solid waste management were built during the late 19th century. Despite continued extension, urban infrastructure is inadequate to meet current demands and changing geophysical and ecological contexts over the last two centuries. Mangroves were reclaimed and ecosystem services were disrupted. Incidentally, East Kolkata Wetlands (EKW) provides several ecological services such as sewage treatment and food supply, but over the last several decades, the area of EKW is shrinking with the onslaught of urbanisation. The local resources such as ponds and forests were reclaimed, eroding the ecological services necessary to supplement urban infrastructure.

Rapid urbanisation and climate change are rolling out together, increasing the vulnerability of the city to shocks and stresses. Climate change is expected to significantly change its risk profile. Now, Kolkata's risk calendar includes winter air quality crises, summer heat waves, monsoon floods and post-monsoon vector-borne disease outbreaks. As the city grows, the resource footprints grow beyond city boundaries and local ecosystems are unable to treat the urban solid and liquid wastes.

Since the last century, several technological disruptions have benefited as well as negatively impacted the cities. Automobiles have reduced travel time, which is neutralized by increased traffic congestions. Computers, mobile communication and satellite and drone based remote sensing have enabled change monitoring and developing scenarios to inform urban planning and management.

As cities get locked into vintage grey infrastructure, they are unable to address climate change induced stresses and shocks. Urban managers across the world are exploring nature-based solutions to supplement grey infrastructure. Nature-based solutions enable us to integrate water-energy-food cycles. Recycling and reuse can reduce overall resource demands. Unlike energy intensive city scale grids, nature-based systems leverage ecological processes by utilizing distributed resources such as sunlight and rainwater, through local interventions without investments from municipalities.

This book suggests multi-stakeholder led interventions across scales and sectors to improve the resilience of the city to shocks and stresses. Emphasis is laid on implementing local scale interventions for supplementing the municipal infrastructure to increase resilience through improved efficiency of urban water-energy-food (carbon) cycles. Waste reduction and reuse through circular economy is another focus of these interventions.

PATHWAYS TO RESILIENT KOLKATA

1. History of Kolkata

The genesis of present-day Kolkata lies in a group of small settlements that grew into an important city due to maritime trade. In 1690, the Bengal headquarters of the East India Company was set up at Sutanuti located on the natural levee of the Hooghly River by Job Charnock. It had become the earliest major port in India by 1800. From 1772 to 1911, "Calcutta" was the capital of British India.

Kolkata lies in a flat and poorly drained delta, prone to waterlogging, leading to mosquito-borne diseases and widespread faecal contamination of water which caused recurrent epidemics of cholera. It is reported that more than a third of the European population perished in such plagues during the 19th century. This earned Calcutta the sobriquet of "Charnock's Folly" and the "Chance Erected City".

To solve recurrent cholera and diarrheal outbreaks, in this city of 500,000 plus population in the 1860s, sewerage, drainage and water supply systems covering a 25 sq.km area were commissioned. The legacy drainage systems are inadequately designed (max of 6mm/hr). Over the next one and half centuries, it has been upgraded and expanded several times. To address the garbage problem, a railway line was also laid in 1868 to transport the city's garbage by train to the Dhapa dump site.

2. Kolkata Today

The Kolkata Municipal Corporation covers a population of 4.5 million and it is situated within an urban agglomeration of more than 14 million people. Kolkata is a delta city with a flat terrain and poor drainage. The daily tides affect both the Hooghly as well as the Kulti River's outfalls of city's drainage. The Hooghly River used to be saline during summers before the diversion of water from Farakka in the 1970's. Salinity increase is being reported over last decade due to reducing summer flows. The northern edge of the city is bounded by East Kolkata Wetlands (EKW). These tidal wetlands were saline in the past, but with the siltation of the Bidyadhari River and disposal of sewage, they have become freshwater bodies. As sewage dependant fishing and vegetable farming in EKW meets significant food demand of the city, Kolkata is referred to as an **"ecologically subsidised city".**

Kolkata's summers are hot and humid, with temperatures occasionally crossing 40°C, causing extreme discomfort due to the high humidity. During the winters, air quality is poor, mainly due to the extensive use of diesel vehicles and the widespread use of coal for cooking, especially by the poor.

During the last two centuries, the urban context has changed, with a population increase by more than 10 times. Reclamation of water bodies and increase in built-up area are increasing the imperviousness resulting in the increase of flood frequency and intensity. Even though Kolkata has a city water and drainage grid, newly developing areas still depend on municipal supply and private tubewells. The peri-urban areas are haphazardly developed without a lifeline infrastructure. Some of the aquifers have high salinity, iron and arsenic levels, which are deleterious to people's health.

Kolkata city, which was originally located on the safer natural levee of the Hooghly has gradually expanded into the more flood prone periphery, and the city has been filling the wetlands, which earlier acted as flood buffers. In an average monsoon, the city faces four to six flood events, inundating roads and blocking traffic. Several extreme flooding events have inundated large parts of the city (1978, 1986, 1999, 2013). Occasional cyclones also hit the city causing widespread flooding and wind damage (e.g., Amphan 2020). Since the old drainage systems are inadequately designed and difficult to upgrade, it is necessary to explore other options to decrease run-off at source to reduce flood risks.

Mixed solid waste is now collected from the city and transported through trucks to the Dhapa dumping site. As the Dhapa dump is now full, KMC is searching for a sanitary landfill site since the last decade, but high real estate values have deterred people from selling land for landfill.

Only about 6% of the area of the city is under roads, resulting in frequent traffic jams across the city even in normal times. The roads are narrow and floods worsen the already stressed traffic situation.

3. Climate Change

Climate change is expected to (a) increase temperature and humidity causing more intense heat waves, (b) increase intensity and frequency of heavy rainfall events along with longer dry periods, and (c) cause sea level rise. These can result in more heatwaves during summers, and an increase in frequency and intensity of flood events. Presently, annual highest tides occasionally cause floods along Tolly Nala even without rains. The sea level rise is expected to reduce the drainage outfall periods into the Kulti and Hooghly resulting in a greater probability of flood events. Temperature increase can cause surge in the energy consumption as space cooling is required for longer periods. The water supply would be affected due to increasing salinity at intake point at Palta and there may also be changes in vector-borne and water-borne disease patterns. There are uncertainties regarding how and when these impacts will roll out.

4. Urban Resilience

Urban Resilience is the **measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming towards sustainability**[1]. In simple words, it is the immunity of the urban systems to hazards and other disruptions. The six main characteristics of urban resilience are presented in Figure 1.

Figure 1: Characteristics of Urban Resilience[2]

[1] Mariani, Luisana. "Urban Resilience Hub". urbanresiliencehub.org.

The six key characteristics of resilience highlight behaviours of urban systems to withstand shocks and stresses and also to enable quick recovery during extreme events[2] . Only some of these characteristics are relevant for each component of urban systems. For example, safe fail is important for physical systems such as buildings and electricity supply; responsiveness and capacity to learn are relevant for social and institutions systems.

To overcome water and energy scarcity, citizens invest in modular and redundant equipment as backups for ensuring water and electricity supply. These include storage tanks, pumps, tubewells and filters for water, gensets and emergency lanterns. While gridded energy systems can collapse suddenly causing blackouts, modular or hybrid systems (e.g., grid+solar) can shift load to alternate sources and prevent rapid collapse of the lifeline services. These diverse, redundant and modular systems provide the flexibility and safe-fail characteristics to withstand shocks and stresses. As these backup systems only increase resilience of households and enterprises who can afford them, they result in hoarding of scarce resources. To avoid such maladaptation, urban local bodies should ensure equitable access to lifeline services for all citizens, especially focusing on the poor and vulnerable.

Early warning systems, disaster management plans and emergency drills provide examples of resourcefulness and responsiveness to deal with hazards. There is an increasing emphasis on developing safe-fail systems to minimize damage from disasters and to provide lag times to deal with the emergencies. The ability to apply lessons from shocks and stresses to improve urban systems is a critical character of resilient social systems and organisations.

5. Opportunities in Disruption

The urban environment is continuously transforming with rapid changes in technology, economy and livelihoods. Computing, communication, and satellite-based earth observation technologies were some of the ground breaking technological disruptions during last two decades. The mobile telephony and digital data revolution have percolated into our daily lives and livelihoods. With advances in satellite remote sensing technologies, it is now possible to observe changes in land, water, air, clouds and vegetation. Modern computing technology enables us to develop future scenarios and it is now possible to visualize the impacts of energy, water, food and mineral resource consumption patterns on the climate, the ecosystems and the environment.

Modern manufacturing technologies aided by computing technologies have also made it possible to automate and miniaturize devices such as water filters, washing machines and enabled development of decentralized options for wastewater treatment. Advances in solar photovoltaics have made it possible to generate energy from rooftops. Diffusion of these technologies is reducing fossil fuel dependency. Electric cars can potentially reduce the urban air pollution. A significant section of consumers is now enabled to become prosumers[3] and achieve some degree of autonomy in resource use.

Satellite remote sensing and granular urban environmental monitoring have enabled us to track the progress of heavy rainfall events, cyclones and heat waves to provide early warnings and timely response to extreme events. With monitoring technologies, it is now possible to improve resource use efficiency and reduce imports of water, energy, and food. With advances in urban agriculture, it is now possible to automate micro-irrigation and use treated wastewater for growing crops on small plots and roofs. It will be possible to mitigate many urban resource challenges as well as reduce impacts of shocks and stresses.

Up to the last century, cyclones used to cause thousands of deaths. Early warning systems and mobile telephony have made it possible to warn and move people well in advance from high-risk areas and reduce mortality by at least an order of magnitude. Such technological disruptions can be leveraged to improve the climate resilience of the cities.

6. New Paradigms

One common assumption is that the municipality and its city scale infrastructure are best suited to provide urban lifeline services such as water and energy. A second common assumption is that larger systems can provide economies of scale and are more efficient. As a result, cities shifted from earlier practices of utilising diverse resources such as rainwater and water bodies, to relying on city-wide centralised supply grids. With the rolling out of climate change impacts, a paradigm shifts is necessary as presented in the following Table:

Older parts of Kolkata have piped water supply sourced from the Hooghly River. The rest depend on groundwater or a combination of groundwater and piped water supply. Groundwater is the only source of water in the newly developing areas even though some of the aquifers have high salinity, iron, and arsenic. Groundwater over-extraction is causing a water table decline and land subsidence. Managed aquifer recharge as well as wastewater treatment along with reuse can reduce waterlogging, dilute pollutants in the groundwater and reduce dependency on treated surface water for low-end uses such as flushing and floor cleaning. Reduction in waterlogging can significantly reduce mosquito breeding and seasonal disease burden from vector-borne and water-borne diseases such as malaria, chikungunya, dengue etc. These decentralised actions can be promoted building level upwards.

Wastewater pisciculture and agriculture in EKW meets a significant part of Kolkata's fish and vegetable demand. Formalising these practices and ensuring food safety is important to ensure food safety for Kolkata's citizens. Farm-to-fork microenterprises can provide better incomes to the farmers and fisherfolks while improving the quality of these products. There are significant opportunities for increasing resilience

Current Paradigm	Resilience Paradigm	Examples
Centralized city infrastructure grid (Water, Energy, Sewerage, Stormwater drainage)	Integrating local resource management in urban planning	Reducing runoff at source by RWH, SuDS; Conjunctive use of local & imported water
Linear economy (Take, Make & Dispose)	Circular economy	Formalizing source segregation & recycling/ reuse of waste, Decentralized biogas systems
Citizen as a consumer	Citizen/communities become Prosumers[3]	Roof top solar photovoltaic systems, RWH, Urban agriculture
Importing food	Urban agriculture & pisciculture	Formalizing farming & pisciculture in East Kolkata Wetlands, Rooftop farming

[2] ACCCRN 2012: ACCCRN City Projects; Jo da Silva , Sam Kernaghan & Andrés Luque (2012) A systems approach to meeting the challenges of urban climate change, International Journal of Urban Sustainable Development, 4:2, 125-145

[3] A ***prosumer*** is an individual/enterprise who is both consumer and producer.

through urban and peri-urban agriculture to reduce imports to meet city's growing food demand.

Kolkata continues to rely on fossil fuels for energy demands for domestic use, industry, and transport, as a result, the air quality reaches dangerous levels during winters. Options such as use of less polluting LPG and solar rooftop systems can reduce reliance on polluting fossil fuels such as coal and improve air quality, especially during winters. A resilience focused approach based on the following principles will be necessary.

6.1 Increasing Modularity, Diversity & Redundancy

When the city faces scarcity, the better off sections adopt coping measures by investing on modular systems such as inverters, back up electricity supplies, water storage tanks, filters and tubewells. While these kneejerk measures reduce water and energy stresses for some sections of the society, the poor who are unable to invest on such coping measures suffer differentially.

Hazard events can have disastrous impacts on gridded electricity and water supply systems affecting large urban populations. Cyclone Amphan and other disasters have shown that recovery can take several weeks, disrupting lives and livelihoods.

Diversification of resources along with conservation measures can improve resilience of the urban systems. Modular and decentralized systems can increase redundancy and diversity of resource use. Even if some of the decentralized systems fail during disasters, the remaining systems can continue to provide emergency backup services. Conjunctive water management including harvested rainwater, managed aquifer recharge and decentralized treatment and reuse of wastewater can significantly improve resilience against stress and shocks on the urban water cycle. Dual piping system for water supply can decouple drinking water from low end uses, which can enable the use of recycled water to improve water use efficiency and also prevent-risks of health impacts. These modular systems can be integrated with the city service grids to supplement the existing system. They are especially useful to supplement the under designed vintage infrastructure.

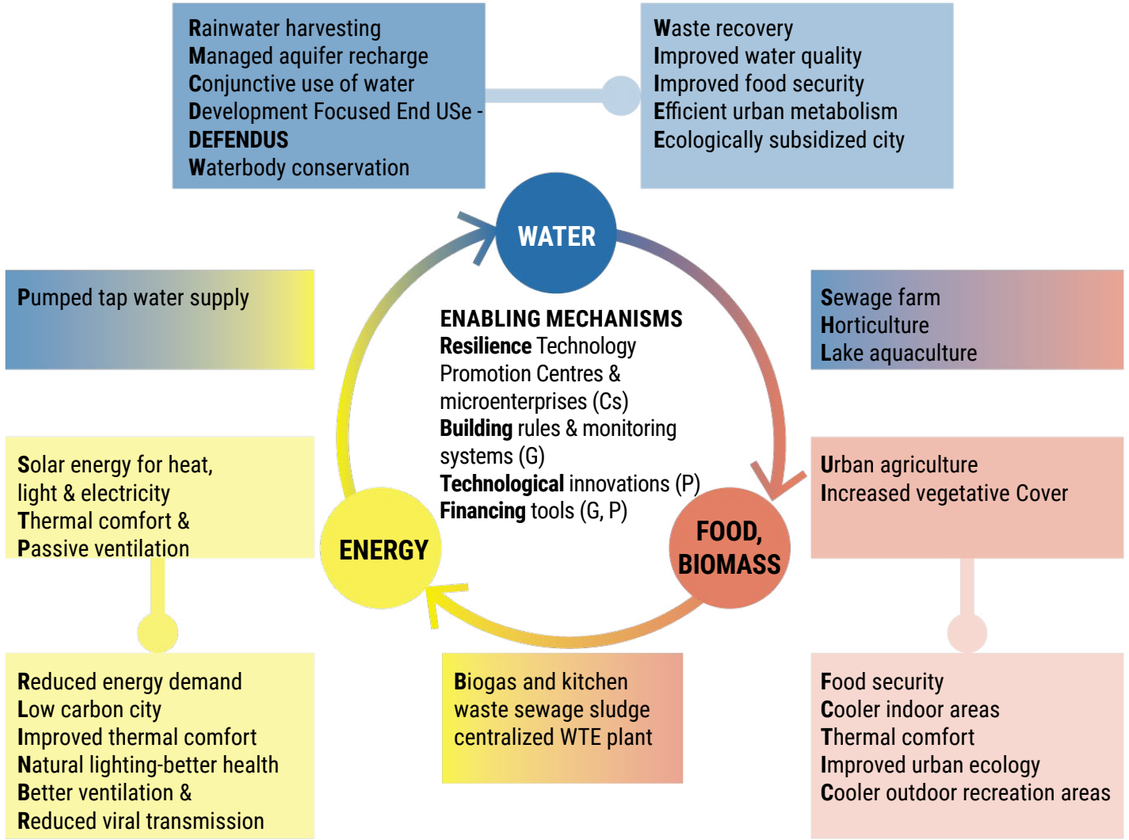
Roof top solar systems can provide decentralized power supply for lighting, pumping and recharging mobile phones during power grid breakdowns. Roof top solar photovoltaics work best with net metering so that energy storage at household levels is not necessary. The city electrical utility can postpone augmentation of power station capacities and also manage peak demands during daytime.

6.2 Managing Connectivity

Current urban service management is compartmentalized, and it needs to explore the possibility of increasing overall efficiency through building connectivity between different sectors such as water, energy and food systems. A healthy urban system should be able to leverage multi-sectoral interventions such as urban horticulture and pisciculture from treated wastewater, as exemplified by wastewater pisciculture and vegetable farming in East Kolkata Wetlands. Miniaturization and automation of such interventions is possible with sensors and controllers. However, formalizing and monitoring of these systems is essential for ensuring food safety.

To maximize the efficiency of urban metabolism, interventions in the water-energy-food cycle need to be implemented across scales starting from house/ building level to city levels. Establishing connectivity between multiple stakeholders as well as across sectors is necessary to maximize benefits. Managing a healthy water-energy-food nexus can increase the efficiency of the urban systems as shown in Figure 2.

Figure 2: Water-Energy-Food Cycle



Inadequate solid waste management causes blockage of stormwater drainage systems. Household level waste segregation and installation of biogas systems can decouple the solid waste system from the drainage, thereby reducing blockage induced frequent flooding. As wet kitchen waste is about one third of the total solid waste generated, decentralized biogas systems can reduce the amount of solid waste required to be transported, provide some energy for local use, and also extend the life of sanitary landfills. Recycling of useful materials from solid waste can reduce the pollution of land, water and air while improving the overall efficiency of the urban metabolism.

6.3 Improving Urban Metabolism Through Circular Economy

Based on the analogy of the human body, the city level process of consumption, utilization and waste disposal is often referred to as urban metabolism. The 20th century mine-use-dispose paradigm was adopted during the period of surplus resources and nominal demand. This paradigm is increasingly challenged as growing resource demands are stressing the regional water and land resources. These resource scarcities are creating increasing conflict between the cities, hinterlands and neighbouring regions. There is a growing opposition by the hinterlands to receive the wastes from the cities. In the face of these challenges, improving the efficiency of the urban metabolism through more efficient resource use and recycling is becoming critical.

