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Theme Paper | Policy Review | Case Studies

COP 28

SHELTER

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FROM THE EDITOR-IN-CHIEF

The recently concluded 28th Conference of the Parties (COP28) has made a resounding declaration, emphasising the urgent need for combating climate change. Globally, 56% of the world population i.e. 4.4 billion inhabitants live in urban areas today. By 2045, the number of people living in cities will increase by 1.5 times to 6 billion, adding 2 billion more urban residents. Cities play a pivotal role in driving economic growth and contributing to the overall economy. With cities consuming over 70% of the world's energy and buildings responsible for a third of global greenhouse gas emissions, the imperative to decarbonise urban landscapes is critical to our survival. According to the International Energy Agency (IEA), energy-related carbon dioxide emissions reached an all-time high in 2021, despite the disruptions caused by the COVID-19 pandemic. The built environment is a significant contributor, with buildings accounting for 28% of total energy-related CO2 emissions. The COP28 findings shed light on the significant role that sustainable urbanisation can play in reducing greenhouse gas emissions and creating a sustainable future.

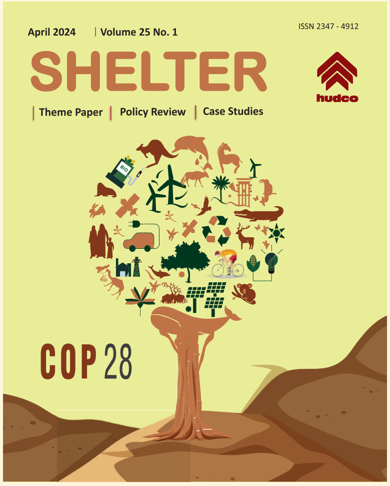
India's proactive role in global climate action is evident through its support for action-oriented measures, rooted in the inseparable connection between people and the planet. The country has committed to ambitious renewable energy targets, aiming to achieve 450 gigawatts of installed renewable energy capacity by 2030. As of 2024, India has made significant progress, with renewable energy sources accounting for over 20% of its total installed capacity. Additionally, India has invested in initiatives such as afforestation, sustainable agriculture practices, and energy-efficient technologies to reduce emissions and enhance resilience to climate impacts. India has also played an active role in international climate negotiations and agreements. It played a significant role in the Paris Agreement in 2016 and has pledged to reduce its emissions intensity by 33-35% by 2030 compared to 2005 levels. Another flagship scheme of the Indian government is Pradhan Mantri Ujjwala Yojana (PMUY) aimed at providing clean cooking fuel (LPG) to households below the poverty line, thereby reducing indoor air pollution and carbon emissions. Till now 10.35 crore cylinders have been released under the scheme.

India has advocated for the principle of "common but differentiated responsibilities" in climate action, emphasising the need for developed countries to take greater responsibility for historical emissions and provide support to developing countries for mitigation and adaptation efforts. Prime Minister Narendra Modi's call to embrace Mission LiFE – Lifestyle for Environment exemplifies India's commitment to tangible actions. In sync with this, India unveiled the Green Credit Initiative at COP28, creating a global platform for innovative environmental programs and instruments. Beyond domestic efforts, India's global contributions include the International Solar Alliance (ISA) , Coalition for Disaster Resilient Infrastructure (CDRI), and the Global Biofuel Alliance. Launched at the G20 leaders' meeting in New Delhi, the Global Biofuel Alliance aims to catalyse global collaboration for the advancement and widespread adoption of bio fuels. The push for electric vehicles (EVs) in India, facilitated by initiative like the FAME India Scheme, is integral to the country's carbon reduction efforts. In FY 2022-23, India registered EV sales for 12,43,258 units, marking a 154% year-on-year growth over FY 2021-22 EV sales numbers, i.e., 4,90,210 units across all vehicle segments. The PM Surya Ghar Muft Bijli Yojana - with an outlay of Rs 75,021 crore is a solar rooftop scheme launched by the Indian government to provide free electricity to households in India. The initiative aims to support households with the installation of solar power systems on their rooftops.

Energy efficiency measures not only combat climate change but also stimulate economic growth. It is estimated that by 2050, energy-efficient measures in cities could save up to $17 trillion globally. These savings arise from reduced energy costs, job creation, and increased productivity, fostering sustainable and prosperous urban economies. The COP28 declaration serves as a call to action, urging governments, city planners, businesses, and citizens to commit to energy-efficient urban development.

This volume of Shelter is based on COP 28 (28th Conference of the Parties of the UNFCC) and contains an array of articles in three sections. The articles provide diverse insights into range of issues related to the theme for reducing carbon emission in building footprint, building urban resilience imperative for safeguarding urban investments and paving the way for a forward-looking, inclusive and integrated approach to energy-efficient urban development. The theme paper authored by Kanagraj Ganesan et al emphasises the importance of Grid-Interactive built environment in driving energy transition within India. The paper by Jit Kumar Gupta highlights multiple approaches to decarbonise buildings, with the goal of making them sustainable while reducing energy and resource usage. In the policy review segment, A. K. Jain underscores the significance of extending the global vision and discussions of COP28 to the

INSIDE



local level and contextualises the challenges in terms of urban policies, strategies, plans, programmes and climate actions. The paper by Simran Vats et al has explored the diverse aspects of sustainable development within the framework of India's shift towards energy-efficient cities.

The case study section features the paper by Ramakrishna Nallathiga, discusses the importance of energy efficiency and emission reduction under PPP in the context of two Indian cities- Pune and Hyderabad. The paper by Debanjali Saha delves into a holistic strategy aimed at enabling Indian cities to attain carbon neutrality, integrating technological innovation, policy adaptation, and community participation. The paper by Dr. P.B. Salim, examines the achievement of West Bengal Power Development Corporation Ltd (WBPDCL) in being recognised as the top-performing power generation company nationwide for the fiscal year 2022-23. In review of the book "Climate Resilient, Green and Low Carbon Built Environment" authored by A. K. Jain and published by Springer Nature, Singapore in 2023, Dr. Akshaya Sen stresses the importance of embracing an integrated approach across various dimensions for fostering sustainability in urban settings. The paper by Somsubhra Panda explores the subject of urban areas and their contribution to greenhouse gas emissions, focusing on identifying their sources, understanding the impacts of urbanisation on emissions, and proposing strategies for mitigation.

I thank all the contributors for an overwhelming response to this issue. I hope the readers enjoy the issue as much as we did putting it together. We value your feedback and would appreciate your comments.

Theme paper

Policy Review

Case studies

IN THE BOX

"HOUSING THE URBAN POOR – POLICY, PLANNING AND IMPLEMENTATION – INDIAN EXPERIENCE" ON 4th - 22nd DECEMBER, 2023

HUDCO's Human Settlement Management Institute (HSMI) organised the 51st International Training Programme on "Housing the Urban Poor – Policy, Planning and Implementation – Indian Experience" on 5th December, 2023 The MEA sponsored ITEC International Training programme was inaugurated by Shri Sanjay Kulshrestha, Chairman & Managing Director, HUDCO in the presence of Shri M. Nagaraj, Director (Corporate Planning) HUDCO, Shri D. Guhan, Director (Finance) HUDCO, Smt. Varsha Punhani, Head HUDCO's HSMI and Shri Surendra Singhai, General Manager (Projects), HUDCO's HSMI.

This training programme aims to promote technical cooperation and experience sharing amongst the developing countries in the areas of policy, planning and implementation of housing programmes for urban poor with special focus on housing for economically weaker sections, affordable housing, universal provision of services, security of tenure, technological interventions and appropriate financing options.

Housing the Urban Poor – Policy, Planning and Implementation – Indian Experience - Batch 2023 with dignitaries, HSMI Faculty and senior HUDCO officials at the Inaugural Session

The training programme was attended by 27 professionals, Architects, Town Planners, Engineers, Administrators, Urban Designers, Community Development Sociologists from 15 countries, namely, Albania, Argentina, Cote D'Ivoire, Indonesia, Jamaica, Lesotho, Maldives, Niger, South Sudan, Sri Lanka, Syria, Tajikistan, Tanzania and Zimbabwe.

GRID-INTERACTIVE BUILT-ENVIRONMENT (GIBE): CATALYSING ENERGY TRANSITION IN INDIA

KANAGARAJ GANESAN[1]
RAJKUMAR BALASUBRAMANIYAN[2]

Increasing energy demand due to intensive energy use in the rising floor areas of the built environment in the Indian cities has led to higher energy consumption, supplied energy costs, and carbon emissions. Intervention measures in the form of energy efficiency, renewable energy, and operational automation systems are being implemented in buildings to reduce the consumption, emissions and costs associated with energy supply. Yet, the goal of providing uninterrupted access for energy to everyone at affordable prices with lower fossil fuel consumption is not being achieved, as there is disparity in the energy supply from utilities to make their businesses profitable. High-paying customers from industries and commercial buildings enjoy the uninterrupted energy supply, whereas the low-income households in suburban areas still face power shortages during summer season where there is a higher need for thermal comfort appliances. Managing the load profile across different electricity users and their appliances using grid-interactive technologies can lead to better efficiency of supply, enhance energy access, improve grid performance, and improve affordability to the growing middle-income population in the country. Grid-interactive technologies has been piloted in the countries like USA and Australia, showing greater potential for energy efficiency and has a strong potential for decarbonisation in built environment.

Keywords: *grid interactive buildings, energy efficiency, renewable energy, energy management, electricity utilities, demand response*

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Introduction

India, boasting a population of 1.4 billion and holding the world's fourth-largest economy position valued at $3.9 trillion in 2023, presently stands as the third-largest contributor to global carbon emissions. In 2021 alone, it accounted for seven percent of the total CO_2 emissions, reaching a staggering 2.7 billion metric tons. Looking ahead, India is poised to become the world's most populous country and the second-largest economy by 2050, anticipating a projected energy consumption growth 1.5 times faster than the global average over the next thirty years [1].

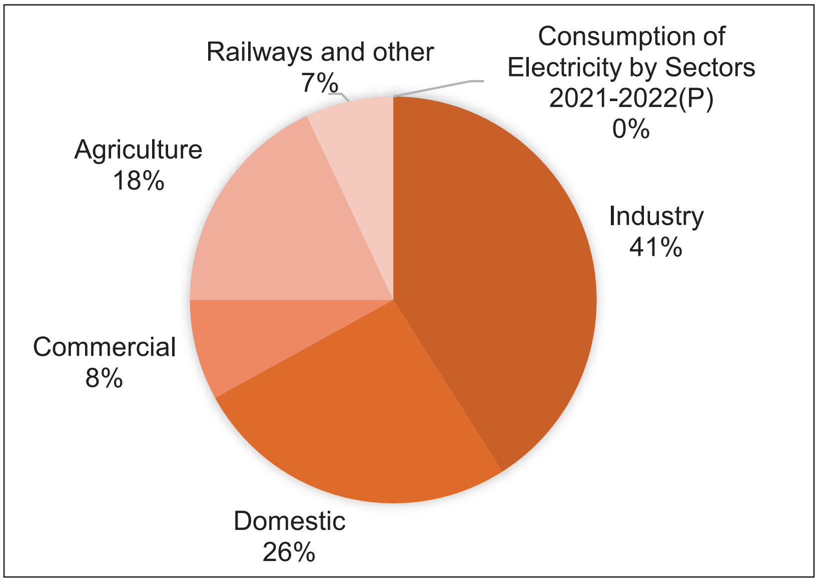

Figure 1: Sector-wise Electricity Consumption in 2021-22

In India, the buildings sector (residential and commercial) contributes to 34% of the total annual electricity consumption and contribute to 41.2% of the total electricity sold by the utilities in India, as shown in the figure [2].

The share of the electricity consumers, their peak energy demand and annual energy consumption, and the revenue gained through the sale of electricity is depicted in figure [3].

As seen from the Figure 2, the total number of residential and commercial building energy consumers has increased by 40% over the past 8 years, with the sale of electricity increasing by 46% in the same period. This indirectly indicates the growth in the energy intensity of the buildings sector overall, looking into the fact that the total connected load had increased by only 14% over the same period. The same period witnessed a 65% increase in the revenue from the electricity sales, indicating cost escalation in electricity price of 5.72 INR/kWh to 6.5 INR/kWh.

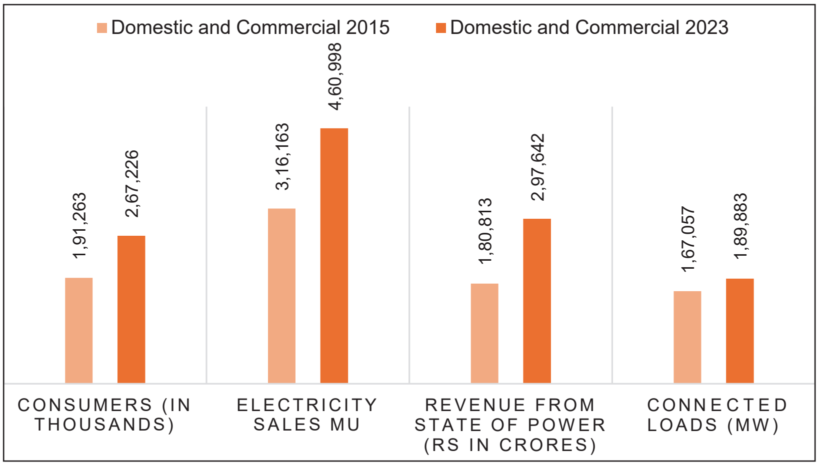

Figure 2: Snapshot of Building Electricity Consumers and Suppliers

Thus, the increasing energy consumption and electricity prices require interventions in terms of improving energy efficiency and utilising renewable energy (available at lower price compared to conventional grid electricity), to meet the demands from upcoming demand centres like electrical vehicle charging infrastructure and demand management strategies like Battery Energy Storage Systems (BESS).

The potential integration of renewable energy emerges as a strategic avenue to optimise energy usage within the economy, boosting overall efficiency. By mitigating losses during energy conversion, this approach minimises the primary energy required to meet existing demands. Furthermore, advancements in energy efficiency not only decrease overall primary energy requirements but also reduce the capacity and cost of low-carbon energy systems necessary for meeting demand.

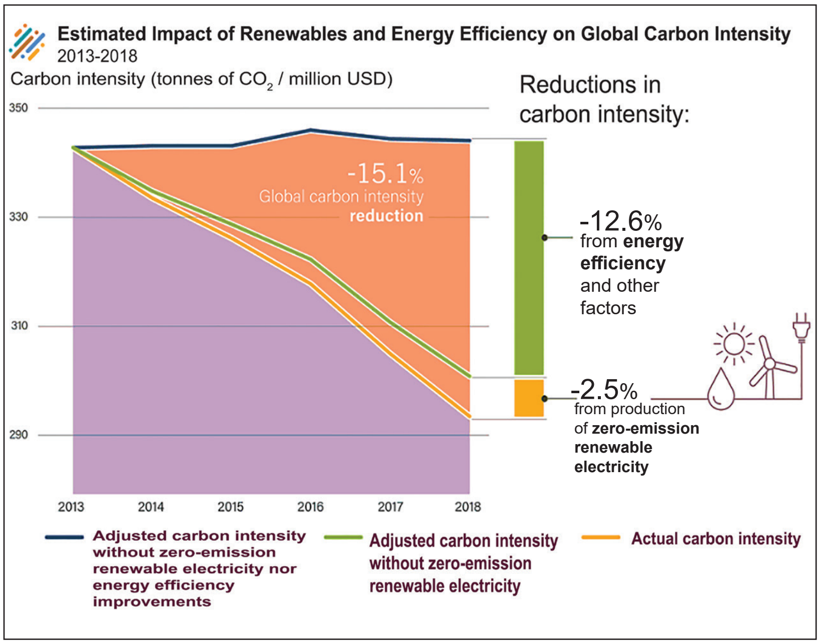

Figure 3: Impact of Renewable Energy and Energy Efficiency in Global Carbon Intensity [4] (Source: REN212021 Global Status Report)

This transformative shift supports a higher proportion of renewable sources in the energy mix, cultivating a more sustainable and cost-effective energy landscape. Forecasts point towards a substantial transition, envisioning a surge in electricity's share in final energy consumption from the present 20% to nearly 50% by 2050. This paradigm shift anticipates over 60% of electricity generation originating from solar and wind. Concurrently, adaptive measures such as adjustments in EV charging, electrified heat, and hydrogen production are expected to accommodate variable renewable energy, contributing to the need for establishing a flexible and resilient energy system.

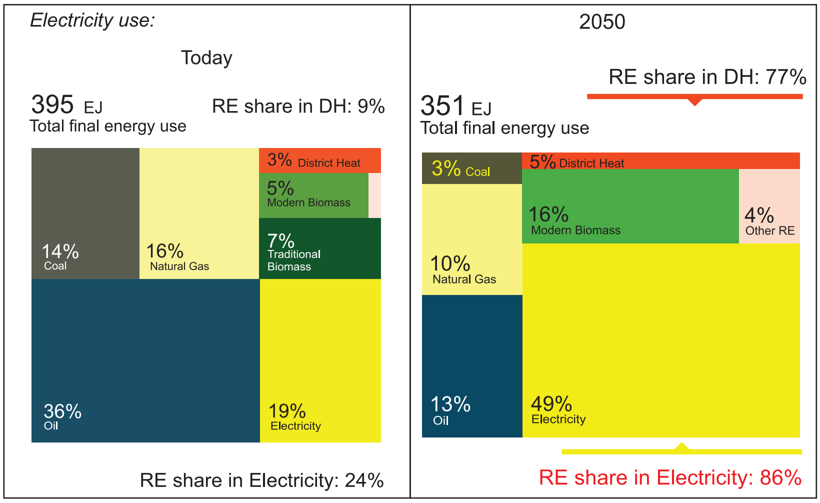

Figure 4: Share of Total Final Energy Use in 2021 and 2050 [4]

Grid-Interactive Built-Environment

Grid-Interactive Built-Environment (GIBE) refers to the individual or group of energy-efficient buildings employing intelligent appliances and/or on-site Distributed Energy Resources (DERs) to offer flexibility in energy demand. It optimally balances energy costs, grid services, and accommodates the needs and preferences of occupants in a seamless and interconnected manner.

These buildings are intelligent, enhancing energy efficiency using sensors, controls, and smart analytics. They come equipped with sensors and meters capable of sending and receiving signals to interact with the grid. Their flexibility allows for optimised energy loads through on-site generation, responding to demand, and utilising energy storage solutions.

A future with net-zero emissions requires increased use of variable renewable energy sources like wind and solar. Smart grids enhance energy production efficiency by minimising

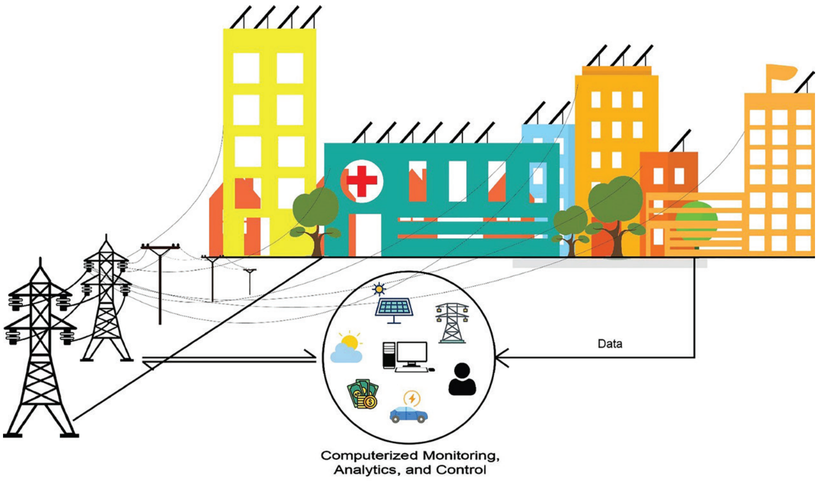

Figure 5: Concept of Grid Interactive Built Environment (GIBE)

transmission losses and integrating renewable sources. They intelligently match energy generation with demand and connect producers to consumers. Upgrading power systems improves resilience and reliability, offering flexibility for faster outage responses, minimising renewable energy waste, and providing backup power during emergencies. Generating renewable energy on-site for self-use and sending excess to the grid reduces reliance on fossil fuels for occupant energy needs, large-scale electricity generation, and lowers transmission and distribution losses.

GIBE contributes to enhancing the stability of electricity supply for the variety of users connected with the grid like residential, commercial, industrial, and agricultural consumers. This flexibility supports in the balancing of grid during peak demand, minimising grid congestion, and lowers the risk of blackouts or voltage fluctuations.

GIBE plays a crucial role in seamlessly incorporating distributed variable renewable energy (VRE) sources into the grid. Given the inherent fluctuations in VRE due to weather conditions, GIBE can be equipped to efficiently use and store excess renewable energy during periods of high generation. This ensures optimal utilisation when VRE generation is low, fostering a smoother integration of VRE, reducing wastage, and maximising the utilisation of clean energy resources.

Benefits of GIBE

GIBE provides the following benefits for the electricity consumers and suppliers as well and supports the country's future expansion of electricity generation plans. The GIBE can enhance decarbonisation by increasing energy efficiency and aids to the achievement of Sustainable Development Goals (SDGs) in the country, in particular, SDG 7 for clean and affordable energy access. The following benefits can be realised through wide-scale application of GIBE in India.

a. **Flexibility for Grid Stability:**

- GIBE dynamically adjust energy consumption and generation in response to grid signals, enhancing electricity supply stability.
- Valuable in balancing the grid during peak demand, reducing congestion, and minimising blackout or voltage fluctuation risks.

b. **Integration of Renewable Energy:**

- GIBE play a crucial role in seamlessly integrating distributed variable renewable energy (VRE) sources into the grid.
- Equipped to optimally use and store excess renewable energy during high-generation periods, ensuring efficient utilisation during low VRE generation.

c. **Grid - Interactive Behaviour:**

- GIBE exhibit grid-

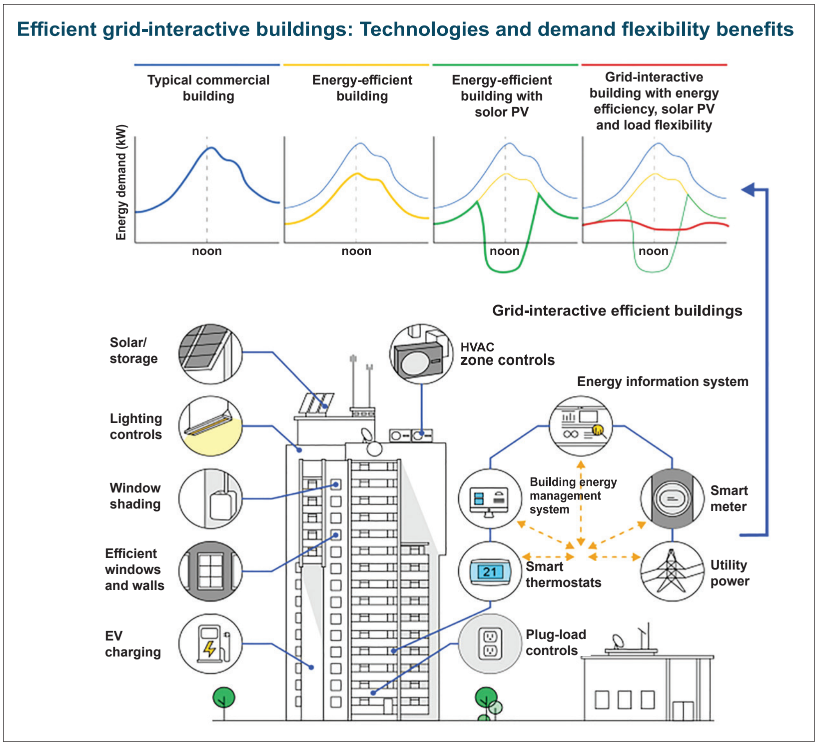

Figure 6: Technologies and demand management relationship (Source: RMI, 2022)

interactive behaviour, enabling smoother VRE integration, reducing curtailment, and maximising the utilisation of clean energy resources.

- GIBE can aid to develop user behavioural change through introducing incentives and penalties for the consumers based on their energy performance and inherently involve users to participate in implementation of GIBE.

Technological Interventions Supporting Adoption of GIBE

GIBE leverages various technologies to enhance energy efficiency, sustainability, and overall performance. These technologies enable buildings to interact with the electrical grid intelligently, optimising energy usage and supporting demand-response initiatives. Here are some key technologies used in grid interactive buildings:
The essential and enhanced technologies associated with successful implementation of GIBE are as follows:

a. **Building Management Systems (BMS):** BMS or Building Automation Systems (BAS) are central to grid interactive buildings. They integrate various components such as HVAC, lighting, security, and more to monitor, control, and optimise energy usage based on real-time data and predefined algorithms.

b. **Smart Sensors and IoT Devices:** Deploying sensors throughout the building allows for real-time data collection on occupancy, temperature, humidity, and other environmental factors. IoT devices enable communication between these sensors and the BMS.

c. **Energy Management Systems (EMS):** EMS helps optimise energy consumption by analysing data from various sources, forecasting demand, and implementing strategies to reduce peak loads or shift energy use to off-peak periods.

d. **Renewable Energy Integration:** Grid interactive buildings often incorporate renewable energy sources such as solar panels, wind turbines, or geothermal systems. These sources contribute to on-site power generation, reducing reliance on the traditional grid.

e. **Energy Storage Systems (ESS):** Batteries and other energy storage solutions allow buildings to store excess energy during periods of low demand and release it during peak times or when renewable sources are not producing power.

f. **Demand Response (DR) Systems:** DR systems enable buildings to respond to signals from the grid, adjusting their energy consumption during peak times or when there is stress on the grid. This helps utilities balance supply and demand.

g. **Smart Grid Technologies:** Integration with smart grid infrastructure allows bidirectional communication between the building and the utility. This enables more efficient energy distribution, load balancing, and improved grid reliability.

h. **Advanced Metering Infrastructure (AMI):** Smart meters provide detailed information on energy consumption, enabling better monitoring and control of energy usage in real-time.

i. **Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML algorithms analyse historical data and real-time inputs to predict energy demand patterns, optimise system performance, and automate decision-making processes for energy management.

j. **Electric Vehicle (EV) Charging Infrastructure:** As electric vehicles become more prevalent, integrating EV charging stations into buildings can be part of a comprehensive grid interactive strategy.

k. **Blockchain Technology:** Blockchain can be used to create decentralised and transparent energy trading platforms, allowing buildings to buy and sell excess energy with other connected entities.

l. **Occupant Engagement Platforms:** These platforms leverage user interfaces and mobile apps to engage building occupants in energy-saving practices, promoting awareness and encouraging sustainable behavior.

Implementing a combination of these technologies can transform traditional buildings into grid interactive ones, contributing to a more resilient, sustainable, and efficient energy ecosystem.

GIBE has the potential to ease the growth in sustainable mobility through integrating electrical vehicle charging infrastructure with Energy Storage Solutions and smart grid solutions. The potential strategy involves:

- Implementing smart charging stations equipped with communication capabilities to interact with the grid and respond to signals for demand response.
- Use of advanced metering and monitoring systems to collect real-time data on energy consumption, grid conditions, and pricing.
- Scheduling EV charging and battery storage activities during off-peak hours when electricity demand is lower, and prices are typically reduced.
- Utilisation of the battery storage system to store excess energy during periods of low demand and discharge it during peak hours to reduce overall grid load
- Explore and implement Vehicle - to - Grid technology, allowing EVs to discharge energy back

to the grid during peak demand periods.

- Use V2G capabilities to provide grid services such as frequency regulation and ancillary services, contributing to grid stability.

- Aggregate multiple EVs and BESS units to create a virtual power plant. This allows for more significant and coordinated contributions to demand response.

- Enable demand response aggregators to communicate with and control a fleet of EVs and BESS units to respond to grid signals effectively.

Status of GIBE in India

To mainstream GIBE, following initiatives has been taken up in India:

i. The Grid Interactive Energy Efficient Affordable Housing Project (GEBA), led by Global Buildings Performance Network (GBPN), through a Memorandum of Understanding (MoU) with builders in the states of Gujarat and Karnataka as part of a project aiming to actively involve the builder community in developing sustainable affordable housing.

ii. The buildings-to-grid (B2G) activities by Lawrence Berkeley National Laboratory (LBNL) leverages parallel Smart Grid activities by the Indian and U.S. stakeholders. This study has revealed the short-term and long-term Demand Response (DR) and energy-efficiency integrated action plans for pilot studies and transformative technologies for mitigation and adaptation of electricity reliability.

iii. The building hosting the offices of the Telangana State Renewable Energy Development Corporation (TSREDCO) and Southern Power Distribution Company of T.G. Limited (TSSPDCL) in Hyderabad, Telangana, is set to become the first ever Grid Interactive Net Zero Energy Building (GI-NZEB) in South Asia. This building is aimed to set a use-case for grid interactive buildings with net zero energy footprint.

Potential for Large Scale Replication

The Demand Response (DR) strategies for GIBE has the potential for a larger scale of adoption by the electricity consumers in the country. Adding to the reduction in energy consumption during periods when the price of electricity is high or when system reliability is threatened, DR strategies has proven capability to balance supply and demand at any time of the day [5] and supports energy efficiency (EE) [6].

In 2012, Frost & Sullivan estimated the business potential of building energy management Systems (BEMS)

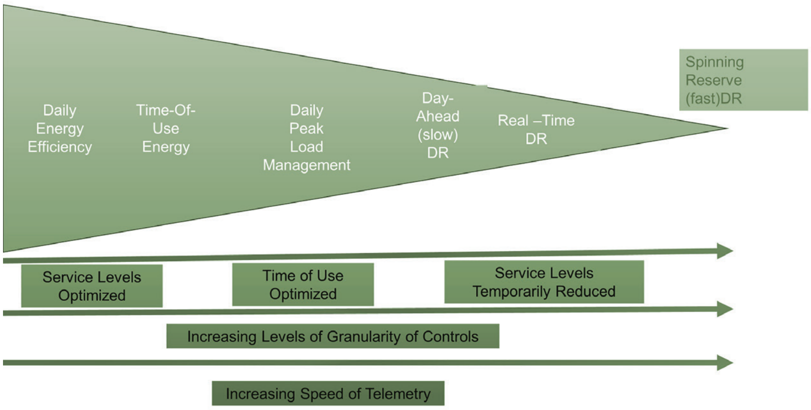

Figure 8: Benefits of DR strategies for GIBE (LBNL Research)

to be approximately $939 million by 2016, across all the building types [7]. The estimated market size for BEMS integration with energy management potential in the commercial sector was $37.5 million in 2011 [7]. Since GIBE implementation is still in emerging phases and requires integration with the BEMS and other building systems, it is expected that the market size of the building-to-grid or DR technologies in the commercial sector to be much larger than the residential buildings sector.