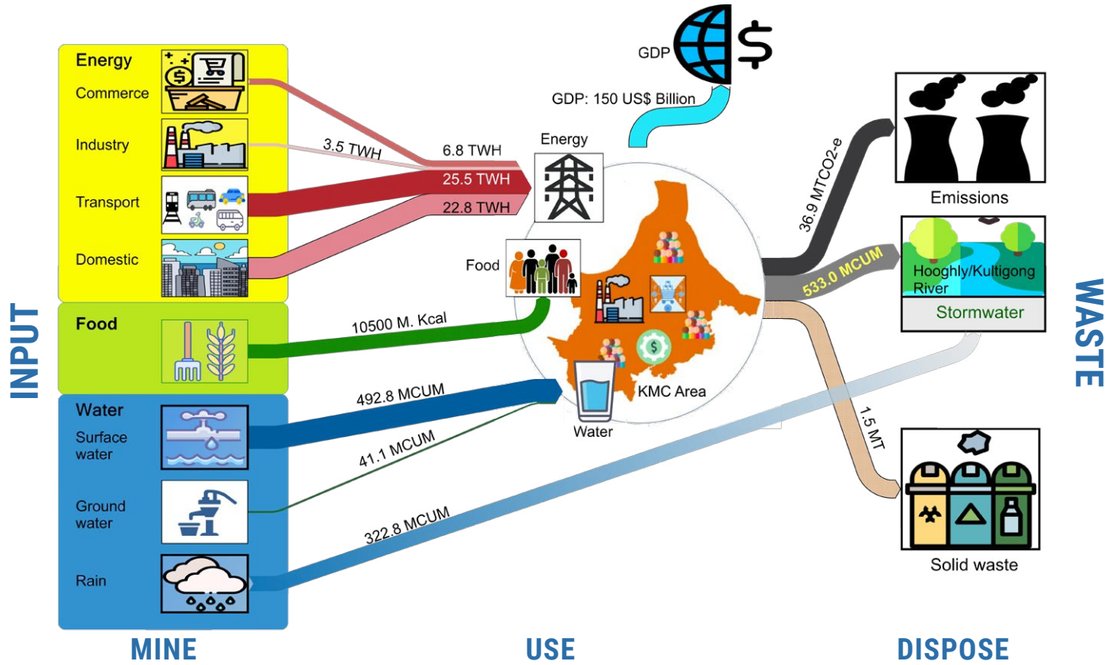
Cities import large amounts of resources such as water, energy, food and other raw materials to support life and livelihoods. Efficiency of resource use and urban services determine urban health as well as economic outputs of the city. In urban areas, water, energy, and food cycles are mediated through four lifeline services, namely, **Wa**ter supply, **S**olid & liquid waste management, **T**ransport and **E**nergy (WaSTE). Interventions to improve the efficiency of these services under changing shock and stress contexts are necessary for managing climate change impacts.

There are multiple options for improving the efficiency of the urban metabolism through recycling and reusing of waste. In the human body, the large intestine extracts water and electrolytes from undigested food before disposal of feces. Similarly, waste materials can be extracted and reused within the city (e.g., urban agriculture and pisciculture from waste, biogas from kitchen waste). While informal waste recycling exists in Kolkata, this needs to be formalized and regulated to reduce pollution and improve efficiency of resource use. In the human body, metabolism processes occur at multiple scales ranging from individual cells to organs. Similarly, in an urban system, actions across scales are necessary. As the municipality works at city scale, actions at individual scales need to supplement the urban metabolism.

Significant reduction in water and energy consumption can be attained by the use of devices such as aerator taps and LED bulbs. Conjunctive water[4] management and roof top solar panels can provide additional sources of water and energy. Decentralized wastewater treatment and biogas systems can reduce the volume of wastes that the city has to transport and dispose in landfills. These multiple options can be easily integrated into the urban planning and management through appropriate legal measures. These measures can be catalyzed by promoting microenterprises to provide installation, maintenance, and monitoring services. Empowering citizens, private sector, and civil society is necessary to ensure adoption of these interventions to improve the urban metabolism.

[4] Use of multiple sources of water such as groundwater, surface water and rainwater for different uses.

Figure 3: Urban Metabolism



6.4 Managing Slow Variables

Human and natural processes cause slow as well as rapid changes in water, land, and ecological systems. Climate change induced sea level rise is a slow process that can increase the salinity of Hooghly and increase the flood prone area. The slow siltation of the Adiganga had to be dealt by deepening of the river in 1770s to maintain the navigability with eastern hinterlands. With urbanization, Adiganga ended up as sewage channel. With the death of the Bidyadhari River, the sewage outfall had to be extended 15 km to the Kulti River in the 1950s. Groundwater over-extraction can trigger land subsidence and damage buildings. These slow changes can imperceptibly increase stress, requiring costly interventions in the long term. Due to high real estate prices, it may not be feasible to undertake many such remedial measures such as augmenting stormwater drainage or finding alternate site for sanitary landfill. Understanding these slow variables can enable anticipatory action to build resilience.

6.5 Anticipatory Planning

There are several tools such as global climate models and urban flood models that can provide insights into possible changes in risks and future resource availability. Remote sensing and satellite meteorology routinely provides warning of extreme events such as cyclones few days in advance. Flood models can delineate high risk areas, and ground level monitoring through IoT devices can validate and improve these models. These tools can provide possible scenarios to inform anticipatory urban planning, which is especially critical for the peripheral areas undergoing urbanization.

7. Creating an Enabling Environment

Decentralized resilience building measures require social mobilization (Information Education and Communication), technical support (design, installation, and maintenance) and funds from multiple stakeholders. Civil society support is required for creating awareness, and diffusion of resilience building action. Private sector support is necessary for financing and marketing these products and services. The municipality needs to create space for these stakeholders and should provide regulatory support.

7.1 Institutional Support

Activities such as awareness building, training of skilled workers (e.g., masons, plumbers, electricians), monitoring, and action research can be supported by Resilience Technology Support Centers (RTSC) run by civil society organisations or private enterprises. The municipality can partner with the RTSCs and transfer some responsibilities to them. These centers can be subsidized by providing them working space and also providing work in the weaker section housing projects. The RTSCs can catalyse setting up of resilience focused start-ups and microenterprises. They can also be engaged in regular monitoring of progress and impacts. The media and academic institutions can partner with them to provide dissemination and research support.

7.2 Financial Support

Many of the resilience building measures have long payback periods and it is one of the reasons for their slower acceptance and diffusion in the markets. Even though they save valuable resources and provide emergency services during shocks and stresses, these advantages are not perceptible during normal periods. However, their economic benefits to the city are high, therefore, it is necessary to incentivize their adoption. The KMC is already providing property tax incentives for investing on rainwater harvesting. Rooftop solar systems are subsidized by renewable energy development agencies. Financial mechanisms to scrap old diesel taxis were developed by the Delhi government through building partnership with banks. It is necessary to enable such public-private-citizen partnerships to promote these measures and to subsidize them through tariff reduction. Long term partnerships with insurance agencies and financial organisations and issuance of municipal bonds may be necessary to mainstream these initiatives. Other tools such as carbon credits can be explored where the direct benefits can be monitored.

UNFCC's Carbon Neutral Now platform provides crowdfunding for climate action for carbon credits to general public, individuals, businesses, and small organizations can participate in this platform and avail credits after due process. RTSCs can be suitable organisations for availing these credits by taking up local actions such as installing solar panels, cool roofs, biogas plants etc.

7.3 Stakeholder Participation

With ballooning population and spatial growth, derelict infrastructure and inadequate finance, the municipal administration ends up in firefighting mode. The municipality can only play a limited regulatory role in decentralized resilience building activities in private buildings and neighbourhoods (e.g., rainwater harvesting, managed aquifer recharge, biogas and composting, roof top solar energy generation). Some of these measures require partnerships between Municipality-Private Sector-Citizen-Civil society to be effective and successful.

Principle of Subsidiarity

Subsidiarity Principle means "that a central authority should have a subsidiary function, performing only those tasks which cannot be performed at a more local level[5]". It is intended to ensure that decisions are taken as closely as possible to the citizen and that constant checks are made as to whether action at Community level is justified in the light of the possibilities available at national, regional, or local level[6].

The Principle of Subsidiarity envisages citizens taking actions on their properties with the urban local body managing city level lifeline services. Civil society can create awareness while the private sector can provide technology support. One of the successful examples of government-private sector- citizen partnerships is the adoption of rooftop solar systems by individual building owners across cities. Similar technology support interventions can incentivize citizens to increase efficiency and resilience. Local microenterprises and technology promotion centers can provide installation and maintenance support. The following roles are possible for the four major stakeholder groups in improving climate change resilience:

Communities 1. Increase autonomy (Water, Energy, Food) 2. Conserve local resources, segregate waste streams, recycle/reuse waste, where feasible. 3. Contribute to local resilience initiatives (e.g., lake and tree cover conservation) 4. Contribute to urban environmental monitoring systems (IoT devices).	**Government** 1. Regional and city planning . 2. Improve efficiency of urban metabolism. 3. Improve, augment and extend urban services. 4. Integrate actions across scales and sectors as per subsidiarity principle to provide space for multiple stakeholders. 5. Regulate informed by monitoring systems.
Private sector 1. Innovate and improve efficiency. 2. Market environmentally sound products. 3. Reduce and recycle waste. 4. Seed and empower microenterprises.	**Civil society** 1. Promote resilience building initiatives. 2. Set up and manage "Resilience Technology Promotion Centres". 3. Conduct training, research, resource audits and monitor progress on (Water-Energy-Food) interventions.

[5] https://www.lexico.com/definition/subsidiarity
[6] http://www.coastalwiki.org/wiki/Principle_of_subsidiarity

SECTORS

01

Water

02

Energy

03

Waste

04

Food & Land Use

05

Mobility

06

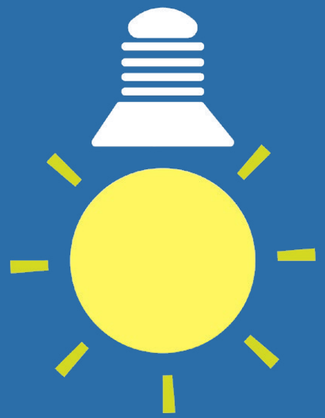
Urban Monitoring System

INTERVENTIONS

- Controlling runoff at source - Rain Water Harvesting (RWH)
- Sustainable Urban Drainage Systems - SuDS
- Conservation of urban water bodies
- Solar energy for heat, light and electricity
- Thermal comfort and passive cooling techniques
- Decentralized waste management
- Decoupling solid waste and stormwater
- House-Farm-Pond-Fish Ecosystem - urban agriculture
- Pocket parks
- Wetlands for sewage treatment & agriculture
- Sustainable transport - pedestrianization, cycling, transport action plan - “SPACE” framework and 15 minute city
- Multimodal transit, last mile connectivity, paratransit and integrated modes of public transport.
- Urban environmental monitoring, urban health monitoring and early warning systems
- Financial and institutional tools

Water

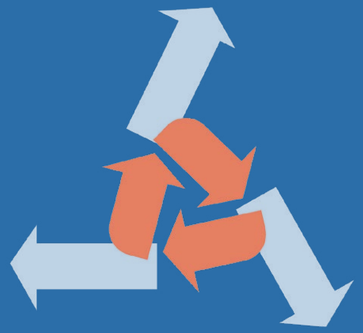
- Reduce leaks & wastage.
- Reduce contamination from waste & drains.
- Audit water supply & safety at various levels.
- Runoff control at source.
- Install rainwater storage tanks, rain gardens & urban flood parks.
- Install dual piping system to reuse treated grey water.
- Install green medians for groundwater recharge.
- Invest in waterbody conservation programs & management plans.



Waste

- Reduce, reuse & recycle.
- Segregate waste at source.
- Avoid mixing of waste.
- Invest in decentralized waste management systems.
- Introduce IWEX (Integrated Waste EXchange) programs at ward level.
- Create awareness about the wetlands, highlighting their role as Kolkata's natural Sewage Treatment Plants (STP).

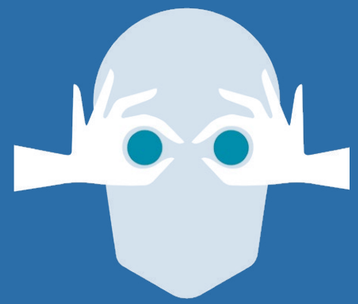
- Use energy efficiently & invest in energy star certified appliances.
- Use passive cooling techniques; like insulated walls, double glazed windows, cool roof & terrace gardens for reducing indoor temperature.
- Increase plants & trees in & around the structures for thermal control.
- Improve natural ventilation to reduce indoor humidity.
- Invest in solar photovoltaics for electricity generation.
- Use solar energy for light , heating water & cooking.



Energy

Mobility

- Develop non-motorised transport systems for short-distance travel.
- Establish clear cycling lanes and footpaths.
- Shift to sustainable modes of transport.
- Actively shift to green transport; electric cars, solar operated buses & hybrid vehicles.
- Integrate all modes of transport to provide fast, cost effective origin to destination solutions.
- Establish multimodal transit systems for faster & efficient travel.
- Choose public transport and reduce private vehicle use.



- Develop an integrated master plan leveraging blue-green infrastructure.
- Invest in urban agriculture.
- Identify & develop unutilised small city spaces as pocket parks.
- Focus on ecosystem conservation.
- Establish connections between consumers & EKW farmers.
- Strengthen EKW Management Authority & establish conservation programs.

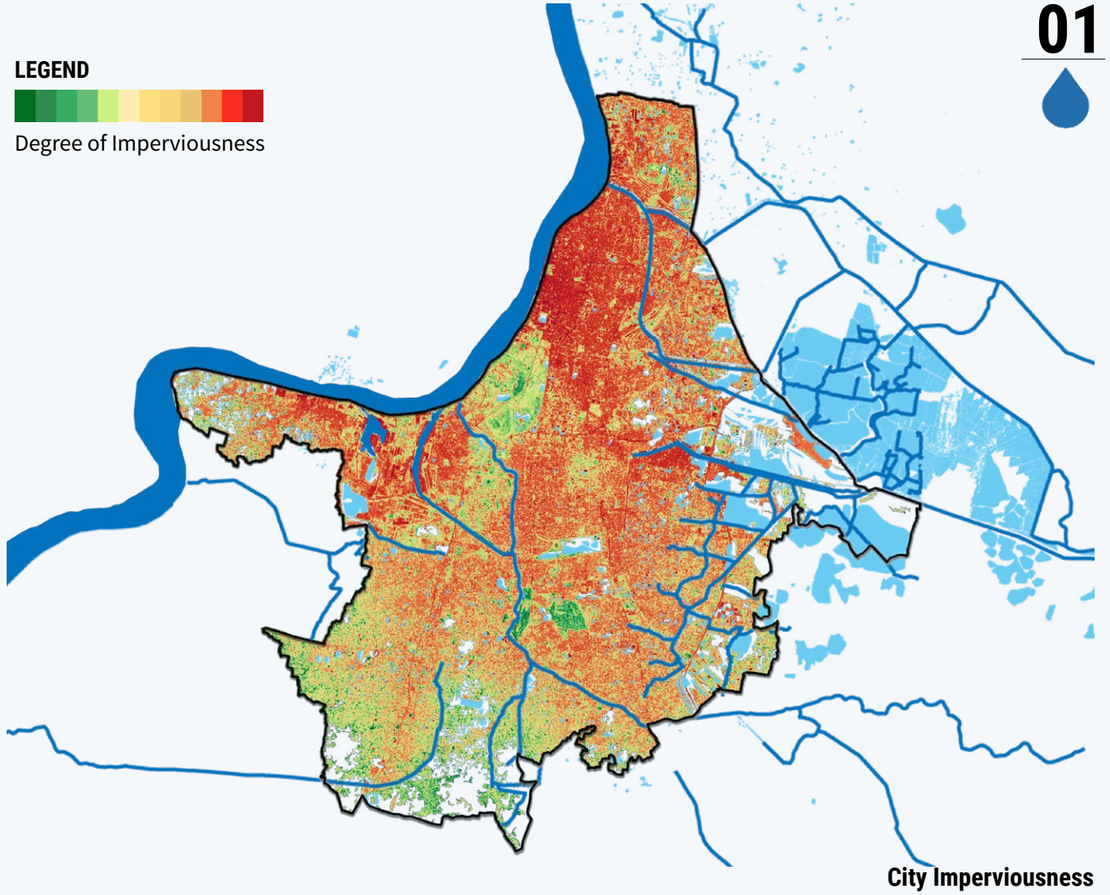
Food & Land Use

- Prioritise IoT based data collection & monitoring.
- Implement ecosystem monitoring across scales for efficient multi-stakeholder planning.
- Implement IoT based environmental monitoring systems to inform urban planning & risk mitigation.
- Plan conservation activities based on ecosystem data.
- Create awareness by sharing environmental data.
- Implement urban health monitoring systems to ensure timely response to disease outbreak.

Urban Monitoring

Water

01



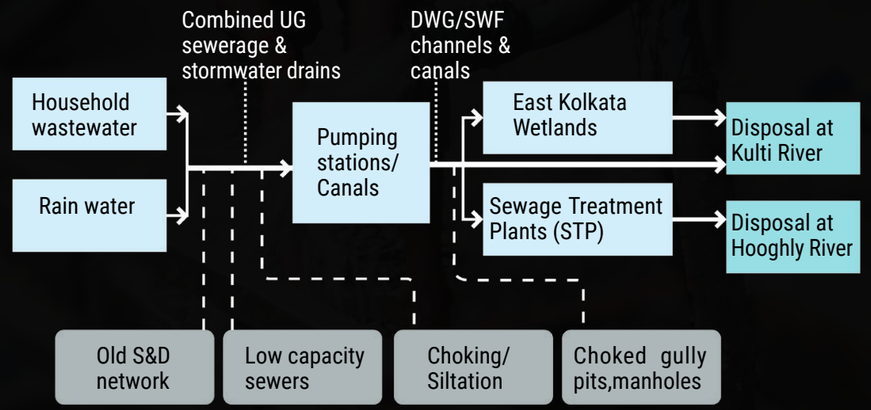
City Imperviousness

Interventions

Controlling Runoff at Source: Rain Water Harvesting (RWH)
Sustainable Urban Drainage (SuDS)
Conservation of Urban Water Bodies

Rain and surface drainage - Kolkata experiences an average rainfall of 1500 mm with peak rainfall events of more than 100 mm/day. As the terrain is flat, the water is “lazy” which results in four to six flood events in an average monsoon. Traffic jams increase due to waterlogging on roads. Occasionally, large parts of the city get affected by floods.
The existing stormwater drainage system is inadequate to deal with extreme rainfall situations. The city has high imperviousness due to its dense settlement pattern, which reduces infiltration and increases flood intensity.

Water Supply - Kolkata lies in a water rich deltaic environment with the Hooghly River and alluvial aquifers as the main water sources. High distribution losses, partial coverage of water supply network and increasing summer salinity of Hooghly River are challenges faced by the city. Peripheral areas still depend significantly on groundwater and suffer from poor water quality with high mineral content like iron, arsenic, and salinity reducing safety. About 30% of the water demand is met by groundwater sources, which is causing a water table decline.



Current System

Controlling Runoff at Source

Rainwater Harvesting

Rainwater Management Systems capture runoff from impervious surfaces such as roof tops. Rainwater is then filtered, stored and reused. Rainwater can be used for mid-range and low-end uses such as washing and flushing, thereby reducing the dependency on other sources while reducing runoff.

Household - RWH system, aquifer recharge, dual piping system.
Neighbourhood level - Rain gardens, *Khambati Kuan*, RWH at public, commercial and government buildings.

RWH systems are **flexible** according to the project scale, **resourceful**, improve **learning capacity** and ensure **safe-fail** as an emergency water source during and after disasters.

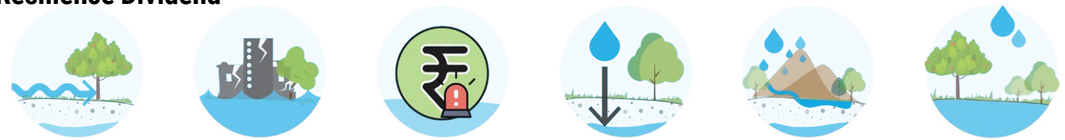
Collection and Use

- Direct use of rainwater
- Recharging groundwater for future & conjunctive use
- Storing and reusing filtered rainwater-RWH

DEFENDUS - Development Focused End-Use

The DEFENDUS approach relies on matching different types of demands with different qualities of supply. It focuses on matching different types of demands with appropriate quality of supply.

Resilience Dividend

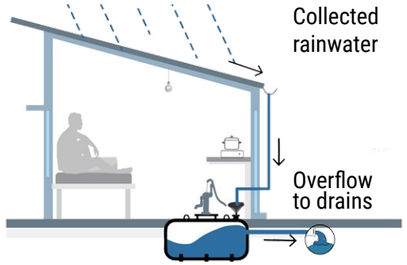


- Reduced runoff, water-logging and water stress
- Flood buffer and surplus management
- Emergency backup resource
- Improved groundwater quality
- Reduced municipal water demand
- Reduced soil erosion and flood intensity

Rainwater Harvesting System

Slums

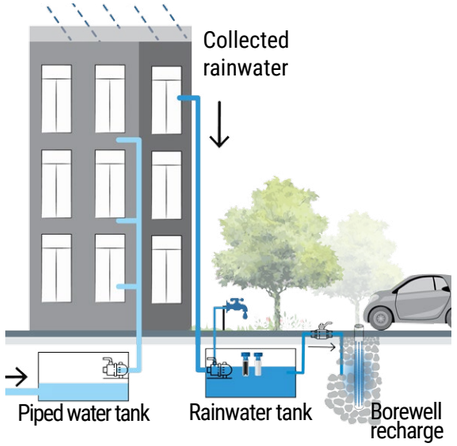
Formalize - Slums lack space. Low cost PVC, cement, underground water storage tanks with hand pumps can ensure water storage during summers and rainwater harvesting during monsoons.



Multi-Storied Buildings

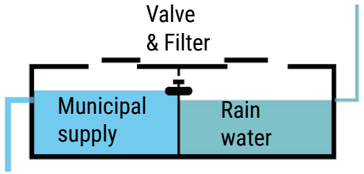
Multi-storied apartments with limited roof area can utilize the collected rainwater for community gardening, car washing and other low-end uses. It can also be filtered for drinking during emergencies (floods, storms).

Potential uses

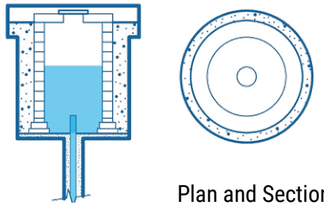


Bungalows/ Institutional Buildings

Partitioned tanks have a wall separating two tanks with a filter and a valve connecting them. Rainwater tank stores rain water during monsoons and fresh water during summers.



A ***Khambati Kuan*** filters runoff from streets and recharges groundwater. It can dilute arsenic, iron and salinity in aquifers.



Plan and Section

BENEFITS

- **Area:** Underground storage tanks save space, especially in low income houses.
- **Health**: Clean filtered water and no mosquito breeding in covered tanks.
- **Autonomy**: Reduced dependency on limited, distant water sources and drought relief for slums. Reduced dependency on groundwater supply for common ancillary functions in multi-storied buildings.

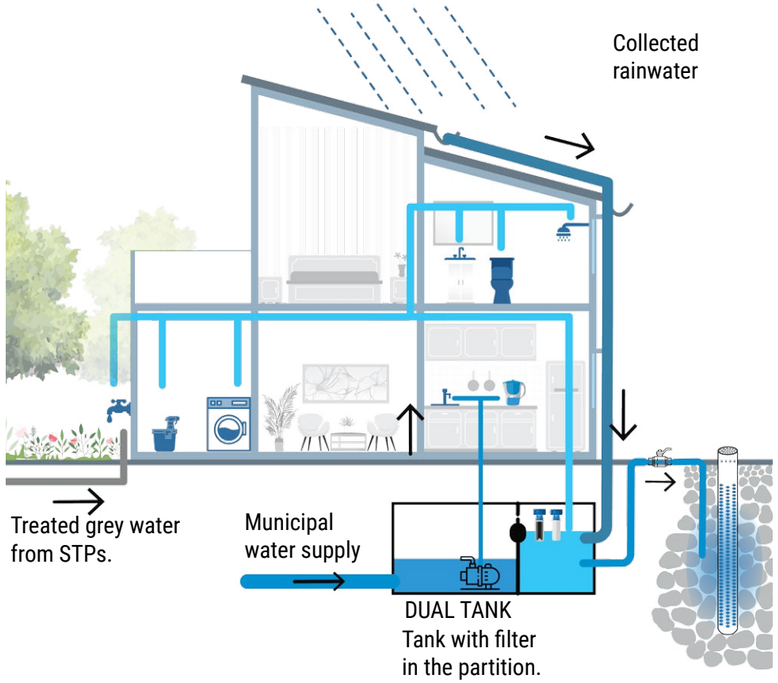
CHALLENGES

- **Area:** Lesser per capita roof collection area in multi-storied buildings.
- **Costs:** High installation costs.
- **Maintenance**: Regular cleaning of tank and periodic chlorination required. Community level monitoring required to avoid pollutants entering the system especially in multi-storied buildings with many households.

Dual Piping System

A system where two separate piping systems (piped water and rainwater water) deliver water to the user preventing the mixing of low quality water with potable water. Clean water collection areas, storage tank, and UV filtration system are needed if low quality water is to be used for high-end uses.

Potential uses of filtered rainwater and groundwater



The surplus water from the tanks is used for aquifer recharge via borewell.

BENEFITS

- **Environment:** Reduced rainwater runoff.
- Filled rainwater can be emptied into drains after receiving flood warning to create flood buffer.
- **Autonomy:** Reduced dependency on municipal supply.
- **Costs:** Simple and cost effective system.

CHALLENGES

- **Retrofitting**: Not always possible due to pre-installed pipeline system.
- **Maintenance**: Regular cleaning of collection area and pre-monsoon emptying of tanks required. Ensure the rainwater collected is free from pollutants and the filtration unit is periodically maintained.

KMC Rainwater Storage Potential:

With 54% land use under buildings - (assuming 50% roof) collection is 66 mcum. If 25% collection is done, 16.5 mcum water can be available for use!

Stakeholder Roles

Government

- (I) **Enforce** installation of rainwater collection systems in private buildings and townships; demonstrate RWH on institutional and government premises.
- (I) **Develop** integrated urban water management master plan to synchronize best practices with city spatial planning and incorporate it into the city's resilience strategy.
- (I) **Create** and support Resilience Technology Promotion Centres (RTPC).
- (F) **Subsidize** water storage tanks in slums and low income settlements.

Civil Society

- (I) **Establish** micro enterprises to provide installation, operation and maintenance services..
- (E) **Promote** habit of emptying rain water tanks on receiving heavy rainfall warnings.
- (E) **Popularise** rainwater harvesting and water recycling through media and demonstration units.
- (E) **Initiate** public awareness programs on RWH and runoff management.

Communities

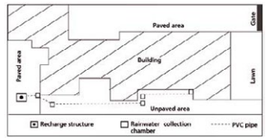
- (E) **Adopt** usage of rainwater, and treated grey water.
- (T) **Connect** with FFEWS for flood warnings and empty rainwater storage tanks before heavy rainfall events.

Private Sector

- (I) **Design and market** RWHs and water management technologies through CREDAI, BNCCI etc.
- (E) **Establish** awards and incentives programs. (water savings awards, best reuse systems and practices)
- (F) **Finance and support** RWH and water storage facilities in LIGs through CSR initiatives.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

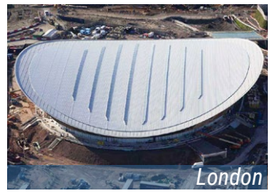


Delhi

Centre for Science and Environment, a Delhi based NGO is providing technical expertise to individuals and organizations interested in undertaking rainwater harvesting.

Bangalore

The Rainwater Club, Bangalore has developed 100,000 recharge wells in the city as a part of the 'Million Wells Project'.



London

London Olympics Velodrome is using rainwater in toilets and gardens. Half of the 13,000 sq.m roof was used for RWH and it reduced city water supply usage by 40%.

London

A maximum of 100 cum/ day is collected from the Millenium Dome roof. Collected rainwater feeds into the main storage system for reuse.

Blue-Green Infrastructure

Urban Water & Drainage

A Blue-Green city aims to improve the urban water cycle by integrating water management with green infrastructure. The vintage stormwater drainage system of Kolkata was designed for a peak rainfall of 4-6 mm/hr, while rainfall intensities of more than 20 mm/hr are frequently reported. Kolkata can significantly reduce runoff, flood frequencies and intensities by adopting blue-green strategies.

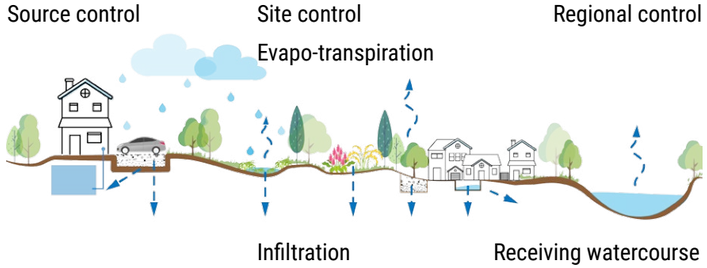
Neighbourhood level - Sustainable urban drainage system (SuDS)
City level - Urban waterbody conservation

SuDS are **flexible, redundant** and site specific, **resourceful, improve learning capacities** and **safe-fail.**

Sustainable Urban Drainage - SuDS

SuDS are a collection of water management practices that aim to align modern drainage systems with natural water processes using synergies between water management and spatial development. They are designed to slow down runoff down (attenuate), improve percolation and transport (convey) runoff, through creating storage and percolation areas along contours to reduce the intensity and frequency of flooding.

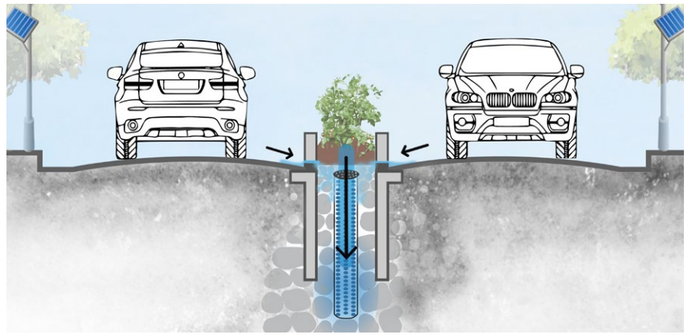
The SuDS management train divides drainage areas into sub-catchments with each having a distinct drainage strategy.



Resilience Dividend

- Reduced impact of urbanisation
- Increased aquifer recharge
- Protected natural flow water courses
- Improved water quality/ reduced pollution
- Reduced heat island effects and temperature
- Protected biodiversity and natural habitats

Green Medians



Green Medians - Wide medians may be utilized for improving infiltration and reducing floods.
Permeable pavement is a porous urban surface which catches runoff, allowing it to infiltrate into the soil below or stored in underground tanks for later use. In newly developing areas with natural soil, bioswales can be built to temporarily store and percolate runoff.

Urban Flood Park

Copenhagen, proposed flood park

Urban flood parks are areas designed to temporarily store runoff water during heavy rainfall events. During dry periods, they can used as playground and parks etc. The temporarily stored water can be passed through bio-filters such as constructed wetlands before recharging aquifers or filling water bodies.

BENEFITS

- **Environment**: Runoff reduction and recharge. Increased green cover reduces temperature. Groundwater recharge via infiltration with porous pavings.
- **Maintenance**: Low maintenance and beautification with plants.

CHALLENGES

- **Land**: Medians need modification to capture street runoff.
- **Costs:** Retrofitting may be expensive.

BENEFITS

- **Environment**: Runoff reduction and effective stormwater drainage.
- **Retrofitting**: Existing parks can be retrofitted to act as flood buffers.

CHALLENGES

- **Maintenance**: Flood parks should be regularly cleaned.

Waterbody Conservation

Water hyacinth covering lake, Indore

Floating island, Indore

Alum treatment, Indore

Water hyacinth removal, Indore

Urban Waterbody Conservation

Physical Conservation

Waste Management - Waste and sewage dumped without treatment causes degradation of water bodies. Social monitoring, cleanliness drives and allocation of funds are necessary to restore urban water bodies.

Water Hyacinth Removal - Water hyacinth cause a major problem by covering entire lakes quickly and cutting off sunlight penetration which leads to serious impacts on the lake ecosystem. This also results in mosquito breeding and fish kills.

Institutional Management by KMC

Preventing Encroachment - Introduction and enforcement of by-laws with heavy penalties for violations are necessary.

Monitoring and Maintenance - Lake conservation and land use protection plans need to be formulated with private sector collaboration and funding from the government and CSR. Social monitoring is necessary to prevent pollution and encroachments.

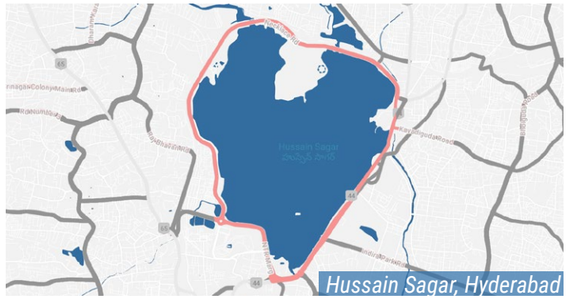
BENEFITS

- **Environment**: Reduced flood intensities by buffering effect, cooler neighbourhoods, reduced impact of urbanization.
- Reduced risks of breaching of lake embankments which can cause major disasters downstream.
- **Use**: The water bodies can be used for recreation, pisciculture and as a water source for low-end uses by neighbouring communities.
- **Health**: Sunlight improves water quality and reduces mosquito menace.

CHALLENGES

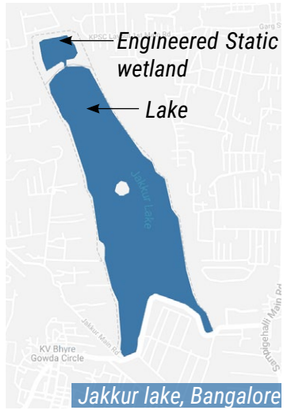
- **Costs**: Removal of water hyacinth after it fully covers the lake is costly.
- **Maintenance**: Regular maintenance is necessary and options such as lake adoption and lake front real estate development can be explored to cover maintenance costs.
- **Enabling factor:** Community may not take interest in monitoring or reporting encroachments.
- Community may not be able to control solid waste dumping and sewage disposal.
- **Acceptability:** Removing encroachments may be socially unacceptable.

Enveloping Walkways and Recreational Activity



Place-making through walkways or streets enveloping urban water bodies with recreational activities planned around them including small food parks and wetland parks can be explored.

Constructed Floating Wetlands



Constructed Wetlands - A portion of the lake should be allocated for constructed wetlands. Treated wastewater from STPs can be passed through these wetlands to filter silt and pollutants before the water flows into the lake.

Artificial floating islands are porous rafts, covered with soil/cocopeat and aquatic plants. They can be fitted with micro-STPs powered by solar panels to treat and aerate stagnant deeper water columns.

BENEFITS

- **Environment**: Reduced risks of encroachments by slums and real estate.
- Water bodies can act as flood buffers.
- **Costs**: Parks, and recreational activities can generate revenues for maintenance.
- **Health**: Well maintained lakes reduce mosquito breeding.

CHALLENGES

- **Costs:** Funding is required to build street/pathways and recreational spaces.

BENEFITS

- **Environment:** They filter pollutants and reduce degradation of lakes. Wetlands create biodiverse ecosystems providing homes for birds, fish, amphibians and various plant species.
- **Costs**: Natural and cost effective cleaning of the water bodies.

CHALLENGES

- **Maintenance**: Regular monitoring and maintenance of artificial wetlands is necessary.

Stakeholder Roles

Government

- (I) **Create** spatial plans. Enact and enforce land use rules for creating “No-Development” or ”seasonal use” zones based on risks and eco-sensitivity of the land especially in newly developing areas.
- (I) **Develop** ward/ pumping station catchment level flood risk management strategies and use water bodies as flood buffers.
- (I) **Develop** policies and action plans to lease out/ adopt water bodies for pisciculture and maintenance.

Civil Society

- (E) **Build** awareness about blue-green infrastructure among citizens.
- (E) **Monitor** water bodies and create “State of City Water” reports with special emphasis on water bodies and flooding.
- (E) **Develop** student programs for monitoring and conservation of local water bodies.

Communities

- (E) **Start** neighbourhood waterbody conservation committees to crowd-fund and manage small parks and water bodies for increasing biodiversity and creating recreational spaces.
- (E) **Promote** community participation in local public space planning.
- (E) **Inform** and educate users on solid waste management and need for maintaining water bodies.