Way Forward

The accelerated adoption of the GIBE requires the integration of the technical specifications and compliance procedures in the energy efficiency standards like Energy Conservation Sustainable Building Code (ECSBC) and Eco Niwas Samhita in India can be enhanced to include mandates for countrywide GIBE adoption. The California Title 24 of Building Standards [8] is an example of such a model of integration of energy efficiency and GIBE standards.

Reliable testing platforms and pilot projects are required to validate the GIBE strategies in a group of electricity consumers at a neighborhood or sub-city levels to understand full-scale impacts. The goal of the pilots would be to facilitate technology penetration through skilled labor generation and proof-of-concept testing of the DR technology GIBE application in India. The testing of the GIBE can also lead to the development of control algorithms for the utilities for use in real-time application.

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DECARBONISING BUILT ENVIRONMENT - ISSUES AND OPTIONS

JIT KUMAR GUPTA

Buildings have been globally valued for promoting industrialisation, generating employment, adding wealth to communities and making human living more qualitative and sustainable. Buildings are also known for its negativities, dualities and contradictions for the reasons that buildings remain large consumers of conventional energy and non-renewable resources besides generators of enormous waste. Consuming half of the global energy, using majority of resources and generating 45% carbon emissions, buildings are not only embedded with large carbon footprints but are considered responsible for climate change, global warming, rising temperature and ozone depletion. Sustainable Development Goal 11, enunciated by UNO, has mandated critical role of buildings in managing global warming and promoting global sustainability by making them carbon neutral. Despite having critical role and relevance in promoting carbon neutrality, majority of buildings are still being planned, designed, constructed and managed without any concern for energy, carbon footprints, resources, environment and bio-diversity. This calls for not only looking for options for decarbonising buildings but also making them sustainable and least consumers of energy and resources. For achieving the goal of carbon neutrality and sustainability, traditional approach to designing, construction and operation of buildings have to be relooked, reviewed, revised and redefined. In search for appropriate solutions to make built environment carbon neutral, qualitative, liveable and more productive, the paper looks at the options of; rationalising approach to planning and designing of buildings; understanding relevance of site and climate; leveraging options for making buildings energy and water efficient; using sustainable building materials and state of the art construction technologies besides making indoor air quality more qualitative to achieve the objectives.

Key Words: *Built environment; Decarbonising; Climate, Energy, Materials*

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Introduction

Preservation, conservation and making value addition to environment, ecology and bio-diversity, has been considered most critical and valuable ingredients for making the planet earth safe, sustainable and qualitative accordingly has been accepted as the basic agenda and prime goal to be reached by all organisations, states and nations. Looking holistically, there exist two distinct categories of environment on the planet earth, one created by nature, called natural environment and other made by human beings, called built environment (buildings). Besides meeting the basic requirements of human living and working, buildings have also been recognised as the definer of human history, growth and development.It has been also accepted that future journey of mankind will also be defined by buildings, which shall be created over a period of time Rapid increase in population, higher level of urbanisation, industrialisation and globalisation, led by changing mindset focussing on increasing prosperity, rising consumerism, ever changing needs and demand for goods and services, the manmade environment has been gaining predominance over natural environment. *'India Urban Awakening: Building Inclusive Cities -Report'*, has projected India, as a nation, will be needing annually 700-900 million sq. mts. of built space (McKinsey Global Institute) to meet the basic needs of living and working in urban India.

Buildings remain vital for human growth and development besides central to all human activities. Buildings are also known to deeply impact the quality of life for the reason that 80% of total human life is spent within four walls of the buildings. Modulating quality of life, buildings are known to make human beings both healthy/ sick, depending upon quality of buildings in which they are living. As polluter of environment/ ecology and generators of large carbon footprints, buildings remain responsible for climate change, global warming and modulators of sustainability.

Large consumption of resources and generation of waste has been attributed to the manner and approach by which buildings are being planned, designed, constructed, operated and maintained.

Making buildings sustainable will hold the key for preserving, protecting and making value addition to resources, environment and ecology. Considering the enormity of built space yet to be created and its implications, as consumers of energy and resources, buildings need to be planned, designed, constructed and operated with utmost care and caution, with focus on minimising energy conservation and promoting sustainability; minimising waste generation and promoting resource efficiency for making human habitat more qualitative and livable.

Implications of Built environment

Studies made and analysis carried out have revealed that buildings remain responsible for consuming large resources, both natural and man made, during its entire lifecycle, spanning from conceptualising to construction, occupation, operation, maintenance and demolition. Studies made of the lifecycle cost and energy used in buildings, have also concluded that only 10% of total cost & 17% of total energy, goes into making of a building; whereas remaining 90% cost & 83% of energy, is used in the operation and maintenance of buildings over its entire life cycle.

According to *World Energy Council Report, 2016;* buildings are known to be responsible for consuming ;

- *over 40% global use of energy,*
- *30% of raw material extracted from earth,*
- *25% of the timber harvested,*
- *16% of fresh water withdrawal,*
- *35% of world's CO2 emission,*

- *generating 40% municipal solid waste and*
- *emitting 50% ozone depleting CFC besides*
- *promoting sick building syndrome.*

Looking at the facts given above, it can be visualised that buildings, as an entity, remain major consumers of resources, water and energy besides generators of large quantities of waste. In the process, buildings pollute environment, water, air and ecology besides destroying bio-diversity. All these negativities of buildings, leading to adversely impacting climate and human health, rising temperature, increasing carbon footprints, global warming and climate change; can be attributed to the manner in which built environment is being planned, designed and constructed. Globally, it has been concluded that if buildings are the prime culprit in adversely impacting the environment, ecology and resources then buildings offer the greatest hope and opportunity to minimise energy consumption and optimise the resources. This can be achieved by merely changing the manner/approach, in which buildings are being designed, constructed and operated. Accordingly, it becomes critical that current options of creating buildings must be reviewed, revised and redefined and new approach is put in place so that buildings are planned, designed and constructed in such a manner that built environment becomes promoters of sustainability and quality human living besides making value addition to the nature and natural resources.

Green Buildings

Known for its positivity, negativities, dualities and contradictions, buildings constitute a complex system of designing, construction, materials, resources, machinery, technology and environment. Revolving around seven layers during its ***life-cycle*** (siting, designing, construction, operation, maintenance, renovation and deconstruction); increasing consumption of resources (energy, water, materials, natural resources) and adversely impacting environment (generating waste, polluting air/water, creating heat islands, increasing storm water run-off); buildings are credited with negativities in terms of adversely impacting human health, environment and precious resources.

Looking at the entire gamut of built environment, Green Buildings have globally emerged as the best option to make buildings sustainable, least consumers of energy and resources. In addition, Green Buildings are known for its distinct advantages of minimising use of water, optimising energy efficiency, conserving natural resources, generating less waste and providing healthier space for occupants, as compared to conventional buildings. Green Buildings are also credited with saving energy up to 50%; reducing water consumption by 40%; reducing carbon emission by 35%; lowering CO_2 by 8000-12000 tons and 3 MW of connected electric load / million sqft building footprints; besides reducing 70% waste. Considering the entire gamut, green buildings have been recognized for its positivities in terms of providing financial, environmental and social benefits besides creating a win-win situation for both owners, occupants, tenants, communities, society and environment. Studies also reveal that,' green schools make learning easy and more meaningful'; 'green houses makes people happy and healthy' and green hospitals cure patients quickly'. Green building may initially cost more, but makes buildings cost-effective over its entire life cycle, through lower operating costs incurred over the life of building. Potential financial benefits of improving indoor environments exceed cost by a factor of 8 and 14. Green Building practices expands/ complements building design concerns of: economy, utility, durability and comfort besides minimising the carbon contents of built environment.

Defining Green Buildings

World Green Building Council has defined Green Building as a, *"Building that, in its design, construction or operation, reduces or eliminates negative impacts and creates positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources, improve quality of life and make our environment more qualitative and liveable*. Green buildings are universally characterised by;

- *Using efficiently; energy, water and other resources*
- *Using renewable energy including solar/wind/ water/geo-thermal*
- *Reducing pollution/ waste, involving refusing, reducing re-cycling, re-using*
- *Promoting good indoor environmental air quality*
- *Using renewable/ non-toxic waste based sustainable materials*
- *Valuing environment, as integral part of design, construction and operation*
- *Ensuring quality of life for occupants*
- *Decarbonising built environment*

Designing for Green Buildings

While options for planning and designing green buildings will vary from region to region and within regions, depending upon prevailing climate, site conditions, cultures, available materials, construction practices, building typologies, environment, economic

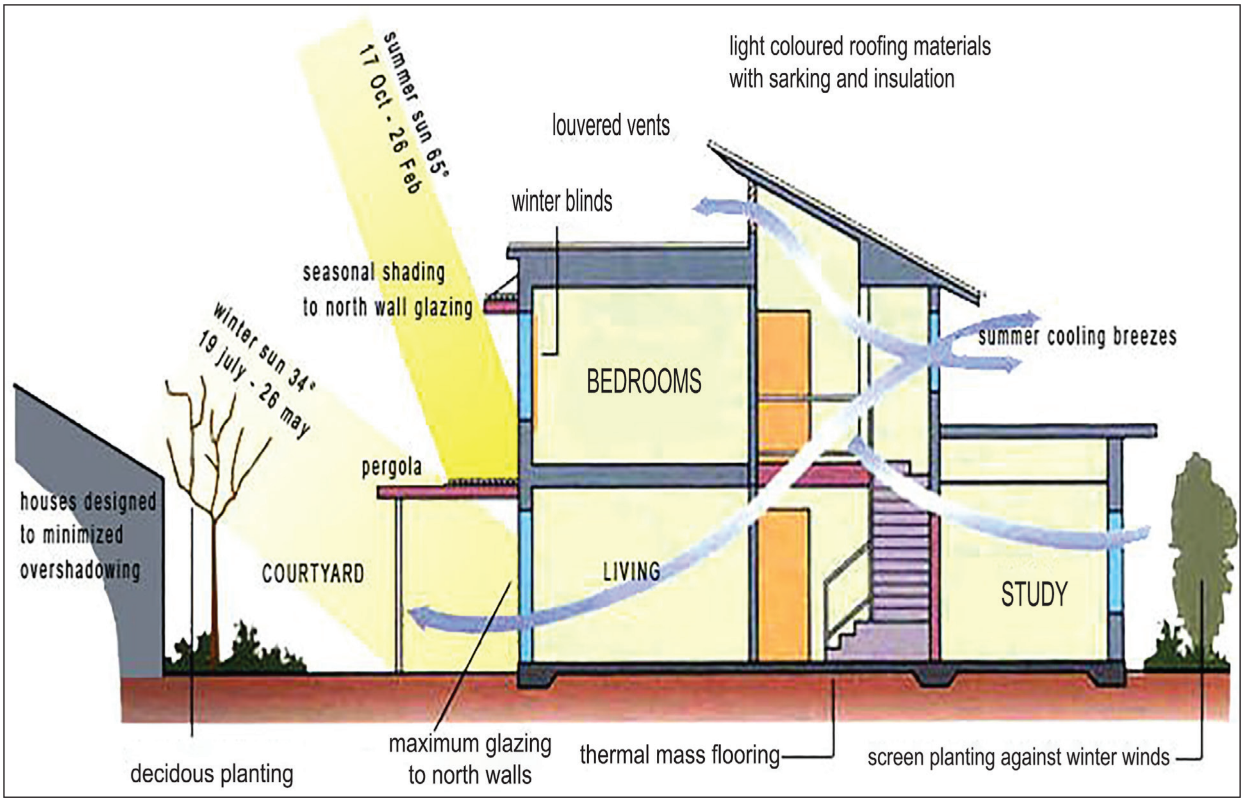

Fig 1: Built form with cross ventillation minimising use of Air-Conditioning

and social priorities the governing principles for making buildings green, remain universal. Buildings, like machines, are large consumers of resources/ energy, but a green building not only minimise/optimise use of resources/energy, but also ensures replacing the conventional non-renewable resources/energy with natural/renewable resources. Basic approach to green buildings invariably revolves around and involve; *designing with nature, making optimum use of natural resources* and *adopting integrated approach to design.* While *Planning with nature* would essentially involve, making optimum use of *Panchbhutas- Prithvi (site), Agni(energy), Jal (water), Vayu (air) and Aakash (Space), for meeting the basic needs of energy and resources for buildings, Integrated approach to building design* essentially revolves around, respecting site, rationalising site planning, rationalising built form; promoting building efficiency; making optimum use of sun and air for lighting, heating, ventilation; minimising waste; using local materials and optimising landscaping etc. Making buildings green, is never reckoned as individual professional responsibility but always considered as a group-based activity, involving professionals like; Architects, Engineers, Structural Engineers, Landscape Experts, Service Providers, Contractors etc. Accordingly, green building projects, shall involve, creating a dedicated team, right at inception, having knowledge, expertise, understanding, experience of designing green buildings in order to ensure that buildings is planned, designed and constructed in a holistic and integrated manner. Being a group based activity, creating such a team would not only help in making optimum use of available professional expertise, but will also go a long way in making building sustainable, cost-effective and resource- efficient in the entire life span.

Climate and Orientation

Climate and Orientation have always been valued as the key for optimising nature, natural resources of sun and air and minimising carbon implications of the building, and accordingly must form integral part of building design for making optimum use of the natural resources and evolving energy efficient building envelop. Since requirements of building design would vary in different climatic zones, accordingly buildings, with regard to climate, sun and wind, will have to be oriented differently and distinctly in different regions. In hot regions, the design options shall invariably involve minimising heat gain and promote heat loss, when excess heat is gained by the building. However in cold regions, the design option shall focus on capturing and retaining sun, so as to make optimum use of solar radiation. Accordingly, north-south shall remain the best orientation in hot regions whereas north shall invariably be avoided while designing buildings in the cold regions. However, architect, on his/ her part has to adopt a holistic approach to building design, so that building gels with nature and makes optimum use of given climate and orientation.

Site Planning

Fig 2: Principles governing site planning

Rational and innovative site planning has great bearing on decarbonising and making buildings green, sustainable and energy efficient. Appropriate site planning helps in determining the extent of building footprint, height/setback; built/open spaces; making optimum use of land; preserving/protecting existing flora & fauna available besides ensuring adequate natural day-lighting, air and ventilation within the buildings. However, for rational site planning, context of site would invariably require detailed study and in-depth analysis in terms of; location, orientation, wind direction, accessibility, size, shape, soil condition, topography, vegetation, natural features, hydrology, precipitation, infrastructure, existing physical characteristics etc. so as to make optimum use of the available natural resources and reduce energy component. Principles governing site planning shall involve; minimising footprints of buildings; maximising open spaces; minimising damage to site; designing with local culture and using hierarchy of preservation, conservation and regeneration in order to make built environment supportive of the environment and ecology.