Private Sector

- (I) **Adopt** water bodies and green spaces for improving biodiversity.
- (T) **Design** new buildings with facilities for flood parks, green areas and underground runoff storage (CREDAI, Architects, Urban designers, Planners)
- (T) **Provide** technical support and CSR funds to neighbourhood communities to manage blue and green spaces.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

Tanner Springs Park, USA

Built green stormwater management system with natural wetlands and functional public park.
Annual Rainfall - 940 mm
Area - 4.800 sq.m

Potsdamer Platz, Berlin

Created a vibrant , ecologically functional public waterscape in dense mixed-use urban center.
Annual Rainfall - 940 mm
Area - 68.000 sq.m

Water square, Rotterdam

Integrated water management at public square doubles as water collection and storage space during high rainfall.
Annual Rainfall - 816 mm
Area - 319 sq.km

Grey to Green, Portland

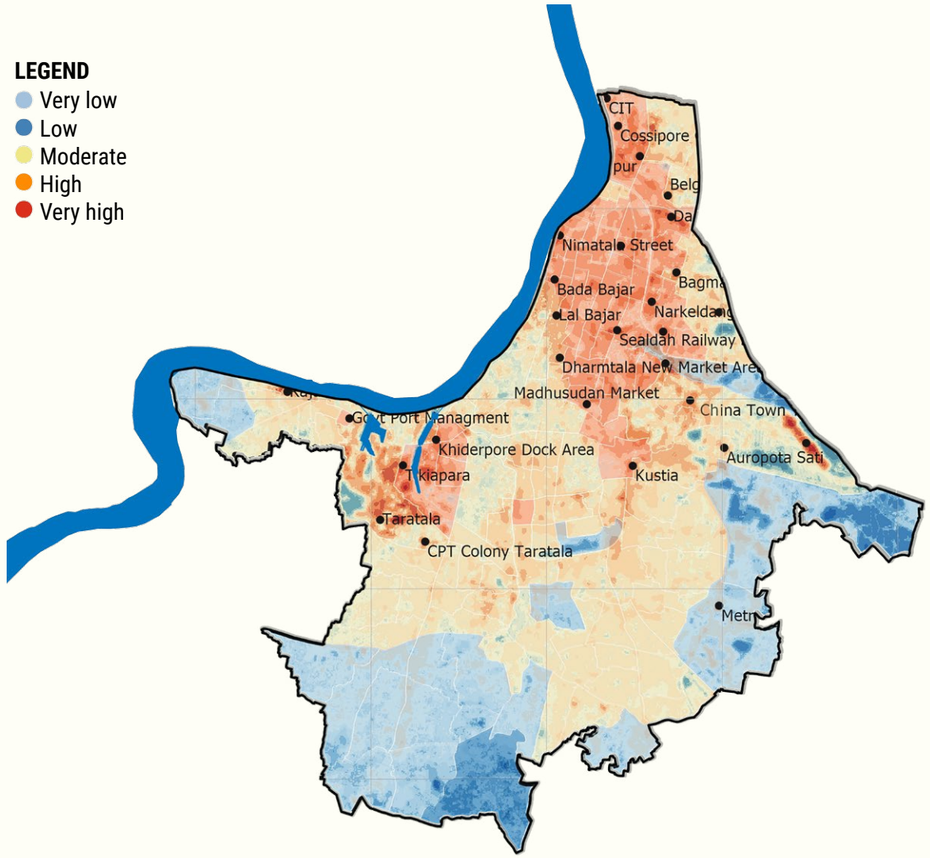
Programs developed to aid green infrastructure and sustainable SWM connected with public education activities.
Annual Rainfall - 940 mm
Area - 376.5 sq.km

Additional Information

	Factors	RWH	SuDS	Waterbody Conservation
1	Risks addressed	Water scarcity & flooding	Flooding, groundwater decline	Flooding, vector-borne diseases
2	Expected benefits	Reduced floods & water scarcity	Reduced floods, groundwater recharge	Reduced floods & heatwaves, mosquito control, fish production
3	Space & other requirements	Underground structures	Open areas, road medians	Existing lakes & their boundaries
4	Basic technical details & specifications	Tank, piping & clean roof, max 1000 litre per sq.m roof area	Bioswales, recharge wells, green roofs, rain gardens, porous paving	Water weed control, prevent waste disposal, pisciculture
5	Indicative costs	Rs.5-7/litre storage	Variable across sites & interventions	Variable, maintenance costs can be recovered by incomes, adoption
6	O&M requirements	Pre-monsoon cleaning, chlorination & water filters	Occasional cleaning, pruning of vegetation	Monthly cleaning of weeds, annual stocking of fish fingerlings
7	How to integrate the interventions with city level infrastructure	Can be connected to municipal supply for summer storage	Use parts to sum approach	Integrate with surface water channels
8	Existing rules & possible institutional support	RWH rules in building byelaws	None	East Kolkata Wetlands (Conservation & Management) Act, 2006, The West Bengal Inland Fisheries (Amendment) Act, 2008

Energy

02



Urban Heat Island & Temperature Variations

Interventions

Solar Energy for Heat, Light and Electricity
Thermal Comfort & Passive Cooling Techniques

Electricity Supply - KMC is currently dependent on Calcutta Electric Supply Corporation (CESC) , which has several coal-based thermal plants.
Climate change - Over the last 63 years, instances of daily maximum temperature exceeding 40˚C have increased. The average annual maximum temperature (31.2˚C) is projected to increase by between 1.0˚ to 1.6˚C by mid-century, and by 1.7˚ to 3.30˚C by end century. Kolkata being hot and humid needs cooling and proper ventilation most of the year. Rapid urbanization has increased temperatures and frequency of heat-waves, particularly during the pre-monsoon season. Rising thermal discomfort periods and increasing affordability has led to widespread use of air conditioners resulting in higher peak electricity demands.
Shocks – In the 1980s Kolkata used to face recurrent power cuts. Improvements in the power supply has reduced stresses. Shocks such as cyclone Amphan, can lead to electricity supply breakdowns lasting several weeks. Kolkata needs to promote decentralised renewable energy sources, such as rooftop solar systems to reduce fossil fuel dependency and to provide emergency supplies. Roof top solar systems can meet part of the peak demand and reduce load shedding.

Solar Energy

Photovoltaic Energy

Solar energy can be used for heating, light and electricity. Roof top photo voltaic (PV) systems generate electricity from the sunlight using solar panels combined with an inverter and other equipment. It is a decentralised, renewable energy source with diverse applications across scales. Efficiency and affordability of solar panels have improved with technological advancements over time.

Household - Thermal comfort and passive ventilation.
Household/ Neighbourhood/ City - Solar energy for heat, light and electricity.

Solar energy is **modular** and **safe-fail** source of renewable energy. **Flexibility** varies due to weather dependency.

Solar PV panels on roof

How to make a difference?

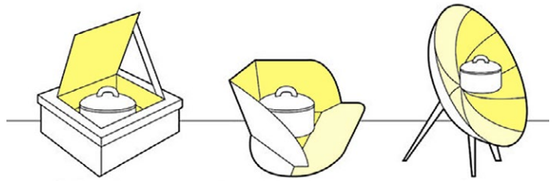
Reduce demand - Thermal power plants use coal causing air pollution and degrading quality of life. Growing energy demands and depleting resources leads to insufficient supply and inability to meet peak demands during summers.
Integration - Integration of solar energy and renewable sources is possible across households to city level.
Technology and innovation - Promoting a mix of new and existing solar energy options can improve resilience against energy shortages as well as prolonged grid failures caused by cyclones and heavy rainfall etc.

Resilience Dividend

- Resourceful and self sufficient energy source
- Reduced green house gases
- Very little or no maintenance required
- Functionality during natural disasters/shocks
- Modular, compact, portable systems
- Sustainable energy on demand

Solar Energy for Heat

Solar Cooking



Solar Oven *Panel Cooker* *Parabolic Cooker*

A solar cooker uses the solar energy to heat and cook food. A variety of solar cookers are available. Most cookers are insulated boxes with mirrors or reflective coating for concentrating sunlight on the pot. Food items such as rice, lentils and vegetables take about 1.5 to 2 hours to cook. Aluminum, hard black coated cooking pots with lids are used.

BENEFITS

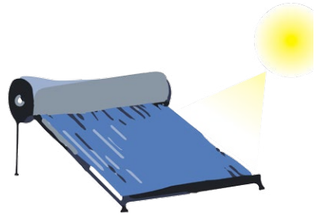
- **Environment**: No air pollution or gas emissions.
- **Health**: Better taste and higher vitamin content in slow cooked food. Sunlight sterilizes food and water.
- **Retrofitting**: Households can use them in balconies and terraces receiving direct sunlight.
- **Costs**: Sunlight is freely available, one time investment for the cooking utensil.
- **Maintenance**: Very basic maintenance required.

CHALLENGES

- **Area**: Multi-storied apartments might not get direct sunlight during cooking periods.
- **Flexibility**: Cannot be used during cloudy or rainy days or during nights.
- **Time**: Cooking time is much higher compared to LPG gas stoves.

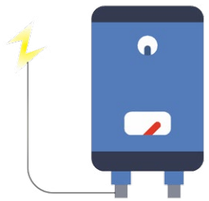
Solar Water Heating

Solar water heater is a device with a thermal collector and insulated hot water tank. The system is installed on a terrace or open space receiving direct sunlight.



Solar heater

Cost: Rs. 16,000 - 22,000 for 100 liter of water. Higher the capacity, lower the cost.
Life: 20-25 years.



Conventional heater

Cost: Heating 15 liter of water, costs Rs. 10,000-15,000 and recurring electrical charges.
Life: 7-10 years.

BENEFITS

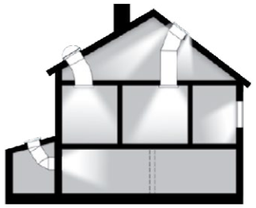
- **Retrofitting**: Households can use terraces receiving direct sunlight.
- **Costs:** High installation cost but complete cost recovery in 5-7 years.
- **Maintenance**: Low maintenance, periodic cleaning of panels needed.

CHALLENGES

- **Flexibility**: Hybrid solar electricity devices are necessary for dealing with cloudy and rainy periods.

Solar Energy for Light

Light Tunnel



A light tunnel is an effective source for providing natural light in darker parts of the house. The light collector collects sunlight from the roof and passes it through the reflector tube with minimal loss. The intensified sunlight is later controlled and distributed by the light diffuser within the room.

BENEFITS

- **Environment**: Reduced heat gain through open windows and other natural light sources.
- **Health**: Increased exposure to sunlight is healthier and better for eyesight.
- **Retrofitting**: Can be retrofitted on existing roofs of low-rise houses, warehouses or industries.
- **Costs**: Reduced use of artificial lights and lower energy bills.

CHALLENGES

- **Flexibility**: Cloudiness reduces intensity of sunlight. Can be used only during day time.
- **Retrofitting**: Cannot work in multi-storied buildings with common roofs or concrete slab roofs.

Solar Bottle Bulb

Liter of Light is an open source design for a low-cost light tube that refracts solar light to provide daytime interior lighting for dwellings with thin roofs. The device is simple: a transparent bottle is filled with water plus a little bleach to inhibit algal growth and fitted into a hole in a roof. A test tube with a small LED light bulb can be hooked up to a **mini-solar panel** and added to the bottle for usage as a light bulb at night.

BENEFITS

- **Environment**: Renewable source, no electricity needed from the grid. Can be installed in houses without electricity supply.
- **Health**: Natural source of daylight.
- **Retrofitting**: Can be retrofitted in existing tin sheet roofs.
- **Costs**: Low-cost lighting solution. Cheap solution for slums, low-income housing.
- **Life**: A properly installed solar bottle bulb can last up to 5 years.

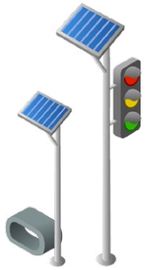
CHALLENGES

- **Flexibility**: Cloudiness affects intensity of sunlight.
- **Retrofitting**: Cannot work in multi-storied buildings.

Solar Energy for Electricity

Solar Street and Traffic Lights

Solar street light



Fixtures and traffic lights

Solar street and traffic lights run on energy generated through photovoltaic panels and stored in batteries. They can also be used during periods following natural disasters and are unaffected by power outages.

BENEFITS

- **Environment**: Functional during disaster events such as floods and cyclones.
- **Maintenance**: Very basic maintenance required.
- **Area**: Can be installed at any scale.
- **Life**: Almost 10 years.

CHALLENGES

- **Costs:** High installation charges but cost recovery in almost 3 years.
- **Flexibility**: Weather change affects sunlight and a hybrid system maybe required as backup.

Solar Rooftop Electricity Generation

The rooftop solar panels absorb and convert sunlight into electricity. The electricity can be sent to the power grid through a net meter.
Net metering is a utility billing metering system that offers credit to residents who supply solar electricity to the grid. The system calculates import and export of electricity to the grid.

BENEFITS

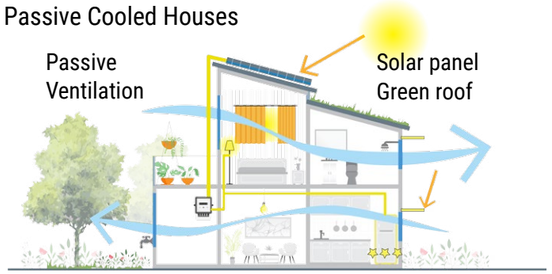
- **Environment**: Reduced dependency on fossil fuel based power plants, no GHG emissions.
- **Retrofitting**: Households can use roofs receiving direct sunlight.
- **Costs**: High installation cost but complete energy solution with reduced bills. Solar panel cost is fast reducing due to technological advancements. Government subsidy and funding available.
- **Maintenance**: Operating and maintenance cost is low, periodic cleaning of panels needed.

CHALLENGES

- **Flexibility**: Cloudy weather reduces power generation and linking with grid is necessary to deal with cloudy weather and to upload excess energy.
- **Costs**: If energy has to be stored, batteries and inverters are needed, increasing the system cost.

Thermal Comfort and Passive Ventilation

Passive Cooled Houses



Daylighting - Well oriented windows and controlled daylighting using blinds and flexible window shutters.
Natural ventilation - Well placed openings and windows to ensure cross ventilation and air movement.
Shading - Large windows, louvers and fixed overhangs restrict direct sunlight entry and ensure cross- ventilation.
Insulation - Double glazed windows and insulated walls reduce heat gain.
Energy efficiency - Using energy star rated appliances, solar powered fans, LEDs reduce costs and improve efficiency.

BENEFITS

- **Environment**: Better indoor thermal comfort and reduced energy demand.
- **Health**: Less thermal stress.
- **Retrofitting**: Houses can easily be modified to adopt passive techniques.
- **Costs**: Reduced energy bills.

CHALLENGES

- **Flexibility**: Retrofitting in some houses may not be possible.

Green Roofs and Live Walls

Vegetative roofs are a Low Impact Development (LID) solution for urban areas, retaining up to 75% of the rainwater for slow release. Flat waterproofed roofs are used for installation of green roofs.
Green walls are constructed panels with a growing medium and plants fitted on external walls along with micro irrigation systems. They keep the walls cool by shading and evaporative cooling.

BENEFITS

- **Environment**: Cooler indoor environment.
- **Autonomy**: Vegetables and flowers can be grown on roof.
- **Health**: Fresh vegetable supply and cooler indoor environment.

CHALLENGES

- **Costs:** High installation costs.
- **Retrofitting**: Dead load adds stress on the roof structure and structural assessment required before installing on old roofs.
- **Maintenance**: Regular maintenance required.

Stakeholder Roles

Government

- I **Enforce** energy saving building regulations, energy star appliance use and LEED certification.
- I **Regulate** demand and supply of energy by efficient monitoring systems and minimize data and energy losses during distribution.
- F **Tax** credits and government rebates for use of solar energy devices and budget allocation for renewable energy projects.

Civil Society

- I **Develop** building type specific standards for green/ cool roofs and promote greener urban areas, green roofs and live walls.
- E **Organize** awareness campaigns on decentralized and renewable energy options, thermal comfort and energy efficiency in buildings.
- E **Emphasize** on the use of solar heat and lighting systems in low income settlements (NGOs).

Communities

- E **Install** rooftop solar energy systems.
- E **Ensure** preventive maintenance and avoid breakdown maintenance.
- F **Invest** in passive ventilation systems to reduce thermal energy demands for cooling/heating.

Private Sector

- E **Adopt** Renewable energy certification and green building solutions (Manufacturer).
- E **Obtain** LEED (Leadership in Energy and Environmental Design) certification for houses and use green solutions for buildings (Real Estate Developers and Builders).
- T **Develop** partnerships among private sector to harness disruptive technologies and reduce costs of devices.

T Technological I Institutional F Financial E Enabling environment

Examples

Clean Cooking-Bangladesh

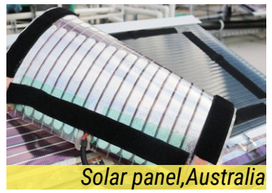
Energizing Finance: National Action Plan for Clean Cooking promotes innovative business and financing models for technologies, providing support to access financing.

Solar Kitchen, Auroville

The Solar kitchen has a big solar bowl on its roof, which generates steam which is used for cooking. Over 300 meals are cooked with steam generated from sunlight.

Liter of light,Philippines

MyShelter Foundation, Liter of Light programme aims to provide poor communities in the Philippines and around the world with cheap, locally produced lighting devices.



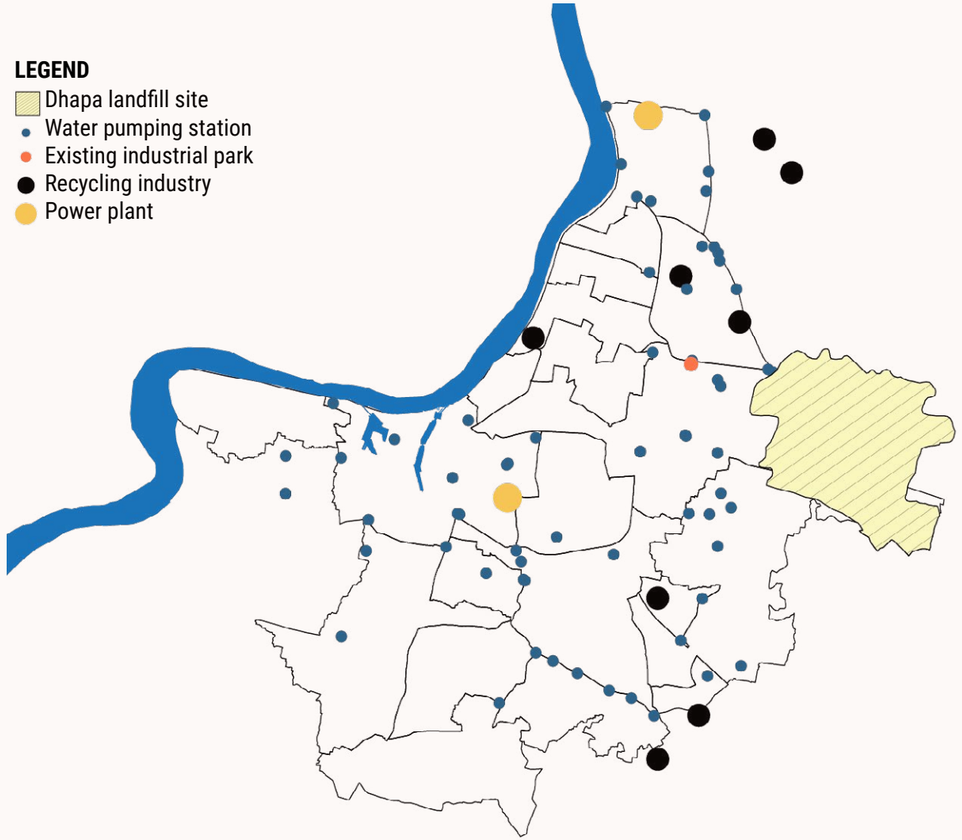
Solar panel,Australia

University of Newcastle, in partnership with CHEP Australia, have entered into large-scale trials for solar panels printed from a conventional printing press.

Additional Information

	Factors	Solar Energy	Thermal Comfort
1	**Risks addressed**	Electricity scarcity, supply breakdowns, high tariff	Heat waves, high electricity bills
2	**Expected benefits**	Increased energy autonomy, lower electricity bills	Cooler indoors, less energy consumption for indoor space cooling
3	**Space & other requirements**	Roof area of over 10 sq.m	Few meters of space between buildings
4	**Basic technical details & specifications**	Solar panel, inverter & net meter, (optional) batteries, 40 sq.m roof/5KW peak.	Provide cross ventilation considering summer sun angle & wind direction
5	**Indicative costs**	Rs.60,000 - 70,000/KWp, subsidy available	Marginal
6	**O&M requirements**	Cleaning once in a fortnight	Maintain shades, prune trees as needed
7	**How to integrate the interventions with city level infrastructure**	Net metering mechanisms exists	Not relevant
8	**Existing rules & possible institutional support**	Electricity Act, 2003 allows net metering, rooftop PV & small scale generation programme (RPSSGP)	KMC building by laws

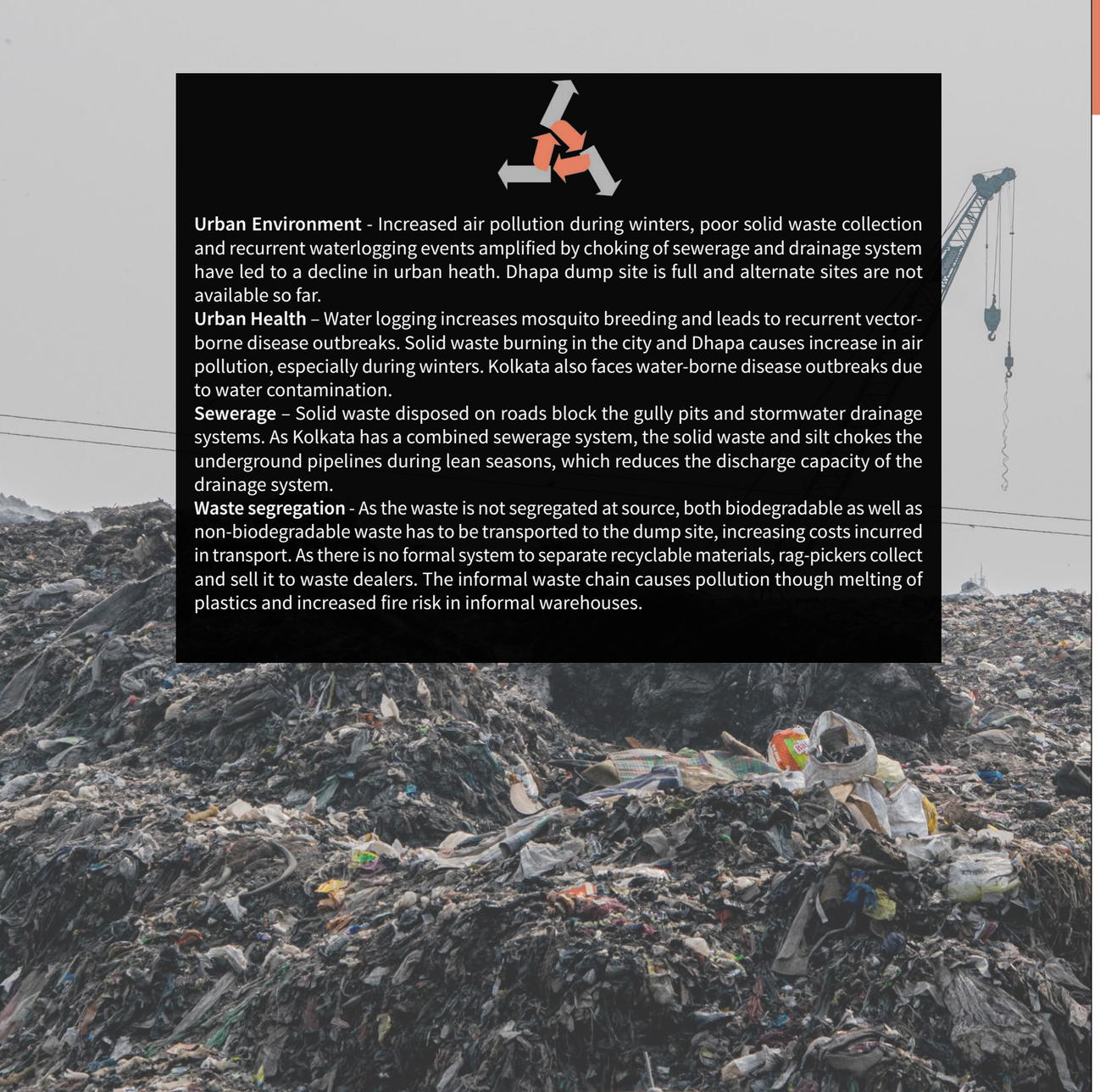
Waste



Kolkata Waste Management

Interventions

Decentralized Waste Management
Decoupling Solid Waste & Stormwater



Urban Environment - Increased air pollution during winters, poor solid waste collection and recurrent waterlogging events amplified by choking of sewerage and drainage system have led to a decline in urban heath. Dhapa dump site is full and alternate sites are not available so far.

Urban Health – Water logging increases mosquito breeding and leads to recurrent vector-borne disease outbreaks. Solid waste burning in the city and Dhapa causes increase in air pollution, especially during winters. Kolkata also faces water-borne disease outbreaks due to water contamination.

Sewerage – Solid waste disposed on roads block the gully pits and stormwater drainage systems. As Kolkata has a combined sewerage system, the solid waste and silt chokes the underground pipelines during lean seasons, which reduces the discharge capacity of the drainage system.

Waste segregation - As the waste is not segregated at source, both biodegradable as well as non-biodegradable waste has to be transported to the dump site, increasing costs incurred in transport. As there is no formal system to separate recyclable materials, rag-pickers collect and sell it to waste dealers. The informal waste chain causes pollution though melting of plastics and increased fire risk in informal warehouses.

Waste Management

Decentralized Waste Management

Waste management includes all actions required to manage waste from its collection to its final disposal. Separation of different types of waste at source is necessary for disposal of waste. The biodegradable waste can be treated at or near source to generate biogas or compost, while valuable materials can be aggregated and treated in central facilities.

Household - Decentralized biogas and composting systems.

Neighbourhood/ City level - Composting, biogas, reuse and recycle – Integrated Waste EXchange (IWEX).

Decentralized waste management is **resourceful**, improves **learning capacity** and **safe-fail**.

Decouple Solid Waste & Stormwater

Solid waste disposed in the streets and neighbourhoods clogs the stormwater drainage system. The waste also pollutes the rivers receiving the outfall. Decoupling the solid waste chain and stormwater drainage can reduce the need for recurrent cleaning of clogged drains.

Subsidiarity Principle Approach

Subsidiarity is the principle that asserts that a central authority should only performing those tasks which cannot be executed at a more local level. Segregation of waste can be done best at source and biodegradable material can be treated locally, while more complex materials can be managed by the municipality.

IWEX Integrated Waste EXchange (IWEX)- This is a freely available service connecting the waste generator and the waste user. Waste materials are often used as raw materials by industries and this platform provides an opportunity to increase efficiency of the waste chain.

Biogas can be generated locally or centrally using kitchen, restaurant and food market waste. It can be used for cooking, lighting and electricity generation. The sludge can be used as manure.

Resilience Dividend

Current Waste Disposal System

Recyclable paper, glass, metal and tins are separated and sold at source.

Biodegradable wet food waste, non-biodegradable medical waste, plastics, bottles, e-waste and other wet-dry things disposed together by the waste generator.

Rag-pickers informally collect and sell items like scrap metal, plastic bottle caps and wires etc. from the dumping grounds to make a living.

Large volumes of mixed waste needs to be transported to the dump yard. Mixed waste at the dumping grounds often catches fire and is a major cause for pollution and diseases.

Methane from waste and combustibles in waste catch fires increasing air pollution. The leachate from the dump pollutes the water bodies and aquifers. Land prices fall in the neighbourhood due to unhygienic environment. Land owners adopt 'Not in My Backyard Policy (NIMBY).

BENEFITS

- **Collection**: Waste collected for recycling at certain stages (even though informally).

CHALLENGES

- **Environment**: Methane dump-yard fires cause major air pollution. Waste dumped informally causes pollution in/around the city.
- **Health**: Mixed waste picking is hazardous for ragpickers. Open dump yards are mosquito breeding grounds.
- **Area**: Dhapa dumping ground is already full and land for new landfill is not available.

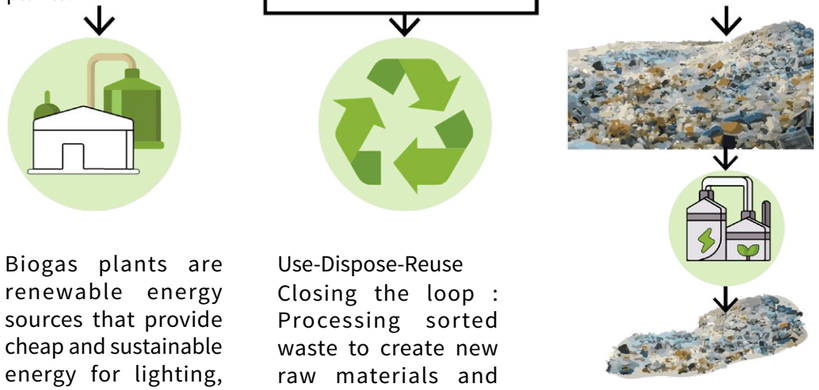
Proposed System

Food and other organic waste should be treated at household level using biogas and composting plants.

Establish a formalized waste chain and identify items for recycling. (Plastics, paper, metal and e-waste).

Cardboard and cups should be cleaned before disposal and a formal collection system for recycling to be established.

Remaining trash should be collected, transported and disposed in sanitary landfills.



Biogas plants are renewable energy sources that provide cheap and sustainable energy for lighting, cooking and other needs at the building level. Production of methane gas is done by anaerobic digestion of sludge, organic food waste and vegetables.

Use-Dispose-Reuse
Closing the loop : Processing sorted waste to create new raw materials and fibers.

Bio-mining methods can be used and sanitary landfills can be designed to extract methane.

BENEFITS

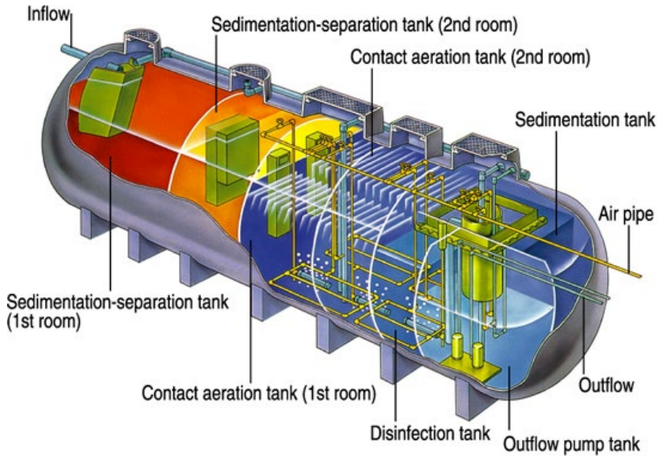
- **Collection**: Reduced air and waste pollution. Improved health and sanitation.
- **Reuse**: Established Integrated Waste Exchange enterprises can ensure one person's waste becomes other person's raw material.
- **Recycle**: Fabric waste and industrial waste can be recycled and sold.
- **Maintenance**: Biogas and composting plants need minimal maintenance.

CHALLENGES

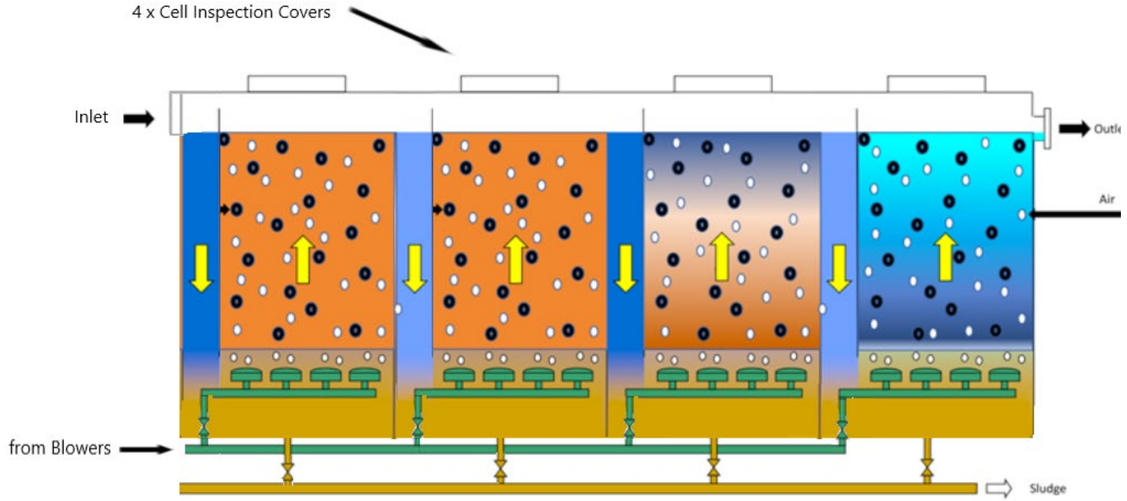
- **Formalization**: As many stakeholders exist in an informal supply chain, formalization would be difficult.
- **Conditioning:** Stakeholders may not be interested in major changes in their current behaviour.
- **Support**: Installation and maintenance support may not be locally available .

Decentralised Wastewater Treatment Systems

Johkasou® System



Moving Bed Biofilm Reactor (MBBR) System



Flow path through MBBR Unit

Decentralised Wastewater Treatment

Sustainable infrastructure development requires mainstreaming of decentralised wastewater treatment systems. Decentralised systems are small, individual or cluster type wastewater treatment systems for reusing wastewater at various scales. In this system wastewater can be treated onsite through aerobic and anaerobic techniques or a mix of both.

Decentralised Wastewater Treatment Systems (DEWATS) ®

A typical DEWATS ® has a combination of technical treatment steps in a modular manner. Primary treatment is done in sedimentation ponds, settlers, septic tanks or biodigester, secondary treatment in anaerobic baffled reactors, anaerobic filters or anaerobic and pond systems. Post-treatment polishing ponds or wetlands filter the water further.

Wastewater treatment systems, Johkasou®

Johkasou® wastewater treatment plants use a mix of aerobic and anaerobic microorganisms to cleanse household wastewater. Traditional septic tanks use only anaerobic microorganisms for treatment and can reduce approximately 50% of contaminants in wastewater. Whereas, Johkasou® wastewater treatment plants can achieve much higher performance by combining both anaerobic and aerobic processes.

Packaged wastewater treatment - Moving Bed Biofilm Reactor (MBBR)

A packaged wastewater treatment solution is typically a collection of discrete treatment capabilities combined in sequence to handle the particular wastewater treatment for specific applications. It can be a totally self-contained or skid-mounted system that is mobile enough to be transported to the end-use location, or it can be a collection of modular components that get connected onsite. While packaged plants are popular for decentralized treatment in smaller municipal applications, their self-contained designs also have value for industrial food and beverage applications.

® Trademark names

BENEFITS

- **Environment**: Reusing wastewater reduces the demand for fresh water supply and the amount of wastewater entering the sewerage sytem.
- **Autonomy**: Efficient use of the reused wastewater for low-end uses in the household and emergency supply during stress situations.

CHALLENGES

- **Acceptability:** Low acceptablity due to the taboo of using wastewater.
- **Area:** Space is required for the installation of the decentralised plant and pipelines.
- **Costs:** High installation costs.
- **Maintenance**: Wastewater treatment plants use microorganisms to perform treatment. Thus maintaining an optimum environment where microorganisms can be most active is essential.

Stakeholder Roles

Government

- (I) **Develop** a stormwater management master plan, integrate with other sectoral master plans and incorporate it into the city's resilience strategy and city planning.
- (I) **Formulate** rules and set up OSRT monitoring.
- (I) **Introduce** performance based incentives for units/wards/collection centres and impose penalties for breaking the rules.
- (I) **Improve** the institutional capacity of the municipality in waste management.

Civil Society

- (I) **Promote** waste segregation, wastewater reuse at source and build sanitary landfills.
- (E) **Undertake** public awareness generation at household and community level.
- (E) **Prepare** annual 'State of Urban Environment' report with section on waste management.
- (E) **Improve** awareness about wastewater reuse and benefits.

Communities

- (E) **Focus** on decentralized segregation of waste at household and neighbourhood level.
- (E) **Develop** local waste collection systems and invest on household/neighbourhood level biogas and wastewater treatment plants.
- (E) **Build** linkage with waste recyclers to sell e-waste, plastics, paper and cardboard.

Private Sector

- (I) **Form** waste management forum in local chambers of industry and trade.
- (E) **Identify** options for exchanging waste for recycling among various industries.
- (T) **Promote** startups to formalize waste recycling.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

Uttarpara-Kotrung,Bengal

India's first controlled sanitary landfill site by KSWMIP, assisted by JICA with soft loan and technical transfer to achieve 60%-80% segregation at source.

IWEX, Cape Town, SA

IWEX is a free online waste exchange platform that connects one's business's unwanted by-products or waste with another business's needs for effective waste recycling and reuse.

Biogas plants, Alappuzha

Clean Homes Clean City initiative has helped Alappuzha's experiments with decentralized waste management by using portable biogas plants and aerobic composting units.

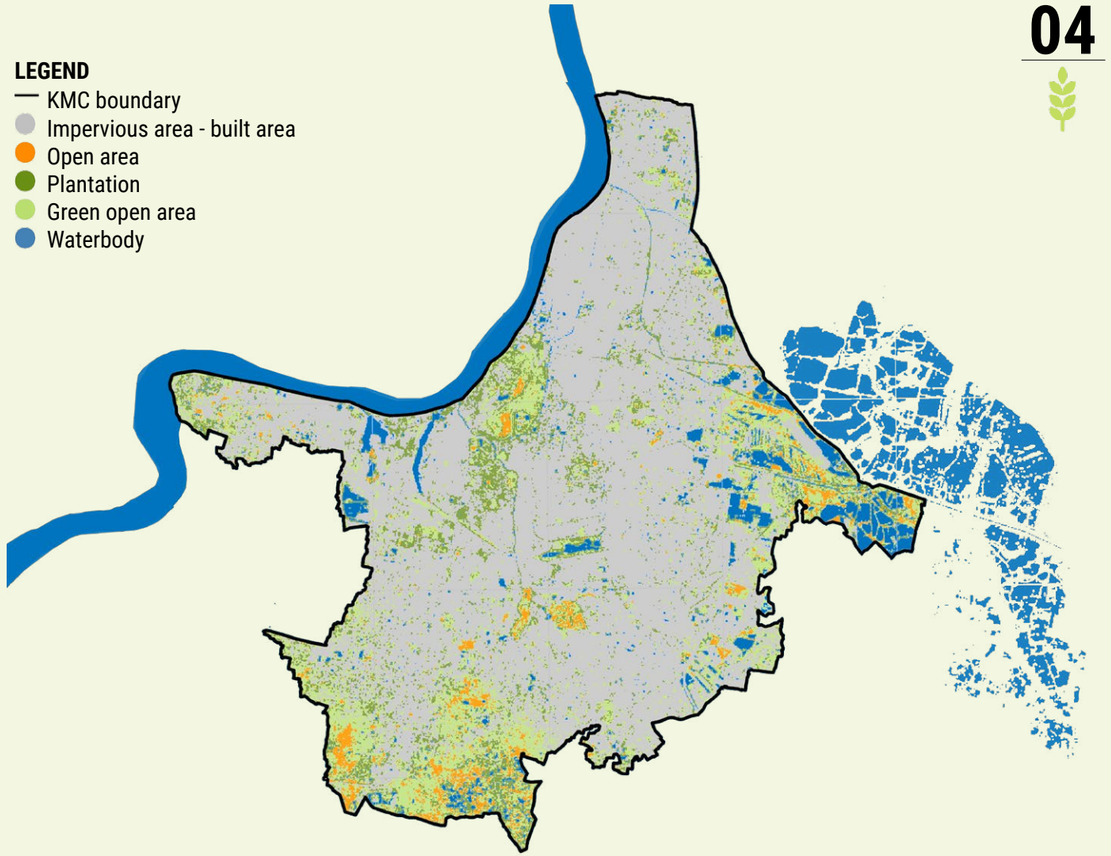
Resolve Trash2cash,Kolkata

Resolve is a local NGO that organises ragpickers, providing them with stable livelihoods, and recycling waste through a multi-stakeholder system.