Designing Building for Carbon Neutrality

Rational design of building envelope and objectively positioning of internal spaces remain critical for reducing the carbon implications and making buildings

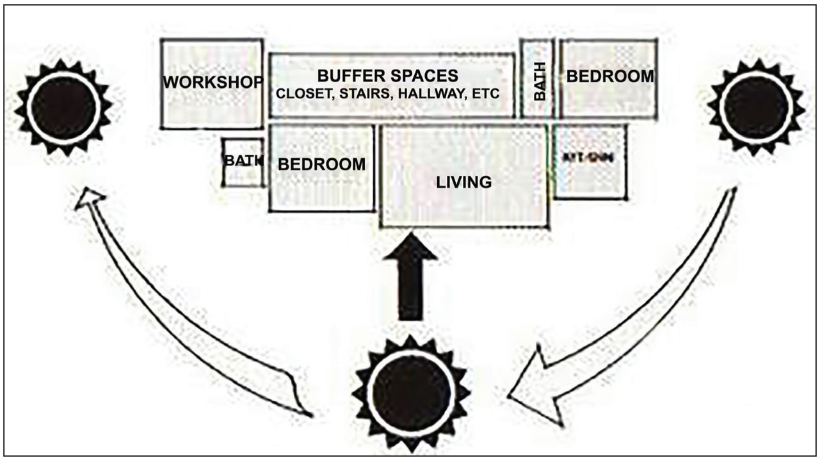

Fig 3: Design Approach for reducing carbon emission

carbon neutral. Accordingly, planning of building shall be based on making optimum use of site conditions, orientation, flora and fauna; minimising wall to area ratio; achieving high building efficiency; positioning all habitable rooms in the best orientation; optimising air and ventilation within and around buildings. Design approach should invariably revolve around making buildings climate responsive. In hot regions, buildings should be painted light to minimise heat gain besides using thick/hollow walls whereas in the case of cold climate, buildings should be painted with dark colours to absorb maximum heat. If typology of open buildings is to be used in hot regions, making buildings compact shall be followed in cold regions. Further, building envelope would also require careful designing and should be guided by; optimising solid-void relationship; careful positioning of openings, projections and shading devices; optimising room size/building height, natural lighting and ventilations; green walls and green roof etc. for decarbonising the buildings.

Promoting Energy Efficiency

Buildings are known to act like a machine, consuming large amount of conventional energy and resources. With technical advancement, buildings are fast emerging as major consumers of energy. Use of black/conventional energy on large scale, remains the root-cause of all building becoming prime source/generator of carbon footprints through its entire life-cycle. For promoting carbon neutrality/ decarbonisation, buildings will have to be planned, designed and constructed considering life time implications of energy. Lifecycle operation of building involves two types of energy – Embodied Energy (energy which goes into making of a building) and Operations & Maintenance Energy (energy consumed by building during its lifetime). Only17 % is embodied energy, whereas O&M operations involves rest of 83% energy. Accordingly, for making buildings energy efficient, both embodied and operational energy components will need reduction. Reducing embodied energy will essentially require; optimising various systems; reducing structural loads; using low-energy construction technologies; creating slim and resilient structures; using local/natural/low energy materials in natural form; using construction/ demolition waste. etc. Properly orienting buildings and adopting passive/ climate responsive design strategies; placing habitable rooms in best orientation; sourcing natural light, proper positioning/sizing of windows, avoiding glare, using minimal glass on east/ west, installing high R-value wall/ ceiling insulation; will go a long way in reducing operational energy demand of buildings. Using properly sized / energy-efficient and rated lighting/ heating/cooling systems in a thermally efficient building shell, will be pre-requisite for decarbonising buildings. In the past, strategy of building design has been focused on; ***making buildings energy efficient***, which now should be taken to the next level of ***zero energy buildings*** before achieving the ultimate objective of making buildings ***energy positive***. This would need dual strategy of; minimising energy consumption and making buildings net generator of on-site renewable energy from natural resources (sun, wind, bio-mass, geo-thermal). It would also involve daylight harvesting; promoting operational / maintenance efficiency through BMS (Building Management System); smart metering besides computer modelling (for optimising design of electrical/ mechanical systems and building shell), coupled with using advanced lighting controls; motion sensors / dimmable lighting controls etc for making buildings energy efficient and carbon neutral.

Terrace Garden

Within built environment, building envelope comprising of outer walls and roof of a building, accounts for about two-third (60%) of total heat gain and heat loss and is known to be a major determinant, dictating the sustainability besides operation and energy consumption pattern of the buildings. Accordingly, roofs and walls have to be planned, designed and constructed carefully and thoughtfully for insulating buildings against gaining/losing undue heat and cold for making buildings sustainable, energy efficient and zero carbon. Green roof, as one of the roof

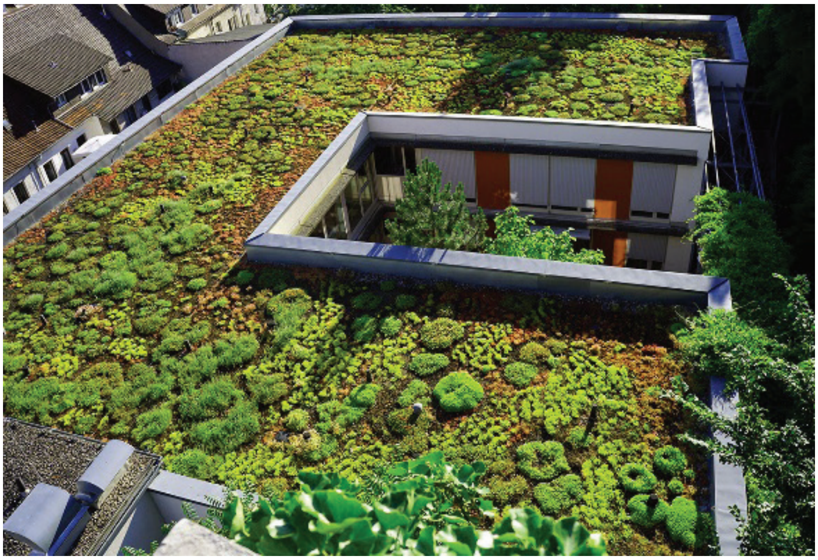

Fig 4: Green roof for reducing heat gain

typology, is fast emerging as a preferred option for promoting sustainability in the buildings. Green roof, is defined as a space on the roof comprising of collection of greenery, planted on top of a man-made structure. Green roof offers enormous social, physical, economic and environmental advantages to the individuals, owners, communities, city, nation and planet earth, in terms of; making buildings cost-effective, energy efficient; consuming limited energy and resources; bringing nature into buildings/ city; reducing urban heat island effect, reducing the intensity of storm water and saving cities from flooding; reducing global warming and lowering carbon footprint of the building/city; conserving rainwater water; meeting deficiency of green spaces in congested parts of cities; making optimum use of available unused roof space without increasing the building footprint; promoting economy; generating employment; promoting socialisation and security; making people happy, healthy and more productive; bringing birds back to the cities; growing vegetables and making cities self-sufficient in daily needs; eliminating transportation and refrigeration of vegetables; increasing value of properties; empowering cities to become zero-carbon. Despite limitations, promoting green roof should be made an integral part of any strategy for decarbonising buildings.

Using Green Materials & Innovative Construction Technologies

Buildings consume three billion tons of raw material annually, constituting 40 percent of total materials used globally (Roodman and Lenssen, 1995). Materials remain major contributor to carbon emission and determinant of embodied energy, cost, quality and maintenance of buildings besides posing serious environmental issues/ carbon emissions by extraction, transportation, processing, fabrication, installation and its disposal. Considering critical environmental and energy implications, choice of building materials should invariably revolve around materials; having minimum carbon footprint, involving minimum embodied energy; minimising maintenance/ replacement costs and creating healthy indoor environment. Accordingly, materials used in buildings should essentially be resource efficient; natural, renewable; energy/water efficient; environment responsive; affordable; recyclable and preferably made from industrial/ agro-waste. In addition, buildings should also, use state of the art, innovative and low-carbon construction technologies, which are cost- effective, speedier, material/energy/ water efficient, safe and generators of minimum waste and carbon emissions.

Conclusion

Buildings, provide space for human living and working and play an important and critical role in making human settlements productive, efficient, liveable and sustainable. No city can ever achieve sustainability, unless it is ably supported by qualitative and nature responsive passive-built environment, which is carbon neutral and generator of minimum waste besides consuming minimum energy and natural resources. Looking at the significant implications of buildings, in terms of energy and resource; planning, designing and constructing sustainable and energy-efficient buildings shall invariably remain critical and will hold the key to tackling climate change, minimising global warming and reducing carbon footprint. World Energy Outlook (IEA, 2019a), has reported that; cost-effective, energy efficiency and decarbonisation measures in buildings could annually save 6.5 Gigatons of CO_2 emissions by 2040. Besides providing healthier, resilient and productive environment, decarbonising buildings presents enormous business opportunity estimated to be approximately USD 24.7 trillion by 2030 (IFC, 2019). Decarbonising buildings also remain fully aligned with the SDGs, because such buildings not only reduce/eliminate negative impacts of building, but also promotes sustainability and increased bio-diversity. Such buildings are also known to offer numerous economic/ financial benefits in terms of; lower operational costs; increased occupancy rates; command 7% higher premium in value over traditional buildings; recording 101% increase in cognitive scores, curing insomnia sleeping 46 minutes more per night with 8% increased productivity.

Decarbonising buildings offer best option for achieving global SDGs; addressing climate change; creating sustainable/ thriving communities; driving economic growth ensuring environmental, economic and social benefits; minimising waste and maximising reuse; promoting health and wellbeing and creating win-win situation for owners, occupants, communities and nations. However, decarbonising buildings would require dedicated policy framework, besides greater collaboration among policy makers, urban planners, architects, developers, investors and construction companies. Considering massive urbanisation and growing needs of built environment, India must immediately put in place an effective/efficient policy framework to retrofit the existing buildings and make all new buildings *net-zero carbon* by 2050, on the pattern suggested by World Green Building Council, to achiever the goal of "*Sustainable India*".

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TRANSFORMING URBAN PLANNING APROPOS OF COP 28

A. K. Jain

A significant outcome of the COP 28 (Dubai, 2023) has been to place the cities at the centre-stage of climate resilience at local level. The deliberations ranged from adaptation and mitigation, low carbon fuels and zero emission industries, equitable development, jobs, renewables and energy efficiency, circularity in construction and resource management, whole government approach, behaviour change and climate finance. These call for a radical transition in habitat planning and its engagement with dynamic tools, simulation, digital twins, GIS, remote sensing and common digital platforms integrating planning regulations and management.

Introduction

The 28th Conference of the Parties (COP28) conducted by the United Nations Framework for Climate Change Convention (UNFCCC) was held from 30 November to 12 December 2023 in Dubai. The conference concluded the global stocktake of climate action under the Paris Agreement and agreed to accelerate short-term climate actions. Other significant achievement have been the operationalisation of the Loss and Damage Fund ($ 700 million against the estimated requirement of $194 to 366 billion per year), Nationally Determined Contributions (NDC) and adoption of a framework for the Global Goal on Adaptation (GGA) to strengthen collective action in building climate resilience.

The deliberations focused on global climate action and sustainability challenges in achieving net-zero climate goal in the urban sector, building and construction industry. Within the overarching Government of India's roadmap towards achieving net zero emissions by 2070, 50% of energy from the renewables by 2030, and reducing emissions by 45%, India is moving towards a developed economy of $36 trillion by the year 2047. It underlined the measures for sustainable resilient habitat and inclusivity by adoption of new policies, reforms and the launch of new Coalition of High Ambition Muti-level Partnerships (CHAMPs) to advance the discourse on sustainable,

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green transportation, energy efficient cities and decarbonising construction and building practices. For cascading the global vision and deliberations at COP28, at the local level it is necessary to contextualise the challenges in terms of urban policies, strategies, plans, programmes and climate actions.

The Urban Challenges

In India, 7935 cities and towns accommodate 377 million people,i.e. 31.16 % of total population (Census 2011).475 Class I cities constitute 42.63 per cent of the total urban population. 3 mega-cities, viz. Greater Mumbai, Delhi and Kolkata have crossed the 10 million population mark, while five cities, viz. Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune have more than 5 million population. From 432 million urban population in 2021, it is projected that by the year 2047, 820 million people will live in India (Table 1).

In 2047, India with a sixth of world's population will be the most populous country. It will have the world's largest workforce and the third largest economy. The ongoing process of urbanisation is vital for economic growth by 2047, 75% of GDP and new jobs will be created in cities. At the same time, it must be sustainable, resilient, inclusive and green. This

Table 1: India's Urban Trajectory

Year	2011	2047
Population	1210 million	1640 million
Urban Population	377 million (31.16%)	820 million
Cities and Towns	7935	-
Million + Cities	53	=

Sources: Census of India, 2011 and the UN

poses a huge challenge that needs transformational policies of urban planning and development.

Towards an Eco-City

It involves an integrated approach of combining **Goal 11 of the SDGs on making cities and communities inclusive, safe, resilient and sustainable**, Goal 13 for combating climate change and its impacts, while also addressing the issues of economic development, environmental sustainability, cultural and social conservation and a focus on the rights of the poor, informal sector, women and vulnerable communities. It requires a shift from linear unsustainable system of a mega city to a circular, sustainable eco-city (Fig 1).