Additional Information

	Factors	Decentralised Waste Management	Decentralised Wastewater Treatment
1	Risks addressed	Public health challenges, choking of drainage system	Water scarcity, sewage pollution
2	Expected benefits	Recycled waste, biogas, reduced flood risks	Recycled water for local reuse
3	Space & other requirements	A few sq.m overground or underground space for biogas plant installation	Variable depending on type of technology, Johkasou® & DEWATS® are underground systems.
4	Basic technical details & specifications	Segregation arrangements, biogas plant: ~1 cum/family, separate bins for kitchen waste, glass, paper & plastics	Combination of anaerobic & aerobic treatment, constructed wetlands may be used for polishing & UV treatment for disinfection
5	Indicative costs	Variable, ~Rs.10,000 to 20,000 per cum depending on capacity	DEWATS® cost: ~ Rs.40,000/ KLD, packaged MBBR unit cost: ~Rs.20,000/KLD
6	O&M requirements	Segregation daily, occasional cleaning of biogas plant	Regular monitoring necessary, power supply necessary for Johkasou® & MBBR units
7	How to integrate the interventions with city level infrastructure	Community level	These units can be used in peripheral areas without a sewerage systems.
8	Existing rules & possible institutional support	Solid Waste Management Rules (SWM) 2016, Guidelines for decentralized wastewater management (2012)	Environment (Protection) Rules, 1986 & proposed amendment to include zero liquid discharge.

Land Use



Kolkata Land Use

Interventions

House-Farm-Pond-Fish Ecosystem: Urban Agriculture
Pocket Parks
Wetlands for Sewage Treatment & Agriculture

Land use - KMC follows zoning based on the use of urban land (e.g. industrial, residential, commercial etc.). Land use planning does not consider disaster risks, climate change impacts and ecosensitive areas.
Core area - The settlement density is exceptionally high in the core areas with old, dilapidated buildings, which need to be demolished for public safety. During the annual maximum tide events, back-flow induced waterlogging is reported in Tolly Nala neighbourhoods.
Peripheral areas - The city is expanding into low elevation areas towards the east. Sea level rise is expected to increase flooding, storm surge, and tidal risk. In such areas, **spatial planning** and delineating **'no development zones'** in eco-sensitive and high-risk areas is necessary to prevent climate change induced risk. Paradigm shifts in planning framework are necessary to make Kolkata resilient to climate risk, which is a challenge in the current institutional environment.

East Kolkata Wetlands

Land Use and Food Cycle

Land Use

The area under water bodies and the green regions are reducing due to reclamation for real estate development which is increasing flood risks and expanding urban heat islands. As a consequence of natural processes and haphazard development, Kolkata is now one of the ten most vulnerable cities in the world to the impacts of climate change.

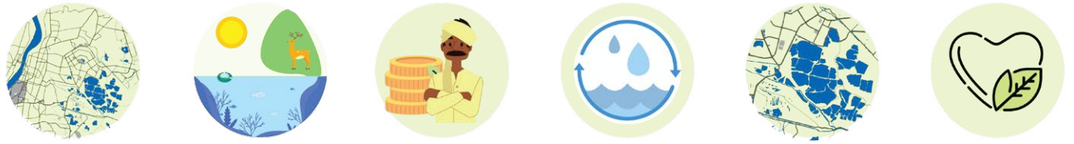
Household systems - Green roofs, live walls.
Neighbourhood/ City level - Pocket parks, street medians, wetland conservation, urban agriculture.

Vegetative covers are **flexible, modular, redundant** systems, matching needs of different project scales. They **enable learning** and are a **resourceful** use of land, offering **safe-fail** mechanisms, while improving quality of life.

Ghar - Baari - Pukur - Maach

House-Farm-Pond-Fish micro-ecosystems of Bengal - In the past, most households in Bengal used to have ponds for pisciculture and farm yards for growing vegetables. There were a multitude of water bodies of various sizes dotting the region. With the increasing densification of settlements, the inter-linkage between the house, pond and the kitchen garden was lost. Increasing land prices and density has led to the reclamation of water bodies and a shift towards multi-storied flats, especially in newly expanding peripheries. The city needs to develop an integrated blue-green master plan. Building rules need to integrate disaster risks, ecological sensitive zoning and climate change adaptability. Peri urban areas can be planned to avoid urban sprawls with "no development zones" and conservation of water bodies.

Resilience Dividend



Flood informed urban planning | Conserved ecosystems and environment | Improved food security and livelihoods | Promotion of urban-rural solidarity | Healthy multi-functional wetlands | Reduced pollution

House-Farm-Pond-Fish Ecosystem

Urban Agriculture

Most new townships have multi-storied buildings with sufficient open spaces. Integrating the *Ghar-Baari-Pukur-Maach* concept in the design of townships/ neighbourhoods can enable them to become prosumers. Existing water bodies can be conserved and pisciculture can be introduced. Open areas, roofs and walls can be used for urban agriculture and pisciculture improving the urban environment and also increasing fresh food availability. These systems can extract nutrients from treated grey water and kitchen waste to produce fish, fruits, flowers and vegetables. Establishing micro enterprises to connect East Kolkata Wetland farmers to consumers (farm to fork) can create win-win options for farmers and households.

Pocket Parks/ Parklets

Pocket park - Franklin Street Park

Pocket parks are created on vacant building lots, unused or underutilized pieces of land.

BENEFITS

- **Environment**: Recreational and food production spaces in urban areas. Reduced runoff. Availability of local fresh food from urban agriculture/pisciculture.
- The pocket parks improve ambience of the neighbourhood.
- **Retrofitting**: Multitude of green and blue areas without large scale redevelopment or investments in dense areas.
- **Property Values**: Green open spaces and well-maintained water bodies can increase property value.

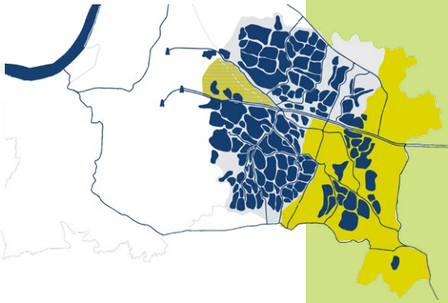
CHALLENGES

- **Maintenance**: Buy in from residents and establishment of mechanisms for regular monitoring and maintenance is required.
- **Land**: Availability of open space is limited in dense settlements.

East Kolkata Wetlands

CITY

4.5 m. Inhabitants
20,300 ha
Sewage: 750 MLD
Solid waste: 3000+ TPD
Rag pickers: 25,000



WETLANDS

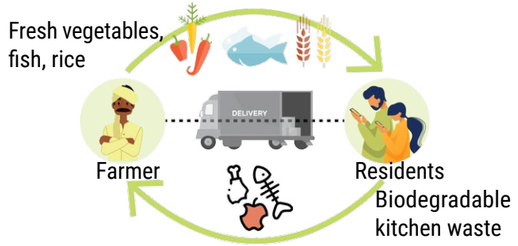
61,000 inhabitants
12,500 ha
Fisheries: 5800 ha
Agriculture: 4700 ha
Employment: 17,000 persons
~15,000 tons fish/ year
~54,000 tons vegetables/ year

East Kolkata Wetlands Management Authority

EKWMA was established for conservation and management of the EKW (Ramsar site) as per East Kolkata Wetlands (Conservation and Management) Act, 2006 .

Proposed Interventions -

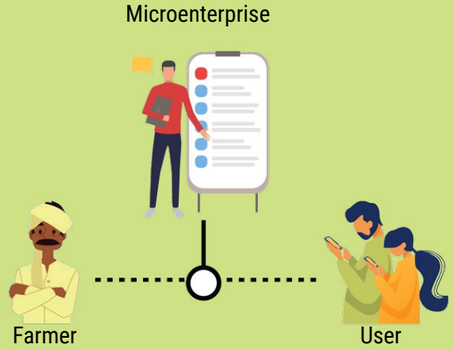
- Develop community monitoring mechanisms to prevent encroachments and haphazard waste dumping.
- Monitor quality of the products, food safety and certify quality of produce available at EKW.
- Establish microenterprises to formalize and improve food supply chain, directly connecting the producers with users (farm to fork linkage). A home delivery system for fish and vegetables can be established to maximize incomes for producers while supplying fresh food to consumers.
- Microenterprises can also collect kitchen waste/ compost from users and provide maintenance support to urban agriculture initiatives.



Linking food and waste cycles enables circular economy.

BENEFITS

- **Environment**: Organic waste collection from households, increased manure availability to farmers. Cleaner environment and ecosystem.
- **Incomes**: Farmers can get better incomes from direct supply to users making them autonomous, generating employment and the wetlands more sustainable.
- **Livelihoods**: Wetland agriculture provides work for over 17,000 people from fisheries, farming and transport jobs.



Stakeholder Roles

Government

- (I) **Integrate** land use planning with conservation of EKW and urban agriculture.
- (I) **Develop** and implement new integrated land use rules and enforce “no development zones’.
- (F) **Strengthen** EKWMA and allocate sufficient budgets for wetland protection.

Civil Society

- (I) **Set up** a public platform for anonymous reporting of encroachments.
- (E) **Prepare** and disseminate ‘Annual State of Kolkata’s Environment’ report with a section on EKW.
- (E) **Create** awareness programs about the role of East Kolkata wetlands.
- (T) **Improve** information symmetry by providing spatial risk and land use plans over WebGIS platforms.

Communities

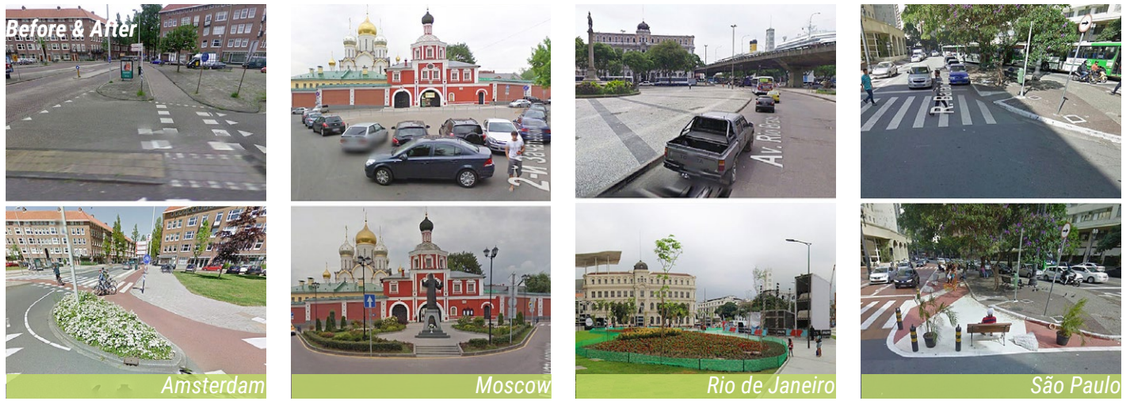
- (E) **Initiate** and participate in urban agriculture interventions.
- (E) **Establish** linkages with EKW’s producer and microenterprises.

Private Sector

- (I) **Set up** and support microenterprises to connect the EKW producers with local residents of the city.
- (E) **Take up** initiatives on EKW conservation.
- (T) **Provide** technical support on organic waste treatment.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

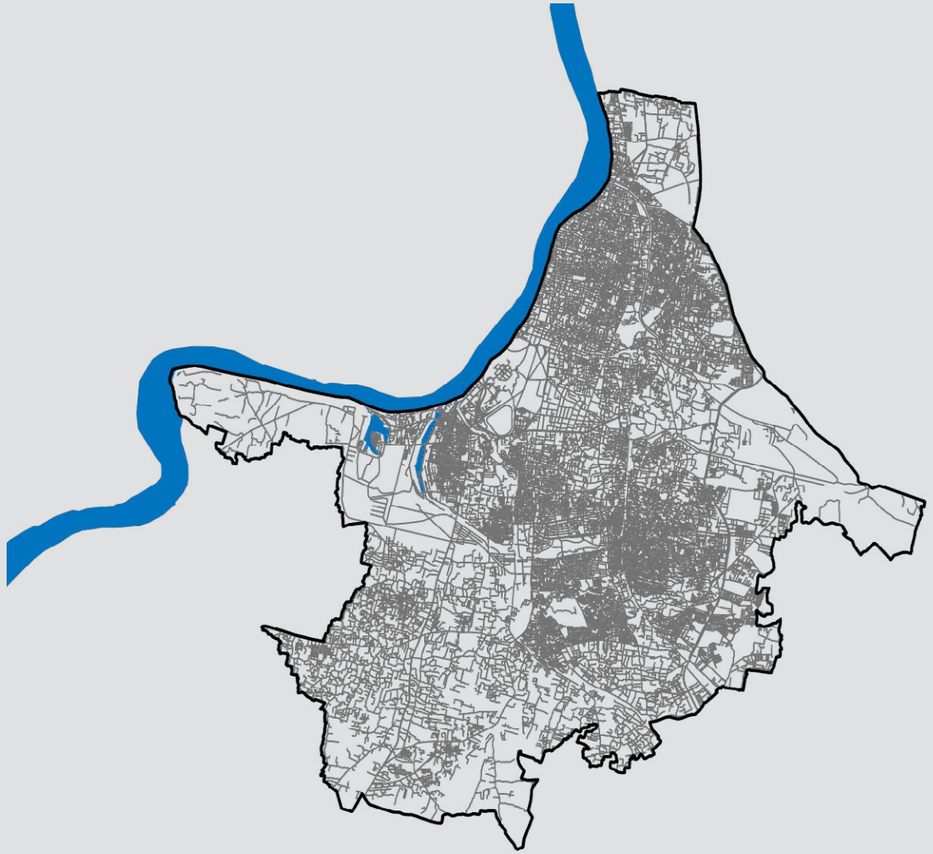
Examples



Additional Information

	Factors	Pocket Parks & Green Medians	Wetland Conservation & Sewage Farming
1	**Risks addressed**	Flooding, heat waves, impermeability	Food scarcity, sewage treatment
2	**Expected benefits**	Increased percolation, reduced floods	Food production, reduced cost of sewage treatment plants
3	**Space & other requirements**	Available small open spaces	Existing EKW area
4	**Basic technical details & specifications**	Build borders, plant a mix of grasses, shrubs & trees, drill shallow tubewells with filters	Formalise the use of sewage for farming with monitoring of products to prevent water-borne diseases, form microenterprises
5	**Indicative costs**	Gardens: ~Rs.250/sq.m, drilling, filters & slotted casing pipe: ~Rs.600/m	Monitoring may be done by government food safety labs
6	**O&M requirements**	Regular pruning of garden, cleaning filters once in 3-5 years	Weekly food contamination monitoring
7	**How to integrate the interventions with city level infrastructure**	Develop local area plans, include green medians with road building	Link with S&D department, state agriculture & fisheries departments & food safety labs.
8	**Existing rules & possible institutional support**	None	Food Safety & Standards Act & Regulations 2006 & amendments

Mobility



Kolkata Road Network

Interventions

Sustainable Transport: Pedestrianization, Cycling, Transport Action Plan – “SPACE” Framework & 15 Minute City
Multimodal Transit: Last Mile Connectivity, Paratransit & Integrated Modes of Public Transport

Environment - Dependency on fossil fuel based vehicles (especially diesel) reduces air quality in the city. Flooding from heavy rains and cyclones inundate key road stretches increasing traffic jams on already congested roads.

Street Network - Kolkata with only 6-8% under roads, struggles with major traffic congestion and parking problems across the city. Many roads are narrow and Kolkata still has large number of human drawn rikshaws operating on these narrow roads. The share of public transport is more than 50%. Most of the buses are old and diesel powered. Recently the city has introduced electric buses, but complete fleet replacement will take many years.

Rapid Motorization - Between 2012 and 2015, the annual growth of registered vehicles in Kolkata was 4.7%. The use of personal vehicles in Kolkata is much lower compared to major cities across India, but the growth rate of registered vehicles is quite high.

Kolkata has a vintage tram system. The metro system connects the city from north to south. An east-west metro rail system is being built. Integration of multiple modes will be necessary to reduce travel time and ensure seamless connections. A shift from use of private vehicles to public transport is necessary to reduce congestion and parking challenges.

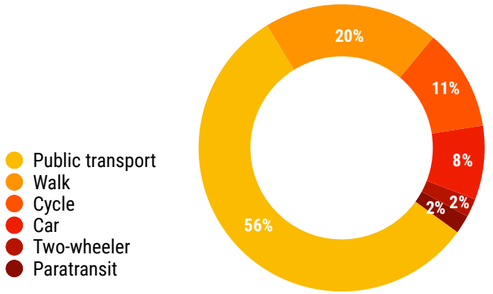
Sustainable Transport

Walkability

Kolkata's urban form with mixed land use and high density enables people to walk and cycle. However, many foot paths, especially in business districts have been encroached by vendors. Kolkata shows very high footfall on major streets.

Walkability and safe access

Figure 4: Kolkata Modal Share



The share of people walking, cycling and using public transport in Kolkata, according to the Census 2011, is 89% - highest among all metro cities in the country. Cars and two wheelers occupy the most street space but carry only 12% of the daily trips. 60% of the city's commuting trips are within 3-4 kilometers.

Neighbourhood/ City level - Pedestrianization, transport action plan - "SPACE" framework and cycling.

Non-motorized transport systems are **redundant, flexible, resourceful,** and provide **safe-fail** options especially during floods.

Green Transportation

Sustainable transportation comprises of modes of transportation that do not depend on fossil fuels and use renewable energy sources or manual power. They have very low impact on the environment, producing minimal or no greenhouse gas emissions.