The cornerstone of making a circular, sustainable eco-city is to adopt an integrated

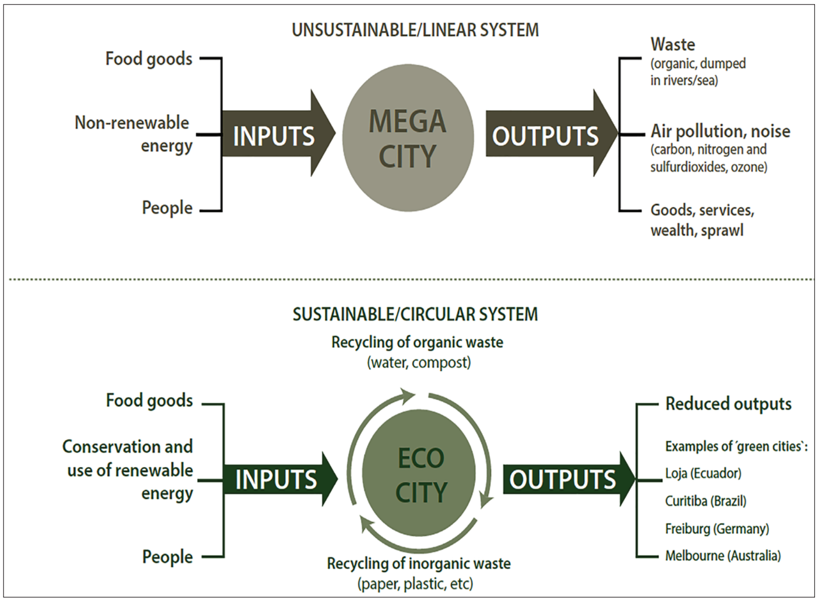

Fig.1: City as a System

Source: UNESCO & MGIEP (2017) Textbooks for Sustainable Development, A Guide to Embedding,UNESCO and Mahatma Gandhi Institute of Education, Peace and Sustainability, New Delhi

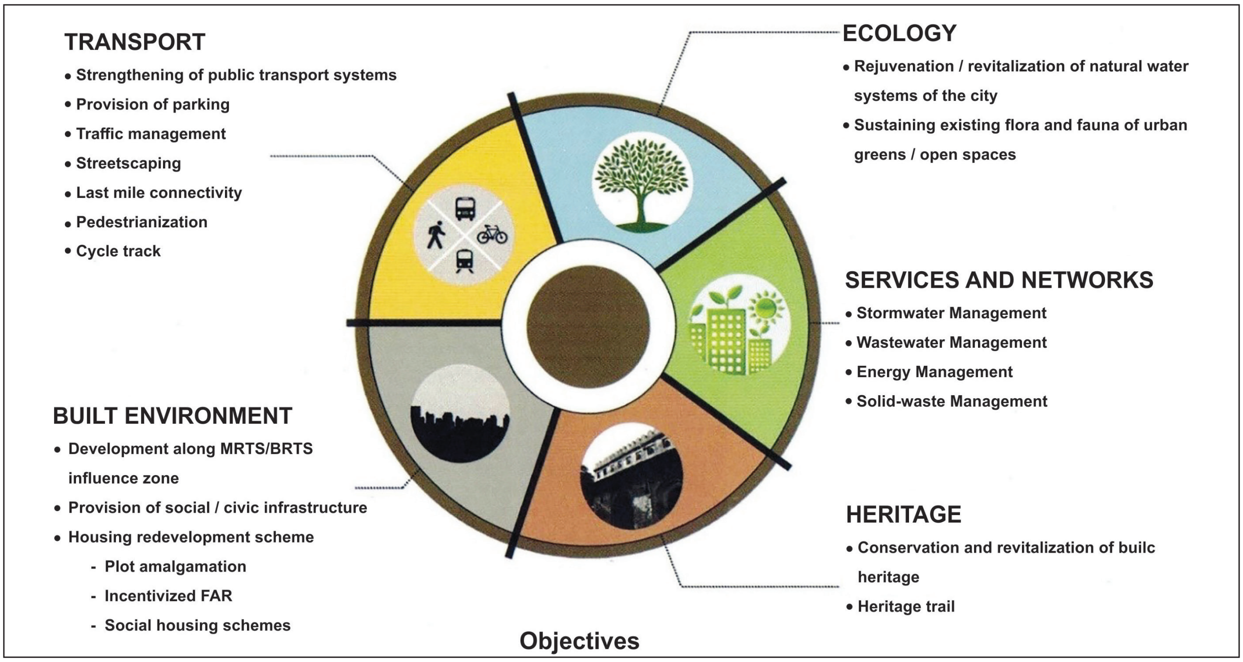

Fig. 2: The cornerstone of a climate resilient and green habitat is by Integrating of the Ecology, Services and Networks, Transport, Built Environment and Heritage

Source: DUAC/Amit Ghoshal (2015) Punjabi Bagh Project, DUAC, New Delhi

approach towards ecology, transport, built environment, services networks and the conservation of the heritage and natural resources – greenery, water supply, air, sewerage, solid waste management, and energy (Fig. 2).

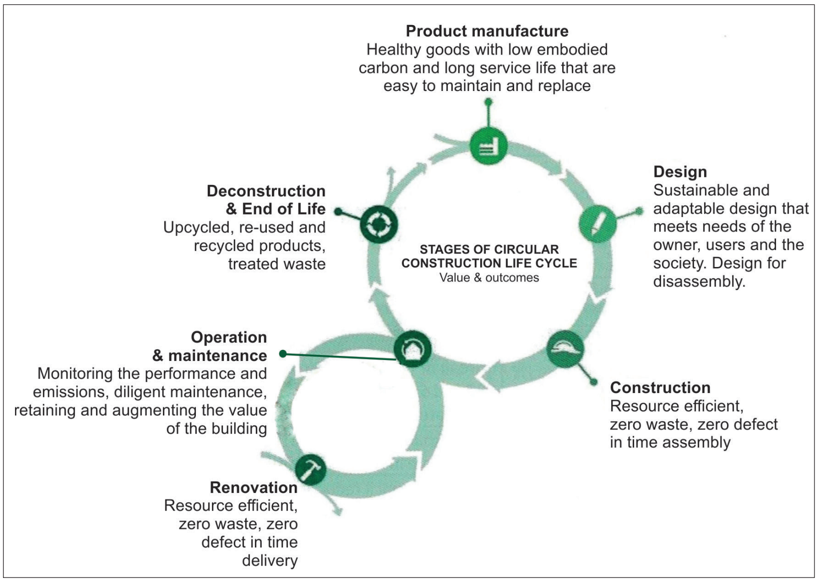

Fig. 3: Circular Construction Life Cycle- Values and Outcomes

Source: Ninni Westerholm (2021) Developed from UNEP

Carbon neutral buildings, energy and transport minimising the use of fossil fuels and by lifecycle approach make the built environment sustainable and energy efficient. The use of (Fig. 3). Trigeneration energy systems, sponge parks and pavements that absorb rainwater, dual piping for recycled wastewater, water saving toilets and taps, and satellite controlled micro-irrigation can cut down water and power consumption significantly.

Strategy of 5 Rs of waste management (Fig. 4), three bin recycling with separate bins for trash, recyclables and compost, enzyme based STP, bio-remedial treatment,

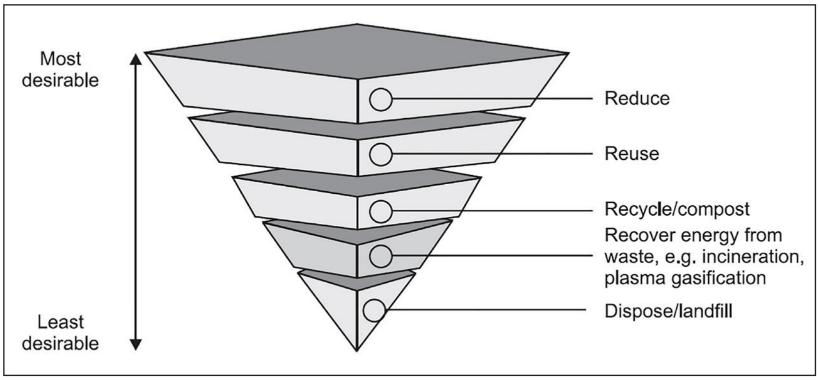

Fig. 4: Strategy of 5 Rs for Waste Management

Source: Ottawa.ca/ Jain A.K. (2018) A Hybrid and Smart Approach Towards Cleaner Cities, Shelter, October

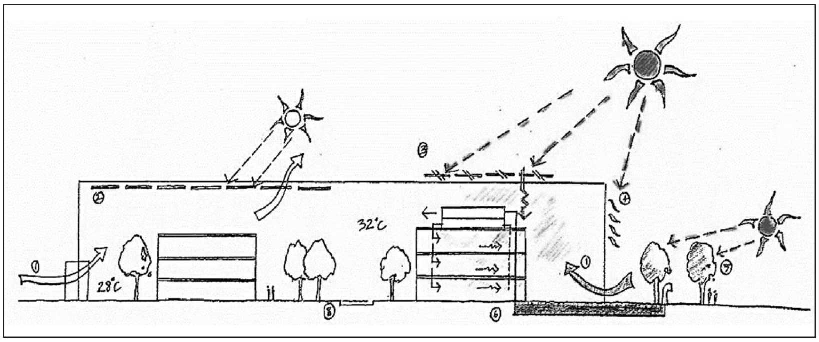

Fig. 5: Design of Research Centre in Wageningen, Netherlands (Behmisch, Behmisch& Partners) features the Sun, Photovoltaic, Courtyard, Skylightand Atrium for Energy Efficiency

Source: Muller Dominique (2004) Sustainable Architecture and Urbanism, Birkhauser, Basel

sludge gas/energy recovery, vermi-culture, fossilisation and composting options are elements of sustainable waste treatment.

Swales, porous paving, bio-drainage and storm surge gates in river, drains and canals and zero run off drainage, conserve water and save human settlements from floods. Passive climate design and rooftop solar panels generate electricity instead of power plants and reduce city's heat build-up (Fig. 5). Rooftop vegetation, ventilation, insulation and super-insulated glazing can ensure the building's thermal performance (Fig. 6).

Smart glass technology and district cooling system with cool air draughts in subterranean clay pipes, save on air-conditioning

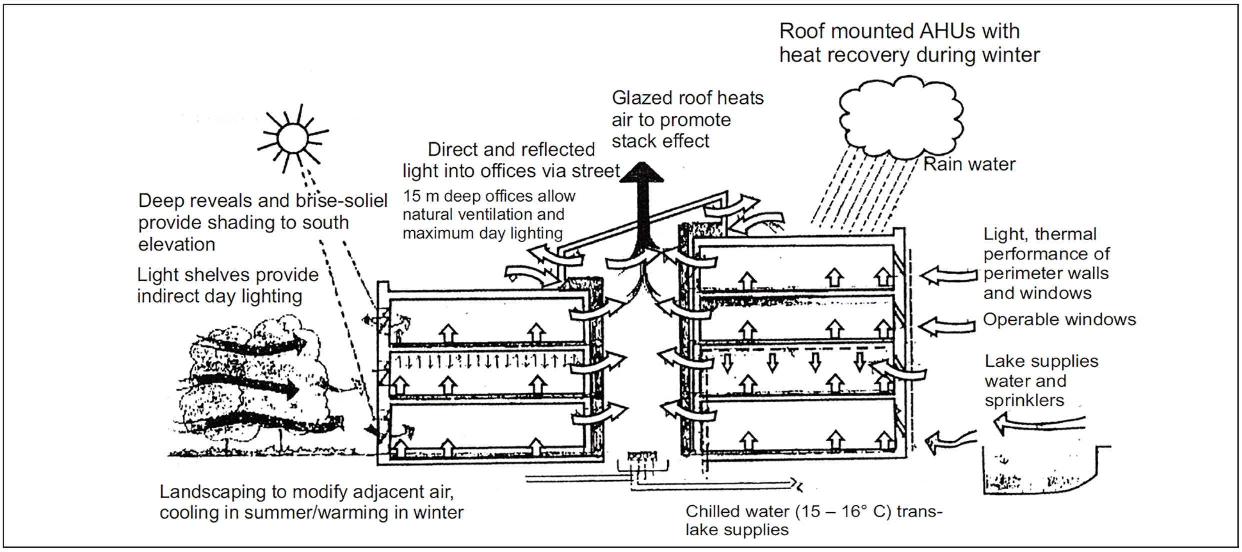

Fig. 6: A Concept of Low Energy Building Design

Source: Jain A.K. (2021) Environment, Urbanisation and Development, Discovery Publishing House, New Delhi

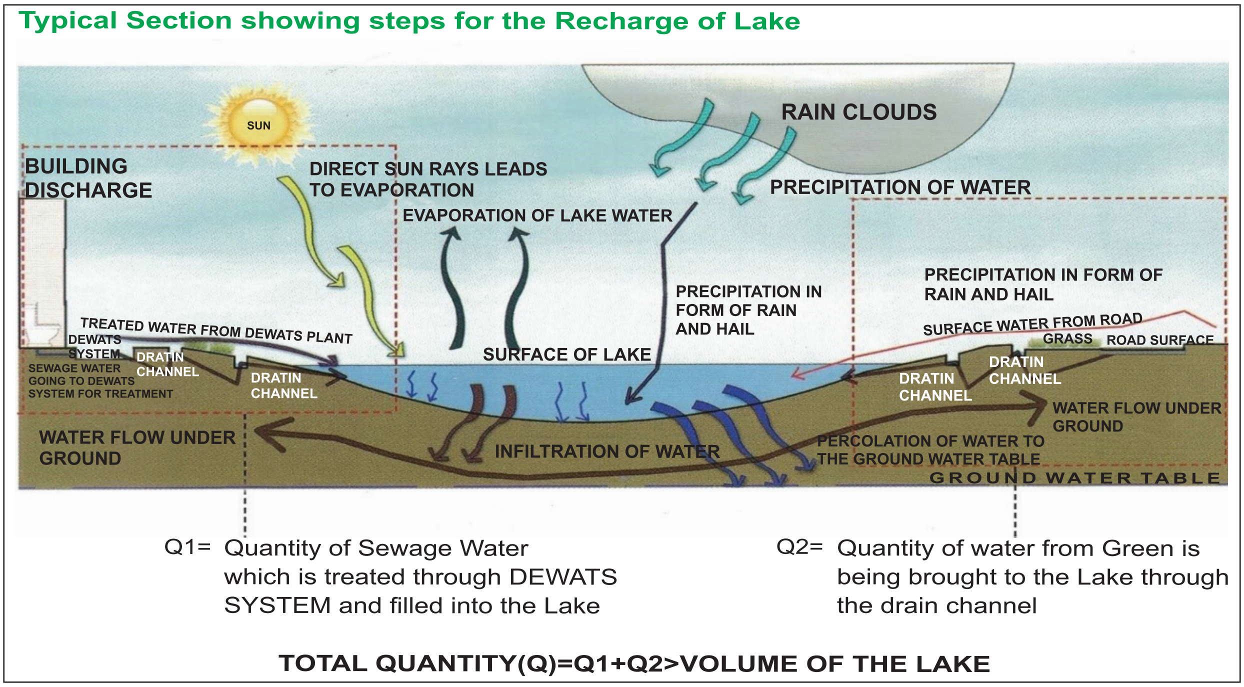

Fig. 7: DEWATS, Stormwater Harvesting and Conservation of Water Bodies
Source: DUAC/Rahoul B Singh (2014) Hari Nagar Greens, DUAC, New Delhi

and energy. These help in reducing the ecological footprint, formation of heat islands and pollution. Energy Conservation Building Code (2017) provides useful mandate for energy efficient building design.

Circular water management focuses on principles of Reduce, Reuse, Recycle, Restore and Recover. Decentralised Wastewater Treatment Systems (DEWATS), Bioswales and revival of water bodies are important tools for sustainable water and drainage management (Figs. 7 & 8).

The LiFE or Lifestyle for the Environment Mission (2022) aims at low carbon lifestyle embedded in social behaviour that minimise the use of natural resources, and emission of waste and pollution. Creating sustainable lifestyle requires a change in social norms and the way of living based on the principles of organicity, non-accumulation (*aparigraha*), minimalism

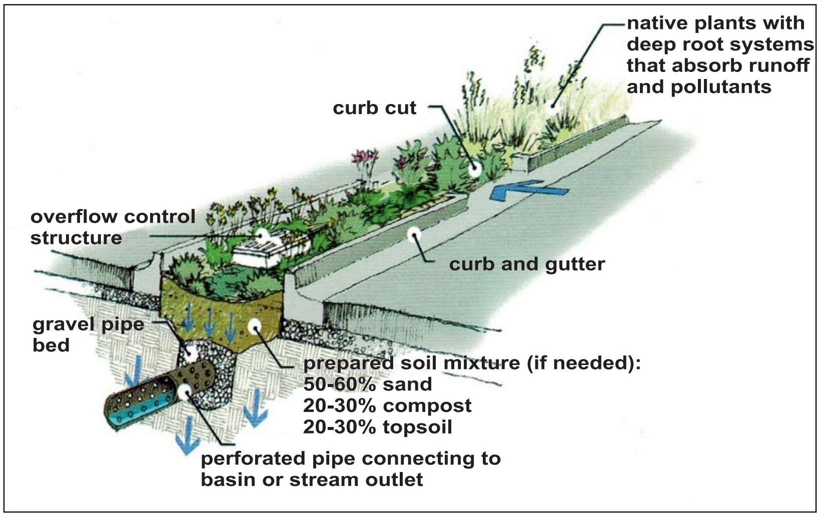

Fig.8: A Bioswale for Sustainable Urban Drainage
Source: http://thewhiteriveralliance.org/eaglecreek//involved/images/bioswale%20enlargement.jpg

and slowing down. It is about caring, sharing, recycling, reuse, repairing and retrofitting for a balanced natural environment. This means adoption of circular economy and systems, which are restorative, regenerative and minimise waste (Fig. 9).

India's Urban and Housing Missions

The Government of India in 2014-15 launched several urban missions, viz. Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Pradhan Mantri Awas Yojana, Heritage City Development and Augmentation Yojana (HRIDAY) and Swachh Bharat Mission (SBM). The Smart Cities Mission envisages development of 100 smart cities which are infused with intelligence, integrity and inclusion with state of the art infrastructure services, transport and housing for all. The PMAY(U) till September 2023 has been able to build and deliver more than 10.3 million houses, while 12.03 million have been sanctioned.

The Atal Mission of Rejuvenation and Urban Transformation (AMRUT) has covered more than 5,800 projects related to water, green space and mobility. The Swachh Bharat Mission (Urban) (SBMU) tackles urban sanitation and waste management, having provided a record

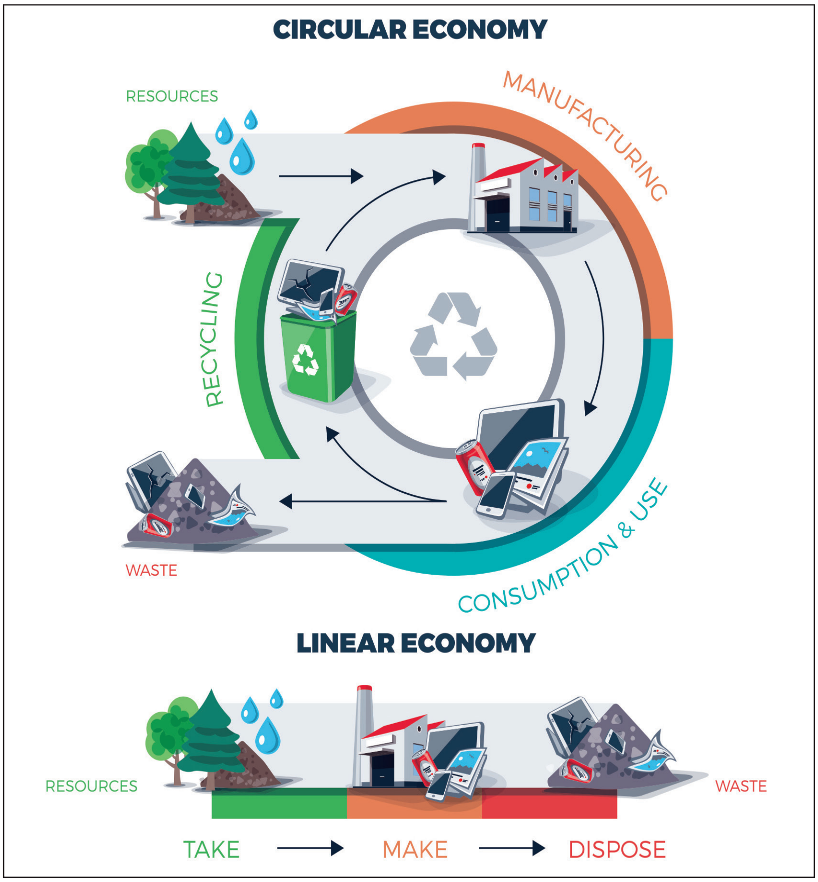

Fig. 9: Circular Economy is Restorative, Regenerative and aims at minimising wastes and making the most of resources

Source: Khan, Khalil Uttah (2022) Wastewater Reuse, Linear Economy to Circular Economy, Shashwat, TERI, New Delhi

9 million toilets. The plans under these missions are based on digital planning via computing processes with net zero energy, water and waste together with circular systems.

In Indian cities more than half of its housing and buildings are unauthorised, dilapidated and falls under the slum category. A major area of focus is informal settlements and promoting inclusive cities. These need to adopt the following measures:

a. Community led mapping and enumeration of slum households

b. Establishing service level benchmarks for assessment of their upgradation needs

c. Forging partnership among the communities for their participation in the decision making and urban planning

d. Granting them occupancy and land rights

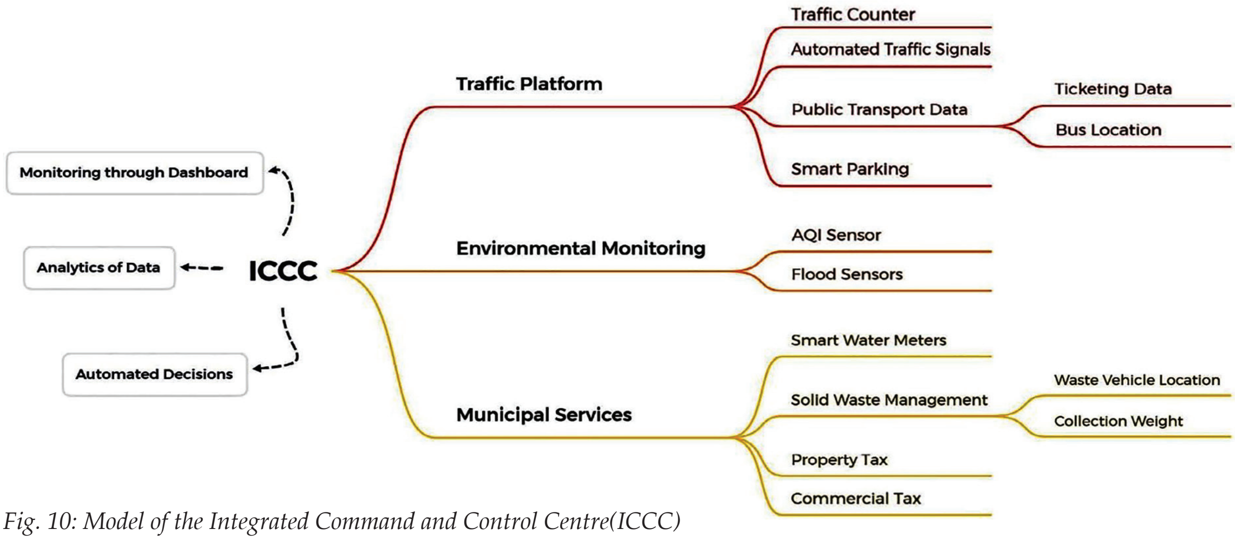

Fig. 10: Model of the Integrated Command and Control Centre(ICCC)

Source: Parkar, Khaliq and Uttara Purandare (2023) Decoding Disitization of Urban Governance in India, Centre for Policy Research, New Delhi

e. Improving urban basic services, public transport, and social facilities

f. Facilitating the informal families access to finances and institutional home loans.

Integrated Command and Control Centre

The Integrated Command and Control Centre (ICCC) is one of the key projects of the cities under the Smart Cities Mission (Fig. 10). The ICCC coordinates multiple municipal functions, disaster management /resilience, traffic and transportation, environmental monitoring, weather, and emergencies.

The PM Gati Shakti Master Plan, launched in 2021, provides valuable lessons for planning of sustainable infrastructure for seamless movement of people, goods and services. It leverages new technologies, breaking the silos of departmentalisation to achieve ease of doing business. PM Gati Shakti is based on the six core

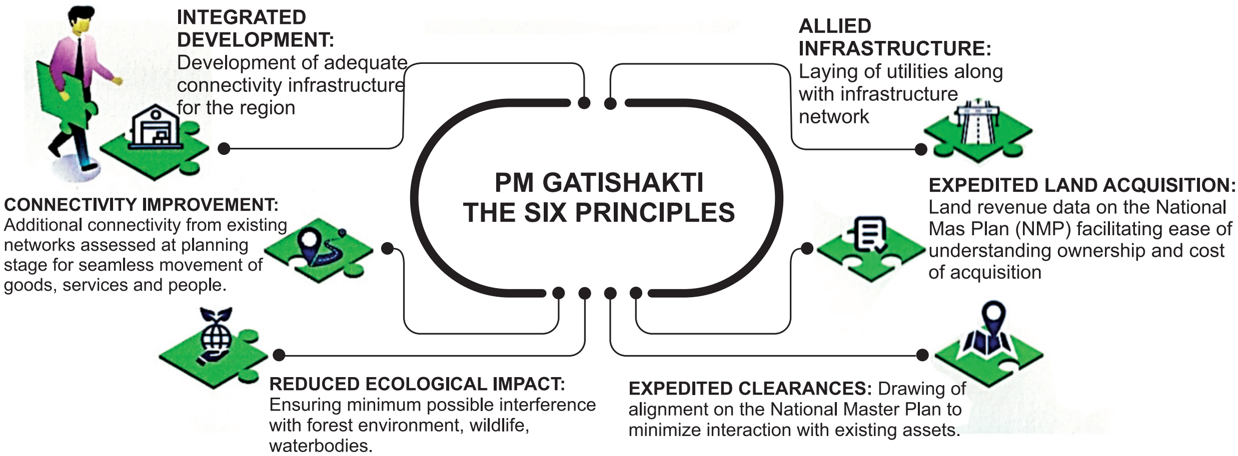

Fig. 11: The six principles of PM Gati Shakti Master Plan

Source: Ministry of Commerce and Industry, GOI 2023

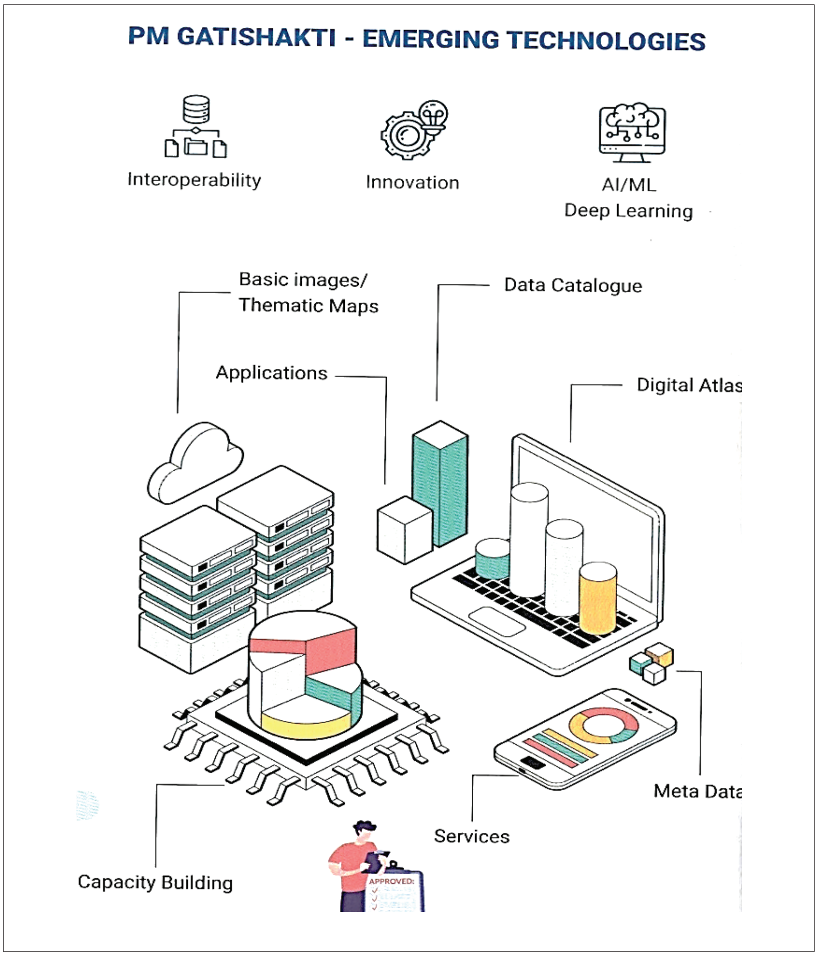

Fig. 12: Emerging Technologies for PM Gati Shakti Master Plan
Source: Ministry of Commerce and Industry, GOI 2023

principles, incorporating infrastructure such as laying utilities during the planning phase, enhancing connectivity to help seamless movement, ensuring ecological focus on conservation of forest, biodiversity, rivers, etc., and faster land acquisition and expeditious clearances (Figs. 11&12).

The outcome is made possible by focussing on each aspect of a project in granularity on one platform, with visibility across stakeholders. This also helps drive faster prioritisation and easier synchronisation to avoid delays. The detailed analysis from the data layer and the tools ensures better optimisation of project and quick interventions for closure. The Gati Shakti Master Plan has coordinated with the Indian Space Research organisation (ISRO) for spatial planning, engaging BISAG (Bhaskaracharya National Institute for Space Applications and Geo Informatics). This GIS platform builds over 1200 data layers from Central Government Departments and 755 from the States/ Union Territories. Multi-modal integration, last mile connectivity and e-governance are the pillars of PM Gati Shakti Master Plan. All the modes of goods and passenger transport are digitised and pooled and

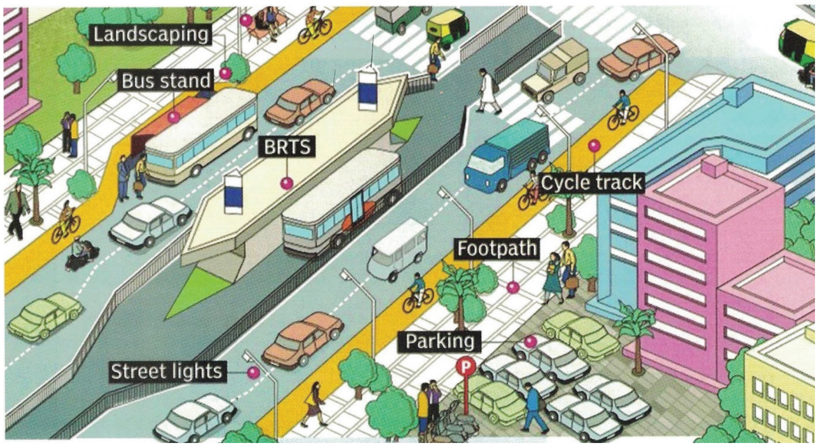

Fig. 13: Road Design with Dedicated Cycle, BRT Tracks and Footpaths
Source: DUAC/Amit Ghoshal (2015), Punjabi Bagh Project, DUAC, New Delhi

adopt Intelligent Transport Systems and transit-oriented development. This involves road design with dedicated tracks for cycles, pedestrians and public transport (Fig. 13). The highways, roads and railways should provide for safe crossing of pedestrians, prams, wheelchairs and animals (Fig 14).