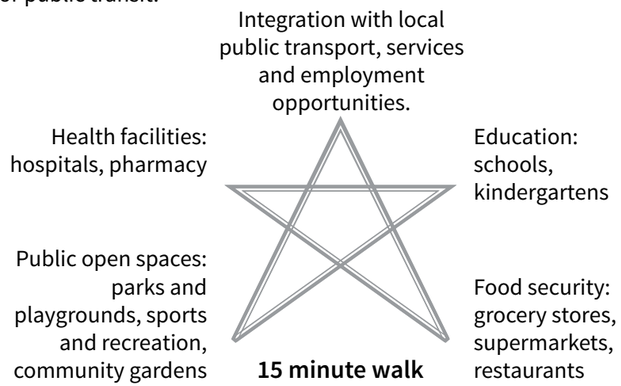
Resilience Dividend

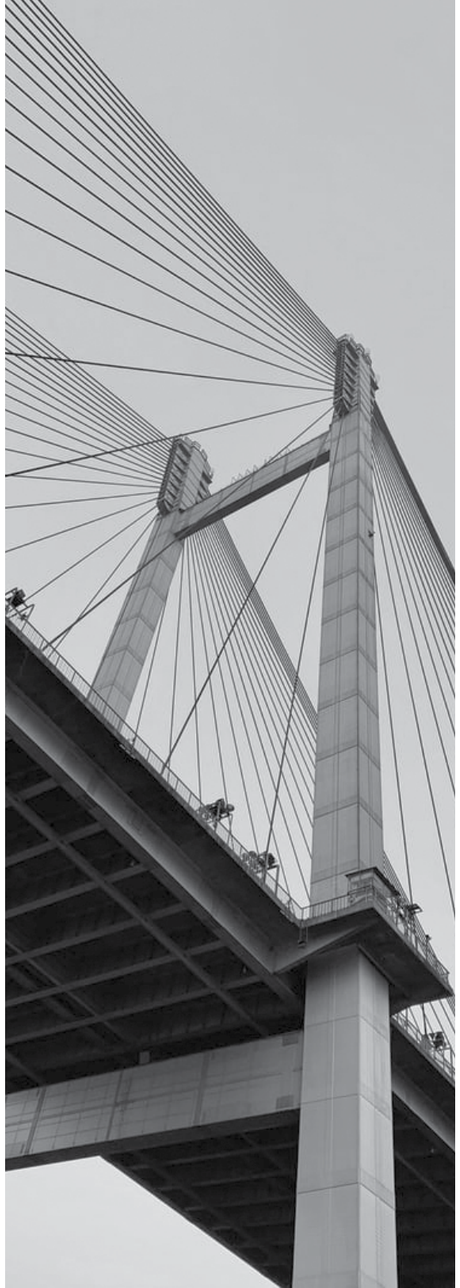
Transport Action Plan - 'SPACE' Framework

Safety First: Setting speed limits for automobiles and a segregation of footpath network.
Identification of underutilized infrastructure and fix damaged roads, open manholes, wobbly paving blocks, full time "functioning" of all traffic signals and lighting of pedestrian areas.
Pedestrian Priority: Clearly demarcated pedestrian zones to ensure road safety.
Accessibility: Improving the ease of walking, providing continuous tree cover, benches and other street furniture. Developing pedestrian maps showing major marketplace routes.
Comfort: Urban acupuncture, tree plantation drives, neighbourhood street furniture installations including seating and potable water facilities. Maintaining streets and formalizing nodes with street markets and vegetable vendor spots for a vibrant and organised market area.
Enforcement - Setting up a maintenance committee to prevent encroachment of footpaths by parked vehicles /vendors. Installation of electrical speed detectors on major streets and penalization to increase confidence among pedestrians.

15 Minute City

The 15 minute city is an urban design concept that aims to improve quality of life by creating cities and neighbourhoods where a resident can reach most commonly used facilities within 15 minutes by foot, bike or public transit.





Green Transport

Electric Vehicles

An electric vehicle (EV) uses electricity for propulsion. They are powered through an electrical battery with or without solar panels. Charging station network is necessary to recharge the vehicles. Electric trains draw power from overhead lines.

Solar Buses

A solar-charged bus is powered exclusively or mainly by solar energy for the propulsion of the vehicle. They have solar photo-voltaic panels on the roof along with batteries to store power.

Hybrid Vehicles

A plug-in hybrid electric vehicle (PHEV) is a vehicle whose battery can be charged by plugging it into an external source of electric power as well as by its on-board engine and generator. Most PHEVs are passenger cars, but there are also PHEV versions of commercial vehicles, utility trucks, buses, trains, and two wheelers.

BENEFITS

- **Environment**: Reduced GHG emissions and air pollution. Less noise and reduced carbon footprint. Very low vehicle exhaust. Waste oil spills are minimized.
- **Costs**: Cost effective in the long run. Government subsidies available for green vehicles.

CHALLENGES

- **Awareness**: As it is a new technology, level of awareness is low. Prospective buyers need confidence on the quality and life of batteries. As the vehicle has to be charged regularly, behaviour change is necessary to shift to electric vehicles.
- **Reliability**: Electric vehicles need to be charged for a few hours before running but public charging station network is yet to be built. Therefore, non-hybrid electric vehicles have to use domestic chargers, which takes a longer time to recharge the batteries.

Stakeholder Roles

Government

- (I) **Implement** policies and measures to reduce need for travel by providing major amenities within 15 minute travel time in the city.
- (I) **Integrate** different modes of transport available in the city.
- (I) **Allocate** sufficient parking facilities and prevent parking on carriage ways.

Civil Society

- (E) **Create** awareness about sustainable transport and eco-mobility options.
- (E) **Create** awareness and promote non-motorized modes of travel (Kolkata Cycle Samaj and other NGOs).
- (T) **Provide** early warning and real time information on traffic bottlenecks to deal with floods and other disasters.

Communities

- (E) **Encourage** behaviour change towards walking and using public transport.
- (E) **Adopt** car pooling and ride sharing to reduce traffic congestion and air pollution.
- (E) **Migrate** to electric vehicles.

Private Sector

- (E) **Manufacture** and market green and more efficient vehicle technologies.
- (T) **Improve** and expand charging station network.
- (F) **Enable** investment linkages between private sector, institutions and banks.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

15 min city - Paris

Paris is turning into a 15 min city by promoting better mobility, safer streets and equitable access to reduce traffic congestion and pollution.


Copenhagen

Copenhagen has 675,000 bicycles and only 120,000 cars. It is the safest city for cycling due to the network of paths, innovative bridges and cycling super highways.


City of boulder, USA

Boulder's multimodal transportation system is based on buses, cycling and walking. It offers discounted annual transit passes under the Eco Pass Program. Buses have bike carriers.


Venice,Italy

Venice is considered one of the best pedestrian cities in the world because it has the largest street network that is free of cars. This tourist city is dense and pedestrian friendly.

Multimodal Transit

Integrated Mass Transit

Kolkata has diverse public transport options encompassing trams, buses, taxis, autos, ferry, metro rail, suburban rail, circular rail and motorised and hand-pulled rickshaws. This network requires modernization, upgradation and system integration. The city mobility plan for Kolkata has set the goal of achieving public transport modal share of 90% by 2025.

Neighbourhood/City level - Last mile connectivity, green transportation and transit oriented development.

Sustainable transport systems are **modular**, **redundant**, **flexible**, **resourceful** and provide **safe-fail** features.

Last Mile Connectivity

The majority of citizens should be able to access high quality public transport within 10 minutes of walking. Network design for public transport systems should be detailed, so that at least 80% of the residents live within a distance of 400-800 meters (10-minute walking distance) of high-quality public transport stations.

Buses form the primary mode of public transport, even in areas where extensive rail systems exists. They can reach closer to the residences and places of work, education, shopping and recreation. Public transport now has over half of the modal share in Kolkata and the demand is more than the current capacity. Public transport strategy must aim for better frequency, reliability, speedy and a comfortable service.

Resilience Dividend

- Reduced energy costs for electric vehicles
- Connectivity and ease of travel with public transport
- Sustainable & clean mode of transport
- No exhaust gases, cleaner air
- Fewer parts in electric vehicles, less maintenance costs
- Reduced noise pollution and health benefits

Strengthening Paratransit

Hand-pulled Rikshaw

The hand-pulled rikshaws are the lifeline of Kolkata's public transport system. The height of the rikshaw and its ability to move in inundated streets make them the most effective vehicle during floods. The government plans to ban these rikshaws on humanitarian grounds but mechanizing them and upgrading this mode of transport would be desirable.

Taxis and Buses

The shift from yellow taxis to app based aggregagator systems (Ola, Uber) is seen over the last few years. The yellow taxis are old, inefficient and more polluting. Following measures are necessary to integrate different modes of public transport improve their efficiency and to reduce travel time.

- Develop performance monitoring of bus operations and services: Periodic audits and surveys are necessary to track performance, service quality and user satisfaction.
- Old polluting taxis should be scrapped and replaced. Green transportation should be given priority.
- Kolkata city initiated the procurement of 'zero emission' electric buses. However, a strategy is necessary for full replacement of diesel buses.
- Finance: The transport company should be able to access green investments for replacing the fleet.
- Commercial development in bus depots can provide additional revenue.

BENEFITS

- **People Oriented**: As most streets are narrow, paratransit enables users to easily connect to public transport systems.
- **Costs**: Public transport is cheaper.
- **Ease**: Reduced walking distances and comfort in all weather conditions is provided by paratransit services.
- **Maintenance**: Paratransit requires low maintenance as simple vehicles are used.

CHALLENGES

- **Enabling factors**: Hand-pulled rikshaws may be banned by the government.
- Yellow taxi operators face strong competition from taxi aggregators, which may lead to conflicts.

Integrate Modes of Public Transport

- Prioritize integration of public transport, para-transit, walking and cycling for a seamless connectivity across the city. This will require adoption of multimodal integration norms for station areas.
- Old metro stations are integrated with bus stops. However, this is not the case for the upcoming metro line. Modifications are necessary to integrate paratransit with public transport system.
- Formalizing rikshaw stands and allocating spaces for parking near bus stops and metro stations would help to avoid chaos and increase the use of public transport, reducing traffic bottlenecks.
- Transit is most efficient when higher traffic densities can be achieved without congestion. However Kolkata's narrow streets are prone to traffic jams. Identification of roads with higher traffic demand and allocating them exclusively for rapid transit is necessary.
- A single citywide travel card system can be implemented to access multiple modes of transport.

BENEFITS

- **Reduced travel time**: Integrated multimodal transportation can significantly reduce travel time.
- **Health and quality of life**: Reduced travel time can increase human productivity and improve quality of life through increased available free time and reduce stress.
- **Reduced transactions**: Single travel card system to access all modes of transport can reduce wastage of time in purchase of tickets etc.

CHALLENGES

- **Enabling factors:** Redesigning connectivity between different modes is a challenge in the denser parts of the city.
- **Design**: Land acquisition for stations and bus stops in dense settlement areas might be a challenge.

Stakeholder Roles

Government

- (I) **Extend** the public transport network and improve connectivity with paratransit systems.
- (I) **Regulations** to reduce private vehicles in core area and increase pedestrian only streets.
- (I) **Build** institutional capacity and allocate resources for transport infrastructure redevelopment.

Civil Society

- (E) **Conduct** action research on improving mobility.
- (E) **Develop** context specific options for improving inter-modal connectivity.
- (E) **Create** awareness and build consensus about reducing carbon emissions from the transport sector.

Communities

- (E) **Prioritize** "Eyes on the street" and community monitoring to make streets and public transport systems safer.
- (E) **Adopt** car pooling and other measures to reduce use of private vehicles.
- (E) **Form** neighbourhood car pooling groups for children's school transport.

Private Sector

- (T) **Develop** and market transport technologies to improve efficiency.
- (F) **Take up** CSR projects in integrated transport systems.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples


Gothenburg

Gothenburg takes the lead in the transition to electrically propelled urban bus transport in Sweden. 95% of all transport shall be migrated to renewable energy by 2025.


Shanghai

Shanghai is generating power for the city's electric buses using a rooftop PV system on the bus depot, and exploring a new model for direct charging of zero emission vehicles.


Washington

Washington introduced priority bus improvements where modifications are done to operations and bus operating environment to improve speed, reliability and reduce delays.

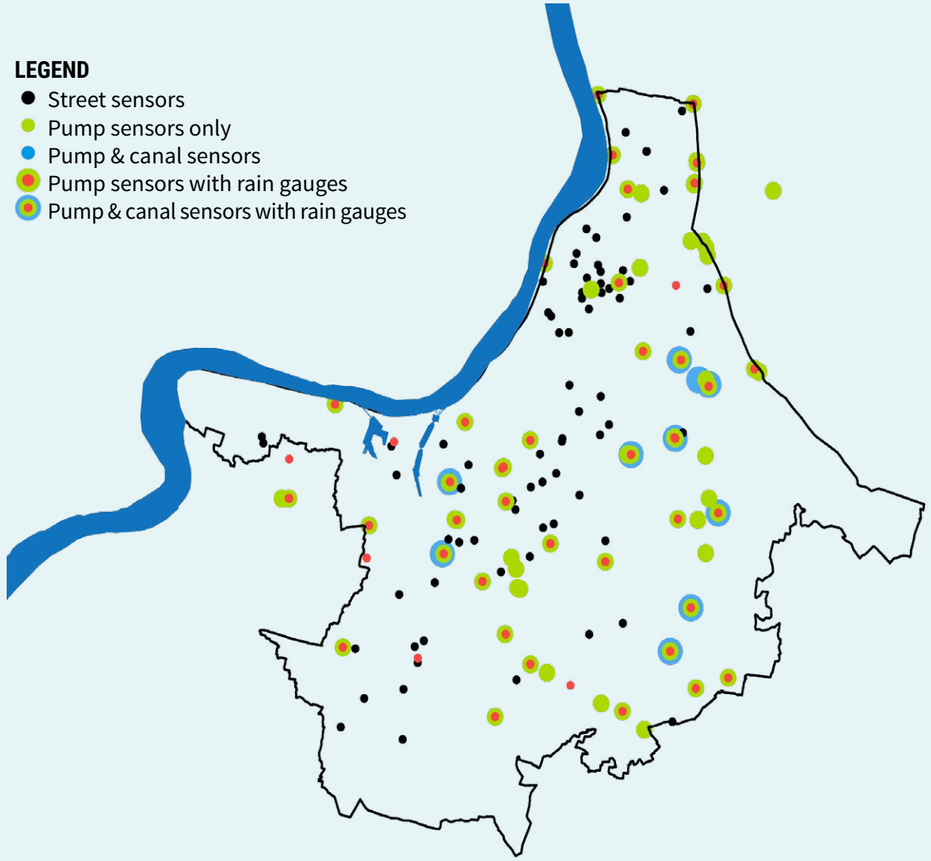

India

E-rickshaw is the preferred mode of last-mile commute for office goers, especially in and around metro routes and highly populated pockets across tier I, II and III cities of India.

Additional Information

	Factors	Sustainable Transport	Multimodal Transit
1	Risks addressed	Traffic safety, congestion, reduction of GHG emissions	Traffic congestion, connectivity between different modes of transport
2	Expected benefits	Safety & space for pedestrians, reduced travel time, seamless connectivity	Reduced need for using private vehicles, ease of travel
3	Space & other requirements	Land for exclusive bike lanes, footpaths	Parking & pickup points for paratransit at metro stations, partnership with banks for online card payment system
4	Basic technical details & specifications	Footpaths & bike lanes delineation, road safety system, seamless connectivity between multiple modes of transport	Allocate land, build parking & connectivity infrastructure. Introduce single payment card for all modes of public transport
5	Indicative costs	Highly variable based on context & mode	Variable depending on contexts & scope
6	O&M requirements	Regular repairs & monitoring, removing encroachments	Regular O&M necessary to maintain hardware & software
7	How to integrate the interventions with city level infrastructure	Granular ward mobility plans may be prepared as per city mobility plans	This intervention covers multimodal transport across the city
8	Existing rules & possible institutional support	Various road transport & metro railway acts; Urban street guidelines of other cites may be used.	Various road transport & metro railway acts.

Urban Monitoring



Real Time Monitoring System: Pumping Stations, Streets & Canals

Interventions

Urban Environmental Monitoring, Urban Health Monitoring, Early Warning Systems

Urban environment is ever changing and any hazard events or stress can impact a large number of citizens. Urban monitoring and early warning systems are essential for managing stresses and shocks. Air pollution can affect large number of people, especially people facing asthma and other pulmonary diseases. Similarly, heat waves can impact health of outdoor workers as well as differentially impact vulnerable population such as children and old people. Kolkata is prone to floods, cyclones and earthquakes. India Meteorological Department (IMD) provides heavy rainfall and cyclone forecasts. Real time data on flooding and performance of drainage system through a granular sensor network can provide situation awareness to manage disasters better. Advance warning can help people to restrict their outdoor activity and prevent loss and damage to their assets.

Urban Monitoring Systems

Urban monitoring

Urban Monitoring is a system for collection, analysis and visualization of various environmental and health parameters for enabling hazard and public health management. It operates in three phases; pre-event phase for planning and preparedness, during the event to ensure safety and create awareness about the ongoing event and lastly in damage assessment, recovery and building event database for future planning.

Household systems - Temperature, humidity, air quality monitoring.
Neighbourhood/City level - Urban environmental and hazard monitoring, urban health monitoring.

Monitoring systems are **resourceful** and **improve learning capacity**. They can provide warning to enable **safe-fail** and increase resilience against extreme events and stresses.

Technological advancements in weather forecasting has enabled cities to reduce casualties, loss of life and damage to assets. The sensors connected to Internet of Things (IoT) devices can provide real time data even from remote areas marooned by floods and cyclones. Kolkata has implemented a **Flood Forecasting and Early Warning System (FFEWS)** that provides access to meteorological forecasts, near real time satellite imagery as well as granular real time data on rainfall, street inundation, temperature, humidity and air quality via IoT devices distributed across the city. FFEWS also collects real time information on the operation of over 350 pumps in drainage pumping stations. This information can be accessed anywhere over the internet through web browsers and an android application. IoT based environmental monitoring and data collection can inform actions to manage disasters, heat waves and air pollution. The managers of drainage systems and citizens can take suitable anticipatory actions to prevent loss of life and property. Similarly, urban health monitoring systems can be used to monitor spatial distribution of vector-borne and water-borne diseases, by using data from hospitals and pathological labs to inform preventive actions to control outbreaks.

Resilience Dividend

Minimized damage from hazards | Resources managed according to needs | Improved capacities by assessing existing realities | Real time monitoring and information | Improved awareness and safety at all levels | Reduced economic and life losses

Urban Monitoring to Informed Actions

UMS	Environmental Monitoring	Urban Heath Monitoring	Disaster & Risk Monitoring
Institution & Regulation	**Develop** urban and local plans informed by environmental data. **Update** environmental, building and city planning standards and bylaws.	**Assess** capacities and resources available at all scales. (Clinics, hospitals, pathological labs etc.) **Develop** cross sectoral collaboration strategy to manage shocks and stresses.	**Train** DM staff and first responders to use FFEWS. **Mainstream** disaster management practices among CBOs, NGOs, volunteers, academia and the private sector.
Knowledge, Education & Assessment	**Assess** linkages between fossil fuel use and pollution as well as land use and temperature. **Develop** and implement action plans and programmes to improve resilience.	**Analyse** linkage between environmental and public health data and map distribution of vulnerable population. **Develop** education programmes and sanitation training in schools and local communities.	**Conduct** risk assessments and prepare disaster risk reduction plans. Disseminate risk maps. **Build** capacities of stakeholders to take up different roles in disaster risk reduction and preparedness.
Finance & Resource	**Develop** incentives and penalties to increase resource resilience and improve compliance to safety standards. **Invest** in and maintain infrastructure to reduce environmental stresses.	**Make** budgetary provisions to train staff and equip emergency response services. **Subsidize** health services to poor and vulnerable.	**Develop** contingency plans for ensuring business continuity during and after disasters. **Develop** CSR projects to improve disaster resilience among low income groups, communities and small businesses.
Infrastructure Protection & Upgrading	**Protect**, restore and enhance urban ecosystems and create flood buffers. **Develop** water bodies and increase vegetative cover.	**Develop** monitoring systems to prevent spread of water-borne and vector-borne diseases. **Develop** capacity of emergency health facilities to address disease outbreaks and pandemics.	**Implement** ecosystem based risk mitigation programs. **Install** early warning systems and invest on emergency equipment to deal with disasters. **Prioritize** retrofitting, demolition and replacement of damaged structures.