The Government platform enables easier collaborations across departments, dramatically simplifying the planning process while ensuring the design that is mindful of economic and social aspects. Area Development Approach has been conceptualised to create convergence of adequate infrastructure catalysing socio-economic development in a sustainable development within a geographical location. Major areas of planning include Integrated Command and Control Centre (ICCC), physical infrastructure, like energy, water supply, sewerage/sanitation, drainage, waste recycling, roads, parking, economic/work spaces and social amenities such as education and hospitals, parks, art and cultural spaces, tourism, etc. together with reformed institutional governance systems at State/District/local levels.

National Monetisation Pipeline has a budget of Rs 6 lakh crore during 2022-25, of which the share of the Railways is Rs. 1.52 lakh crore. Railways Infrastructure Investment Trust (InvITs) is being anchored by the Dedicated Freight Corridor Corporation (DFCC) for redevelopment of railway stations, warehousing, commercial and entertainment hubs. In the budget (2023-24) 1275 railway stations are being redeveloped through EPC contracts. The funds have also been allocated for Rapid Train Projects, Railway Bridges, High-Speed Railway Corridors, Dedicated Freight Corridors (3581 km), Hydrogen Powered Trains, Gati Shakti Units and Transit Oriented Development.

The investments go hand in hand with innovations, viz. digitisation of railway supply chain, artificial intelligence, biometric token system, contactless travel, driverless train operations, head on generation system, LIDAR technology, online monitoring of rolling stock, cyber security and Kavach safety technology.

The Smart Cities Mission, Gati Shakti Master Plan and the National Monetisation Pipeline are for a horizon of 5 years replacing the 20-year colonial model of Master Planning. The circular economy is the basis of these missions.

Fig. 14: Highway/Roads/Railway Lines must provide Safe Crossing for pedestrians, wheelchairs, prams and animals

Financing

The McKinsey report estimates that nearly 45% of the urban financial requirements can be met through various land and asset monetisation strategies, such as development charges, impact fees, building fees, land use conversion charges and sale of Floor Area Ratio (F.A.R) or air rights. The City and Industrial Development Corporation of Maharashtra (CIDCO) has developed commercial office space above suburban railway stations in Navi Mumbai. The Rail Land Development Authority (RLDA) has redeveloped Gandhi Nagar Railway Station with a five-star hotel.

To encourage optimum use of land and densification by higher FAR, through two-tier FAR structure can be adopted with a basic FAR bundled with property right and the remaining to be purchased to enable value capture. This has been used to subsidise in-situ slum rehabilitation, project whereby 40% of land/FAR for market sale can finance the whole project, e.g. Kathputli Slum Rehabilitation Project in Delhi.

Impact fees are levied on new constructions in an area where large public investments such as major roads and highways, metro rail, industrial corridors, ports, airports, and other public infrastructure are undertaken. An example of impact fee is new developments within the 1 km wide Growth Corridor (GC) on the 162 km Outer Ring Road (ORR) around Hyderabad. The impact fees are higher for commercial use, and increases with the FAR. However, there has been a wide resources gap between the estimated and actual recovery.

Engagement with Industry 4.0 Standards

During last decade, new age technology has changed the script of urban planning and management. As demonstrated by Smart Cities Mission and PM Gati Shakti Master Plan, the new technology is vital for delivery with speed, scale and skills. The ICT (Information and Communication Technology), Artificial Intelligence, Big Data Analytics, Machine Learning, Deep Learning, blockchain, GIS, GPS, etc. are disrupting the urban processes by intelligent and smart planning, infrastructure and services, transport systems, land management and enforcement. Digital India, National Digital Urban Platform and Urban Platform for Delivery Online Governance (UPYOG) are leading to digital of municipal services with speed and without red tape.

According to NASSCOM-McKinsey Report 'Sustainability Opportunity for Tech Services and Solutions' (2022) digital technologies such as Cloud, IOT, Blockchain and AI (Artificial Intelligence) can be critical in evolving sustainability solutions, energy management, real estate and buildings which end up benefitting bottom lines and accelerating deliveries. It is estimated that during the next 25 years, the number of buildings in India will multiply six times. These have to be net zero and energy efficient. This involves upgrading the power monitoring system, unlocking renewables, smart waste management/recycling with easy to digest dashboards. There is a need to provide real time measurement of power load at the circuit and building level to make it net zero and climate resilient.

Under the Geospatial Policy 2022, 3D Digital Twins allow collating and creating content in partnership with ESRI India. It provides a technology platform for 3D modelling and virtual representation of an object or a system that uses sensors, drones, 5G Internet of Things (IoT) and industrial IoT (IIot) data. It applies advanced analytics, machine learning and Artificial Intelligence (AI) to derive real time insight into the performance, operation and sustainability of a project or a city. These cover buildings, energy, low carbon zones and tri-generation energy systems (combining power, cooling and heating).

Artificial Intelligence (AI) and Machine Learning (MI) is planned to be integrated with GIS to enable recognition and labelling of objects, extraction of features, route optimisation, etc. Integration with Natural Language Processing (NLP) enables users to interact with GIS.

The use of technologies, such as digital blockchain, combinatorial and discrete optimisation, algorithms, complexity theory, artificial intelligence, big data, ubiquitous cloud and hash algorithm enable planning and integration of services (Fig. 15) can revolutionise planing & designing in a way which has till now been thought as impossible.

The Ministry of Housing and Urban Affairs (MoHUA) and National Institute of Urban Affairs (NIUA), along with the Bureau of Indian Standards (BIS) have developed 15 Smart City Standards. These focus on the use of new technological systems, such as GIS, sensors and networks. The Unified Digital Infrastructure – ICT Reference Architecture Standards (IS 18000:2020) is a comprehensive document for digitalization of urban practice. It defines the "Unified Digital Infrastructure" as the sensors, data systems, IoT systems and platforms. Smart Cities – GIS (IS 18008: 2020) standards define key formats for GIS platforms; and Unified Data Exchange Standards lay out the architecture for instituting data exchanges or marketplaces.

The Niti Ayog has built National Data Analytical Platform which provides data sets in machine readable formats. This can be used for planning and policy making such as Aspirational District Programme. The Ministry of Housing and Urban Affairs (MoHUA) in February 2021 launched the National Urban Digital Mission (NUDM), which aims to push for the outcome-based digitalisation of urban planning and governance. The Data Acquisition and Exchange Programme enables data to be exchanged, analysed and marketed on various portal along with National Urban Learning Platform, Smart Code, National Urban Governance Platform and National Urban Development Mission.

The breakthrough in digital technology and informatics has multiplied space, energy and time. It is time that new forms of energy, services, construction and recycling

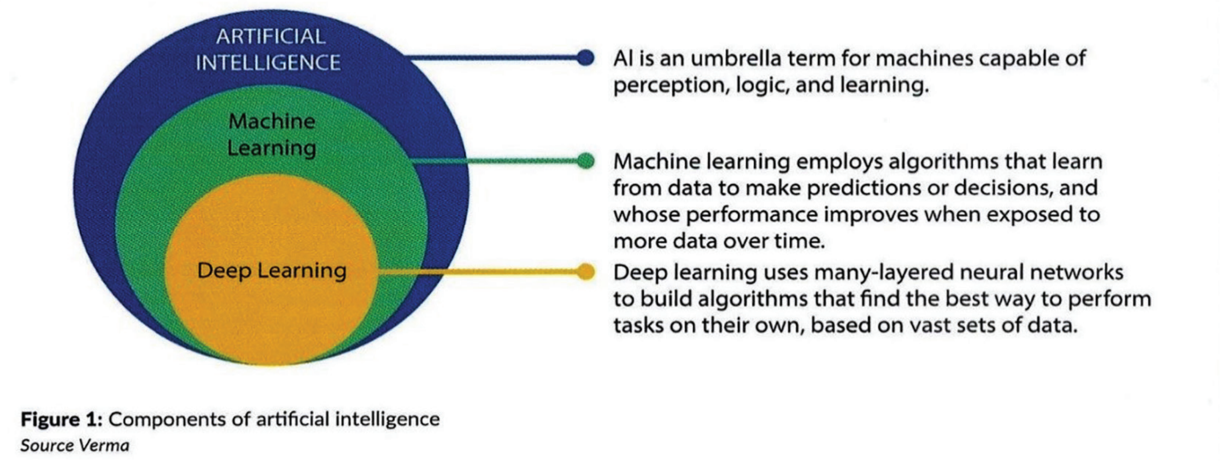

Fig. 15: Components of Artificial Intelligence

Source: Verma, Seema, Towards Data Science, Shashwat (2022) TERI, New Delhi are evolved, which are characterized by online exchange of information, interactions, dynamic networks and floating nodes. Global positioning systems and satellite-guided GPS devices are increasingly being used for urban surveys, planning and laying of services. By data analytics, it is possible to plan and implement the projects with precision and accuracy. Integration of land use, utilities, transport and building on a common network helps optimise space efficiency and energy use. By developing sector–focused, cluster–based intelligent city strategies, territories can set in motion innovation mechanisms and enhance sustainability of their services and systems.

An intelligent geo-portal can bring together various line departments on a platform for e-service delivery. This yields better co-ordination and exchange of information, cost and time management. Citizen engagement becomes much easier and viable by virtual town halls.

Smart chips and systems can be embedded almost in every urban service and structure, making them smart and intelligent. The "smart nodes on a smart grid" concept can be used to provide services to enhance users experience, such as high-speed communication and data management, carbon-emission accounting and performance objectives. This implies integration of green concepts with new technology for resilient and low carbon infrastructure services and transport. It can also help in the integration of citizen participation, governance and online consultation over plans and programmes of local development.

Blockchains is emerging as a new age technology for urban development and management, real estate, title transfer, etc. A digital ledger is a geographically distributed database that is shared and synchronized across a network of participants. In a blockchain structure the data is stored in blocks, linked and secured by cryptography for handling identities, contracts and assets. It is based on a hash algorithm that converts data into a block. Digital distributed ledger technology can simplify the complex and open to manipulation paperwork involved in property records.

Unified Development Control and Building Regulations

With the passage of time development control regulations and building byelaws have become too complex together with several regulatory authorities controlling the following:

- FAR- Ground Coverage-Height- Setbacks, Transferable Development Rights (TDR), Accommodation Reservation stipulations
- Form Based Codes
- LOP/Layout Plan/Sub-Division/ Land Pooling Regulations
- Regulations for Unauthorised Colonies, Special Area, Redevelopment
- Transit Oriented Development, Traffic and Transport/Parking Regulations
- Mixed Use Regulations
- Amenities and Infra Services Regulations
- EIA Regulations/ Green Building Regulations
- ECBC 2017
- Heritage Regulations
- Heat Mitigation, Climate and Disaster Resilience Regulations
- Building Byelaws

All these need to be put on a common digital platform-integrating diverse planning regulations and management.

Conclusions

India's proactive role in the 28th

Conference of Parties (COP 28) needs to be complemented by reimagining the urban sector, which is sustainable and low carbon. With India on a rapid trajectory of economic growth and urbanisation, a major challenge is to visualise planning which synchronises with the aspirations of the next generation of a developed country. This calls for transforming the processes of urban planning and development for an inclusive, resilient, green and circular path invoking new technologies.

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Public-Private-Philanthropic Partnerships (PPPP) are central to Asia-Pacific's climate action

Globally, the United Nations has issued a call to urgently unlock and redirect trillions of dollars in financing to address the imperative for climate-resilient development. The first Global Stocktake (GST) at COP28 estimated that $5.9 trillion in climate financing is needed by 2050. Given the magnitude of this funding requirement, it must be sourced from a variety of channels, with philanthropy being one of them.

Climate change presents a global, multifaceted challenge that requires collective action. Individual efforts are insufficient to tackle the immense and diverse challenges posed by climate change. Hence, the concept of Public-Private-Philanthropic Partnerships (PPPPs) has emerged. PPPPs, characterized by their multi-stakeholder nature and comprehensive approach, can help address some of the deficiencies in current efforts by fostering broader capacity, knowledge sharing, and the development of best practices and cultivate a 'green talent pipeline.' PPPPs are built on collective action and typically engage local voices and NGOs, which brings much-needed on-the-ground knowledge and viewpoints to a project, ensuring that the initiative meets specific local needs. This also helps to develop the capacity of the at-risk communities, providing them with skills, tools, and knowledge to pursue the systemic changes that are often at the heart of the solution.

At the 2024 World Economic Forum Annual Meeting, the Philanthropy Asia Alliance (PAA) convened the 'Partnering with the Impact Generation to Scale Climate Action in Asia' session and collaborate with Giving to Amplify Earth Action (GAEA) initiative to institute the GAEA Davos Awards. These awards aim to recognize successful PPPPs driving systemic change in the climate and nature sectors.

INDIA'S TRANSITION TO ENERGY-EFFICIENT CITIES: A MULTIFACETED PERSPECTIVE

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The paper aims to analyse the pivotal role energy-efficient cities will play in India's future urban economy. It delves into the essential components of sustainable urban development, scrutinises the encountered challenges and opportunities, and presents exemplary case studies nationwide. Emphasising the significance of energy-efficient cities in curbing energy consumption and greenhouse gas emissions, it underscores the importance of technological advancements and innovative approaches to enhance urban energy efficiency. This includes integrating renewable energies, intelligent grids, the Internet of Things (IoT), and construction automation systems to change the future urban landscape. Additionally, it evaluates the impact of government policies, public-private partnerships, and community engagement in advancing this transformative agenda. Lastly, it addresses the obstacles hindering the scalability of energy efficiency initiatives in India, such as lack of awareness, high initial costs, policy barriers, and technical proficiency.

Key Words: *Energy-efficient cities, Sustainable urban development, Technological solutions, Government policies.*

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Introduction

In the wake of rapid urbanisation and escalating energy demands, sustainable development has become a major objective for countries across the world, especially India As the second most populous country on the globe and a swiftly urbanising landscape, India faces a critical juncture in shaping its urban future towards one that is environmentally resilient, socially inclusive, and economically vibrant. The key to this transformational journey is the concept of an energy-efficient city, in which sustainability principles are correlated with urban planning, infrastructure development, and policy implementation.

Sustainable development, as defined by the United Nations, entails meeting the needs of the present without compromising the ability of future generations to meet their own needs[1]. In the Indian context, this necessitates a shift towards urban development that not only addresses the pressing challenges of urbanisation but also prioritises environmental conservation, social equity, and economic prosperity. Energy efficiency is an integral part, if not the key, of green and sustainable buildings[2]. Energy-efficient cities are key components of sustainable urban development[3].

The imperative for energy-efficient cities in India stems from the intertwined crises of climate change, resource depletion, and urban sprawl. Urban areas account for more than 60 percent of global energy consumption and about 70 percent of greenhouse gas emissions [4], the need for sustainable urban development strategies becomes increasingly apparent. In India, rapid urbanisation has led to soaring energy demands, exacerbating environmental degradation and straining existing infrastructure [5]. As such, the transition to energy-efficient cities emerges not only as a response to environmental imperatives but also as a strategic imperative for ensuring long-term resilience and competitiveness in the global arena.

We explore the key elements of sustainable urban development, examine the challenges and opportunities faced along the way and present examples of case studies from all over the country. Furthermore, we analyse the role of government policy, public-private partnerships, and community participation in the achievement of this transformational agenda. Through a comprehensive lens, we aim to clarify the essential role of energy-efficient cities in the promotion of sustainable development and the development of India's future urban future.