Flood Forecast and Early Warning System

The FFEWS for Kolkata is the first comprehensive city-level early warning system in India. It presents IMD's forecasts as well as real-time updates from sensor nodes installed at critical locations across the city.

Disaster Monitoring - Avoiding Shocks

Pre-disaster preparedness: Early warning can be useful to postpone avoidable travel as well as stock emergency supplies and equipment (food, torch, candles, medicines etc.).
During disasters: Real-time data on street flooding and traffic control to help people avoid/delay travel.
Post Disaster: The real time data series can be used to identify damaged areas and to improve disaster management plans.

Environmental Monitoring - Avoiding stress

FFEWS also provides granular temperature, humidity and air quality data from sensors distributed across the city. It can provide data to enable remedial measures to avoid impacts of heat and air pollution. Water quality can also be monitored with sensors, which can provide data on contaminants.

Expansion of FFEWS - Health Monitoring - Avoiding Shocks

Patient data from hospitals, clinics and pathological labs can be used to identify hotspots of transmissible diseases. It can warn citizens about impending risk of water-borne and vector-borne diseases and take preventive measures such as water treatment, avoiding street food and mosquito control.
The spatially explicit health data can help in taking preventive measures such as vector control, distribution of chlorine tablets etc.

BENEFITS

- **Environment**: Early warning can reduce damage to life and infrastructure. Cars can be moved and assets can be shifted to safer places.
- **Monitoring**: Maps and data analysis can help in identifying hotspots to direct emergency operations.
- **Costs**: The system is cost effective and can save lives and property.
- **Accessibility**: The flood data and reports along with real time monitoring can be accessible through apps and via internet browsers.

CHALLENGES

- **Marketing**: Mainstreaming of FFEW system among the public is a challenge.
- **Life**: IoT devices have a life of 3 years and regular technology upgradation is necessary.

Stakeholder Roles

Government

- (I) **Implement** early warning system, build staff capacity and allocate budget.
- (I) **Improve** disaster management plans informed by time series data from early warning systems.
- (I) **Develop** building rules based on the spatial risk information from past disasters.

Civil Society

- (E) **Raise** awareness and use scientific and traditional knowledge in disaster risk reduction practices. Ensure that local capacities are enhanced and valued.
- (E) **Develop** context specific nature based solutions.
- (T) **Introduce** IT enabled health monitoring systems.

Communities

- (E) **Prepare** teams for improving neighbourhood level resilience and disaster prevention.
- (T) **Use** advance warning and real time data to take preventive action.
- (F) **Invest** in asset insurance to reduce losses.
- (F) **Plan** ahead for disaster losses.

Private Sector

- (I) **Conduct** site risk assessments and develop disaster risk reduction plans.
- (I) **Use** insurance tools to reduce impacts of disasters.
- (F) **Develop** business continuity plans to avoid disruptions in case of disasters.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

Cayman Islands

The 124 bed Cayman Islands hospital built to Category 5 hurricane standards, remained functional during and after Hurricane Ivan providing shelter for more than 1,000 people.

Pune, India

A multi-stakeholder initiative to implement a city-wide action plan for restoring natural drainage, widening streams etc. and property tax incentives to mitigate city flood risks.

Kuala Lumpur

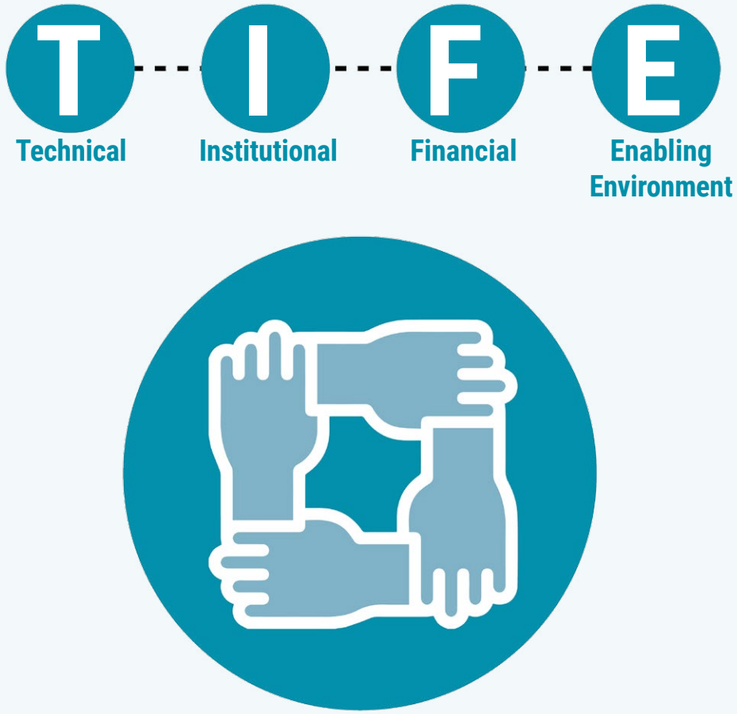
Execution of multipurpose infrastructure projects such as the Stormwater Management and Road Tunnel used to divert excess water and prevent disastrous flash floods.

Mudslide, Manizales

The government created tax incentives for ecological protection and a surcharge on petrol to fund disaster prevention and mitigation.

Additional Information

	Factors	Urban Environmental Monitoring
1	Risks addressed	Extreme events, disease outbreaks
2	Expected benefits	Reduced damage & loss form extreme events, reduced epidemics
3	Space & other requirements	Control room in municipality, space for onsite & off-site sensors, power supply
4	Basic technical details & specifications	Ultrasonic, temperature, humidity, current sensors, IoT devices, cloud storage, web platform
5	Indicative costs	Minimum Rs.15 million & additional costs for expansion
6	O&M requirements	Frequent O&M of sensors in corrosive environments, routine O&M of web platform
7	How to integrate the interventions with city level infrastructure	Forecasts, warnings & realtime data should be provided to user departments & other stakeholders
8	Existing rules & possible institutional support	NDMA Act (2005) & disaster management guidelines



Financial & Institutional Tools

Financial Tools

Corporate Social Responsibility (CSR)

The private sector is mandated to allocate funds under CSR. These funds can be be used for community development activities and neighbourhood improvement programs etc. Parks, lake restoration projects etc. can be funded through CSR.

Public - Private Partnerships (PPPs)

Municipalities can partner with private companies to maintain parks, water bodies etc. Solid waste management at city level is increasingly being handled by PPP ventures. These partnerships can be used to develop nature-based solutions to mitigate flood risks. The private sector can lease in or adopt small land parcels for development of parks and public spaces,adding to realesetate values.

Carbon Credit Systems

A carbon credit is a tradeable permit or certificate that provides the holder of the credit the right to emit one ton of carbon dioxide or an equivalent of another greenhouse gas. It is essentially an offset for producers of such gases. The main goal for the creation of carbon credits is the reduction of emissions of carbon dioxide and other greenhouse gases from industrial activities to reduce the effects of global warming. Resilience Technology Promotion Centres can take up activities to reduce emissions and claim carbon credits.

BENEFITS

- **Environment**: PPP ventures can enhance environmental quality through development of parks and restoring water bodies.
- **Place-making:** Improving public infrastructure enhances urban ecosystems and livability.
- **Savings**: Reduced energy consumption through adoption of more efficient systems can be used to claim carbon credits.

CHALLENGES

- **Management**: Building partnerships between different stakeholders is a challenge.
- **Acceptance:** Resilience building and risk mitigation projects require investments which can only provide long term payback. Getting buyin from prospective beneficiaries is a challenge.

Institutional Tools

Developing Resilience Technology Promotion Centres (RTPC)

- Train building workers and practitioners.
- Promote microenterprises and startups to provide installation and maintenance support to community and enterprise users.
- Conduct awareness programmes.
- Promote resilience building technologies and processes to create markets for resilience building action.
- Develop de-carbonization programs across scales and sectors.
- Develop awards and incentives - Best green housing society, sustainable neighbourhoods, energy efficient work places etc.
- Monitor urban environment and conduct action research.

These centres can be promoted through partnership between civil society organizations and KMC. KMC can outsource some of the resilience building activities to the RTPCs. They can generate funds from carbon credits by implementing projects to reduce carbon intensity, such as implementation of large scale cool roof technologies and water conservation programs etc.

BENEFITS

- **Environment**: Helps in capacity building and improving city resilience against stresses and shocks.
- **Accessibility**: Helps to diffuse state of art technology to potential users.

CHALLENGES

- **Costs**: Initial setup cost for enterprises, marketing, promotion and employees can be high.

Stakeholder Roles

Government

- (I) **Create** disaster management and climate resilience department in KMC.
- (E) **Support** Resilience Technology Promotion Centres (RTPC) and Public Private Partnership projects to improve resilience.
- (F) **Provide** additional incentives to assist vulnerable communities and small businesses to improve their resilience.

Civil Society

- (I) **Develop** and support Resilience Technology Promotion Centres (RTPC) to mainstream climate resilience.
- (I) **Prepare** annual state of environment reports with special section on disaster mitigation and resilience.
- (E) **Create** platforms for sharing lessons learnt from implementation of projects.

Communities

- (E) **Adopt** resilience building activities.
- (E) **Support** crowd sourcing of urban environmental data.
- (E) **Improve** local environment through resilience building activities.

Private Sector

- (I) **Set up** startups to promote resilience building activities.
- (E) **Support** resilience building activities by engaging with the communities and civil society organizations.
- (T) **Identify**, develop and market resilience building technologies.
- (F) **Take up** PPP projects in environment improvement, nature-based solutions and waste management etc.

(T) Technological (I) Institutional (F) Financial (E) Enabling environment

Examples

Alappuzah

'Clean Home Clean City' campaign fixed the problem of solid waste management. 'Energy Conservation award' received by the municipality for promoting small biogas systems.

Brandywine creek

Revolving Water Fund model - Finance and governance mechanism for downstream beneficiaries to invest in upstream conservation practices designed to secure freshwater resources.

Washington DC

Post Construction Stormwater Trading - Stormwater market created for compliance and added stormwater fee reduction incentives.

California: Capinero Creek

Sustainable Water Impact Fund - Invests in agricultural and water assets to deliver competitive returns and environmental and social objectives.

Additional Information

	Factors	Financial & Institutional Tools
1	Risks addressed	All types of risks
2	Expected benefits	Institutional & financial support for DRR & resilience action
3	Space & other requirements	Office space for RTPCs in each ward, interested CSO/NGO/private sector groups
4	Basic technical details & specifications	Set up RTPCs across the city, identify funding mechanisms, build partnerships
5	Indicative costs	Variable depending on funding availability. Pilot RTPC can be set up with ~ Rs.1 million
6	O&M requirements	Training on entrepreneurship development & new initiatives necessary
7	How to integrate the interventions with city level infrastructure	Pilot RTPCs can be set up & expanded into all wards
8	Existing rules & possible institutional support	None

Solutions Across Scales

Typology / Intervention	Slum	Independent House LIG/MIG	Low-Rise Flats (<5 storey)	Bungalows (HIG)	Townships with High-Rise Flats	Community Level
UG water storage tank	●	●		●		
Rain Water Harvesting		●	●	●	●	●
Rain gardens		●	●	●	●	●
Waterbody conservation					●	●
Floating wetlands					●	●
Solar bottle bulb	●					
Rooftop solar PV energy		●	●	●	●	●
Light tunnels		●		●		
Biogas plant (BP)		●	●	●	●	●
Decentralized sewage treatment		●	●	●	●	●
Urban agriculture		●	●	●	●	●
Pocket parks					●	●

FAQ

How to proceed with the adoption of resilience-building technologies?
Detail out the issue you are facing and collect relevant data. Identify your goals and outcomes. Prepare a list of resources required. Work out land and other resources availability. Do an internet search for more details and contact local suppliers/service providers. Discuss with existing users. Get information on capital and O&M costs. Decide on the best options.

What are the requirements for a home biogas unit?
About 1 cum biogas plant is necessary for processing kitchen waste from a family of 5 persons. About 2 sq.m area is required for 1 cum capacity overground systems. Only wet kitchen waste should be fed and careful segregation of plastics, paper and glass wastes to be done before disposing of kitchen waste in the biogas unit. Use underground biogas units in cities where temperature seasonally goes below 5°C. Use biogas stoves only.

How can I reuse greywater in my home?
It is better to install a decentralized wastewater treatment system in case sewage contains both grey and black water. The packaged decentralized systems have capacities of more than 10 cum/day, which is sufficient for 20 households. Constructed wetlands can be used for single-family households. Toilet wastewater contains more pathogens and must not be used directly in constructed wetlands. The grey water (from washbasins, washing machines, bathrooms, and kitchen sinks) can be passed through constructed wetlands, whose outflow can be reused for flushing.

What is Safe-fail?
Infrastructure such as buildings can fail catastrophically without time to take preventive action and save lives. They can also fail slowly providing time for people to escape. Early warning systems also can provide sufficient respite time so that people can escape from high-risk areas and assets can be saved. Safe fail systems provide sufficient time to reduce loss of life, casualties, and assets.

How to initiate and sustain community-driven initiatives to improve resilience?
Any community-driven initiative requires common issues that the majority of the community faces. First of all, it is necessary to discuss these challenges and reach a consensus on addressing these issues. Transparent management and social accounting processes are necessary for the sustainability of community-driven initiatives. Also, it is often necessary to identify a champion to drive these initiatives as most members are likely to lose interest over time. Operation and maintenance costs and management mechanisms need to be worked out in the beginning and shared with all members.

What are Resilience Technology Promotion Centres?
Most interventions such as urban agriculture, biogas, wastewater treatment plants etc. require regular technical inputs, monitoring services, and O&M, which is beyond the capacity of the communities. RTPCs are local enterprises that can offer marketing, installation, and O&M services and also monitor the quality of outputs. These can be managed by a partnership between civil society organizations, the private sector and the government. They can use financial tools such as carbon credits by aggregation of multiple small interventions. They can offer one-stop solutions to resilience-building interventions.

Do's & Don'ts

1. **Do** check the full lifetime costs, benefits, challenges as well as maintenance requirements before installing any systems.
2. **Do** conduct energy and water budgeting and assess the savings and payback periods before installing any technologies.
3. **Do** discuss pros and cons in resident welfare associations and reach a consensus before installing any system.
4. **Do** distinguish between tasks you can do and tasks to be done by trained people.
5. **Do** check availability of operation and maintenance services and cost of AMC before adopting any technology.
6. **Do** develop watertight AMC contracts and check credentials of service providers before signing any AMC agreements. Work out frequency of maintenance with the AMC provider. Always insist on regular preventive maintenance.
7. **Do** report any degradation of quality of outputs to the AMC provider immediately.
8. **Do** reduce the use of energy and water by installing water and energy-saving devices. About 25-50% saving can be achieved by using efficient devices such as aerator faucets, reusing reject water from RO water filters, installing LED bulbs and using five-star rated air conditioners and appliances.
9. **Do** ensure water and air filters are kept clean through regular maintenance.
10. **Do not** service any equipment that does not have user-serviceable parts. Always ask for maintenance or repair by manufacturers or AMC's engineers.
11. **Do not** mix different waste streams. As far as possible, segregate and then treat/ sell different wastes.
12. **Do not** throw solid wastes in washbasins and toilets. Also avoid disposing of human hair, medicines, plastics, waste oil and grease into the toilet.

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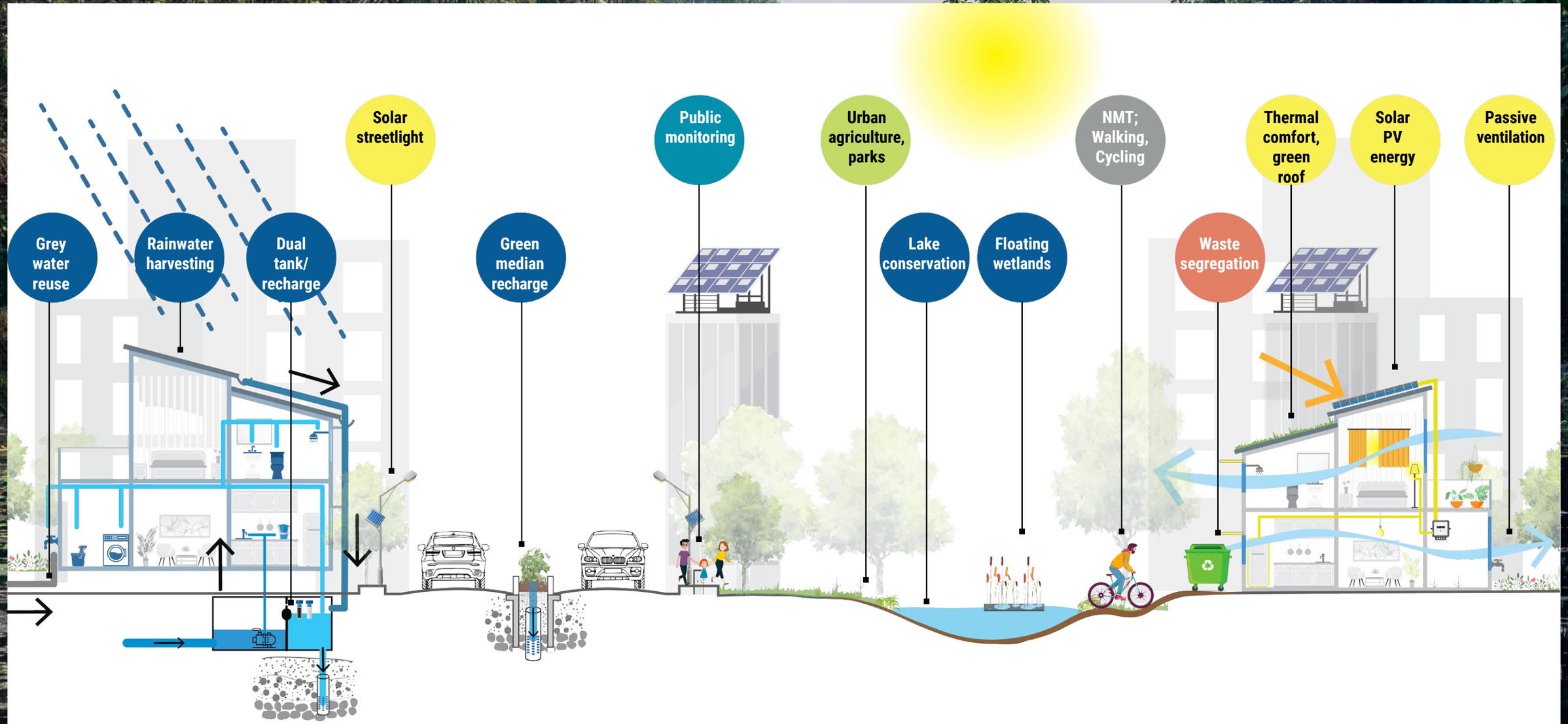
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Urban agriculture, parks
Lake conservation
Floating wetlands
NMT; Walking, Cycling
Waste segregation
Thermal comfort, green roof
Solar PV energy
Passive ventilation


S.K. ENTERPRISES


Uber