Energy Efficiency in Urban Context

India's long-term low-carbon development policy emphasises how important energy-efficient cities are to long-term, sustainable urban growth. In addition to improving energy and resource efficiency in urban planning guidelines, rules, and regulations, the text emphasises the integration of adaptation techniques into urban planning [3]. Cities with low energy consumption are essential for reducing greenhouse gas emissions, promoting sustainable development, and reducing energy use[6]. Efficient urban planning plays a key role in creating sustainable, resilient, and liveable cities that support India's green economy goals[7]. The plan also highlights how important it is to plan, develop, and manage urban buildings with an emphasis on making them robust to environmental problems and climate-responsive, for both current and future projects.[3]. These measures contribute to reducing energy demand, improving energy efficiency, and attenuating the impact of climate change on urban infrastructure.

Overall, promoting energy-efficient cities is essential for achieving sustainable urbanisation, reducing carbon emissions, and creating liveable and resilient urban environments in India. By integrating energy-efficient practices into urban planning and development, cities can contribute to the country's long-term low-carbon growth strategy and transition towards a more sustainable future.

Rapid urbanisation and population growth, which increase the demand for energy and resources, as well as the generation of waste and emissions. Lack of reliable and disaggregated data on urban energy use, greenhouse gas emissions, and other environmental indicators, which hinders the planning and implementation of effective policies and measures[8]. The challenges of the environment impact in Indian cities are the high levels of air pollution from car emissions, industrial activities and construction that contribute to environmental degradation. An improper waste management method leads to water pollution and soil pollution in urban areas. Deforestation and loss of urban green space contribute to climate change, and the loss of biodiversity is one of the challenges facing Indian cities with regard to energy consumption and environmental impacts. Inadequate infrastructure and governance, which affect the provision and efficiency of energy, water, transport, waste management, and sanitation services, as well as the coordination among various stakeholders and sectors. Low awareness and capacity limits the adoption and implementation of sustainable and low-carbon solutions such as renewable energy, energy efficiency, green buildings, and intelligent mobility. [9] also stated that climate change, which exacerbates the environmental risks and vulnerabilities of Indian cities, such as sea-level rise, flooding, droughts, and heat waves.

The use of sustainable and low carbon solutions can reduce the energy demand and greenhouse gas emissions of cities, thereby favourably impacting the global energy consumption and the environment. [8]. Also, it can lower the infrastructure costs and investments for energy supply and distribution, as well as improve the reliability and affordability of energy services for urban residents and businesses. It can enhance the liveability and social and economic resilience of cities by improving the quality of life, health, and well-being of urban dwellers, as well as creating new opportunities for employment, innovation, and competitiveness[10]. Therefore, integrating energy efficiency measures into urban planning and development is a key strategy for achieving sustainable and low-carbon urbanisation.

Policy Framework and Initiatives

According to Indian's Energy Efficiency Landscape Report [11], National and state-level policies in India are driving initiatives to promote energy efficiency in cities, focusing on sustainable urban development and reduced energy consumption. The National Sustainable Habitat Mission (NMSH) emphasises improvements in energy efficiency in buildings, waste management and public transportation systems to make cities more sustainable. Energy-saving building regulations (ECBC) are standards for optimising energy use in commercial buildings, while Smart City Mission integrates energy-efficient solutions for urban development. State energy conservation policies complement these efforts with incentives and regulations to reduce energy consumption and greenhouse gas emissions. Cities are also embracing renewable energy integration, particularly solar power, to enhance energy efficiency and sustainability. These policies are aimed at creating resilient low-carbon cities that improve the quality of life of residents and mitigate environmental impact.

The Indian Smart City Mission is a flagship initiative aimed at transforming urban areas into sustainable and technologically advanced centres. One of the key focus area of this mission is on developing energy-efficient infrastructure to enhance sustainability and reduce energy consumption in cities. As part of the Smart City Mission, cities are encouraged to implement intelligent energy management systems, renewable energy solutions and energy-efficient technologies to optimise resource utilisation and reduce environmental impacts. This includes initiatives such as smart street lighting, energy-efficient buildings, intelligent transportation systems, and waste-to-energy projects.

By integrating energy-efficient infrastructure into urban development projects, The Smart City Mission is aimed not only at improving the quality of life of residents, but also at contributing to the overall goal of creating low-carbon and sustainable cities. These initiatives contribute to reducing energy costs, reducing greenhouse gas emissions and promoting a cleaner and greener urban environment. In addition, the Smart Cities Mission focuses on the use of innovative technologies and data-based solutions to effectively monitor and manage energy consumption. Using digital tools and smart technologies, cities can optimise energy use, improve operational efficiency and promote a more sustainable urban ecosystem. Smart buildings are an essential part of intelligent cities aimed at improving energy efficiency, reducing energy consumption and ensuring sustainability [12]. Overall, the focus of the Intelligent Cities Mission on energy-efficient infrastructure plays an important role in promoting sustainable urban development, encouraging economic growth and addressing environmental challenges in Indian cities.

Many countries, including India, are actively seeking to become an intelligent city by adopting the latest technologies for various applications such as intelligent transport, air quality monitoring, cultural characteristics, medical diagnosis and disaster management. The main objective is to reduce human efforts and effectively utilise technology to provide safe and sophisticated living conditions[12]. Nagpur places great emphasis on the use of renewable energy and energy efficiency technologies to significantly reduce conventional energy consumption. Nagpur has earned the distinction of being recognised as the inaugural model Solar City in India[13]. Pune, Maharashtra, has focused on promoting energy-efficient buildings through initiatives such as the Energy Conservation Building Code (ECBC) and green construction practices [14]. By incorporating energy-efficient design features and renewable energy systems, Pune successfully reduced energy consumption and carbon emissions. Bengaluru, Karnataka, replaced traditional street lights with energy-efficient LED systems city-wide, resulting in significant energy savings, cost efficiency, and reduced carbon emissions[13]. Jaipur, Rajasthan, encouraged solar rooftop installations to promote renewable energy generation and energy self-sufficiency. By incentivising the adoption of solar power systems, Jaipur reduced reliance on conventional energy, lowered electricity bills, and mitigated environmental impact. These initiatives demonstrate successful energy efficiency measures in Indian cities, showcasing the positive impact on sustainability and quality of urban life.

Technological Solutions for Energy Efficiency

In order to tackle the issues presented by climate change and sustainable development, it is necessary to have conversations about cutting-edge technology and solutions that are designed to improve metropolitan areas' energy efficiency. Using information from the World Resources Institute (WRI) 2016 research[15], we look at eight crucial steps that cities can take to promote the construction of greener and more energy-efficient buildings. These include putting building efficiency standards and regulations into practice, establishing efficiency improvement goals, guaranteeing openness and performance certification, providing financial support and incentives, demonstrating government leadership by example, involving building owners, managers, and occupants, working with technical and financial service providers, and interacting closely with public services. These practices will provide a comprehensive framework for improving urban energy performance, which will ultimately lead to a more sustainable future and reduce energy costs and environmental impact.

Smart cities are using technology to improve the efficiency, sustainability and quality of life of its residents. In this context, integrated renewable energy, smart grids, the Internet of Things (IoT) and a variety of other technologies are being implemented. Building automation systems plays a major role in shaping the future of urban environments. These technologies are instrumental in optimising energy usage, reducing carbon footprint, and improving overall resource management within smart cities. By using solar power, wind power, and hydroelectric power, cities can reduce carbon dioxide emissions and promote cleaner urban environments. Smart networks are essential to efficiently distribute energy in smart cities, maximising energy use using advanced technologies such as sensors and automation, and improving the reliability of the network. The Internet of Things (IoT) is an essential tool for connecting smart city devices and infrastructure, enabling data-based decision-making and real-time energy system monitoring to improve efficiency. Building automation systems further enhance energy efficiency in smart cities by automating building functions based on occupancy and energy demand, leading to cost savings and improved sustainability[16]. The integration of these technologies in smart city planning is essential for creating energy-efficient, sustainable, and interconnected urban environments.

Cities are live example of how cutting-edge technologies can enhance energy efficiency and sustainability in an urban setup. Chandigarh, known for its planned layout, and Shillong, a city under the Smart Cities Mission, are prime examples of this trend. Chandigarh Smart City Limited is implementing energy reform projects like energy-efficient buildings and smart grid systems to optimise energy consumption and reduce carbon emissions. Additionally, Chandigarh's e-governance initiatives have transformed the city into a knowledge-based society. Similarly, Shillong is prioritising energy efficiency and sustainability through renewable energy adoption and smart infrastructure development. Other cities like Bhopal and Pune are also leveraging technology for energy-efficient infrastructure, smart transportation systems, and green building practices. These case studies demonstrate how Indian cities are embracing technology to create eco-friendly urban spaces and set new standards for smart city development in the country[17].

Community Engagement and Behavioural Change

Community involvement and awareness are pivotal in fostering energy-efficient practices within smart cities. Engaging residents in energy-saving initiatives and promoting sustainable behaviours can significantly reduce energy consumption and environmental impact. Participation in energy efficiency programs fosters behavioural changes supporting the adoption of energy-saving technologies. Involving members of the community in sustainable projects and teaching them about the advantages of energy efficiency fosters a sense of shared responsibility and community ownership for environmental preservation. Local community-led initiatives provide people the power to make educated decisions, which contributes to overall energy saving.

Through advocacy and smart technology adoption, communities drive positive change towards greener urban environments, enhancing residents' quality of life[18]. India's Long-Term Low-Carbon Development Strategy encourages the development of behavioural changes toward adopting energy-efficient lifestyles in order to achieve sustainable development.

One impactful strategy highlighted in the document is the Lifestyle for Environment (LiFE) initiative, which aims to inspire individuals, communities, and institutions to embrace eco-friendly practices in their daily routines. By tapping into India's rich tradition of environmental stewardship and promoting collective action, LiFE seeks to significantly reduce global carbon emissions and promote a culture of mindful consumption. Through collaborative efforts with global scholars and institutions, India is working towards identifying and sharing best practices for sustainable living, emphasising the importance of individual actions in driving positive environmental change.

Economic Benefits and Business Opportunities

Exploring economic benefits, investment opportunities, and successful public-private partnerships in advancing energy efficiency goals for cities and businesses is essential for sustainable urban development. By leveraging energy-efficient practices, cities and businesses can not only reduce operational costs but also contribute to environmental conservation and long-term economic growth[16]. According to studies, investing in energy efficiency measures not only reduces energy consumption and operational costs but also enhances property values and lowers maintenance expenses, thereby fostering economic growth and sustainability[19]. Moreover, there exist promising investment opportunities in the energy efficiency sector for both public and private entities. Governments can attract investments through incentives and financing mechanisms, while private investors can capitalise on the rising demand for sustainable solutions by funding innovative technologies and infrastructure upgrades. Encouraging public-private collaborations are essential for advancing energy-saving projects. These collaborations can combine knowledge, resources, and financing to accomplish large-scale energy efficiency in projects, facilitate knowledge sharing, and promote sustainable energy solutions by working with government agencies, commercial corporations, and non-profit groups. Through these concerted efforts, cities and businesses can accelerate their transition towards energy efficiency, mitigate carbon emissions, and cultivate more sustainable and resilient urban environments.

Faster economic growth as a result of enterprises being attracted to these places by the residents' creative potential, improved communication networks, dependable infrastructure, and more sophisticated consumer [16]. There are potential economic gains associated with energy efficiency measures, such as reduced operational costs, increased competitiveness, and enhanced resource utilisation [3] . By investing in energy-efficient practices and technology, cities and companies may reduce their energy costs and promote environmental sustainability, which will result in long-term financial benefits.

Successful public-private partnerships play a crucial role in advancing energy efficiency goals. Collaborations between government entities, private sector companies, and civil society organisations can drive innovation, scale up energy efficiency in projects, and leverage diverse expertise and resources to achieve sustainable outcomes[7]. Cities and companies may find new paths for prosperity, innovation, and environmental stewardship by putting an emphasis on energy efficiency, investing in sustainable practices, and encouraging collaboration across different sectors. This will pave the way for a more successful and sustainable future.

Challenges and Future Outlook

Addressing challenges and outlining future strategies for scaling up energy efficiency initiatives in Indian urban areas through stakeholder collaboration is crucial for sustainable urban development. By engaging stakeholders from government, industry, academia, and civil society, cities in India can overcome adoption barriers and drive the implementation of energy-efficient practices[16]. Scaling up energy efficiency initiatives in Indian urban areas face challenges like lack of awareness, high initial costs, policy hurdles, and technical expertise. Future strategies include stakeholder collaboration, capacity building, financial incentives, and policy alignment to drive adoption[7]. Recommendations to overcome barriers involve raising awareness through campaigns, facilitating access to financing with subsidies, streamlining regulatory processes, and promoting knowledge sharing among stakeholders. The significance of including a variety of stakeholders, such as local communities, businesses, governments, and civil society organisations to drive the adoption of energy-efficient practices [3]. By fostering multi-stakeholder partnerships and promoting knowledge sharing, capacity building, and technology transfer, cities can overcome barriers to widespread implementation of energy efficiency measures. Recommendations for scaling up energy efficiency initiatives include developing tailor made strategies for different urban contexts, providing financial incentives and technical assistance to support implementation, and raising awareness about the benefits of energy efficiency among stakeholders[3].

Conclusion

In the face of rapid urbanisation and escalating energy demands, the pursuit of sustainable development has become imperative for nations worldwide, with India standing at a critical juncture in shaping its urban future. This paper has delved into the multifaceted dimensions of sustainable development in the context of India's transition to energy-efficient cities.

There is an urgent need to transition towards energy-efficient cities to address challenges posed by climate change, resource depletion, and urban sprawl. Through exploration of various facets including policy frameworks, technological solutions, community engagement, economic benefits, and future outlook, several key findings have emerged. Firstly, the paper underscores the significance of energy-efficient cities in lowering greenhouse gas emissions, cutting energy use, and advancing sustainable development. It highlights the pivotal role of national and state-level policies, such as the Smart Cities Mission, in driving initiatives to promote energy efficiency and sustainable urban development. Secondly, the paper looks at creative approaches and cutting-edge technology to increase energy efficiency in cities, with a focus on how building automation systems, smart grids, renewable energy sources, and the Internet of Things (IoT) will shape urban environments in the future. Furthermore, the importance of community engagement and behavioural change in fostering energy-efficient practices within smart cities is emphasised, along with the economic benefits and business opportunities associated with advancing energy efficiency goals.

Despite the progress made, the paper acknowledges the challenges faced in scaling up energy efficiency initiatives in Indian urban areas, including lack of awareness, high initial costs, policy hurdles, and technical expertise. However, it also offers recommendations for overcoming these barriers through stakeholder collaboration, capacity building, financial incentives, and policy alignment.

In conclusion, the transition to energy-efficient cities in India is essential for achieving sustainable urbanisation, reducing carbon emissions, and creating liveable and resilient urban environments. India can set the path for future generations to enjoy a more sustainable and affluent future by incorporating energy-efficient methods into urban planning design and construction.

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ACHIEVING ENERGY EFFICIENCY THROUGH PUBLIC PRIVATE PARTNERSHIPS: A STUDY OF STREETLIGHT RETROFITTING PROJECTS IN TWO INDIAN CITIES

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"Energy conservation is the foundation of energy independence."

— Tom Allen

"Energy is essential for development, and sustainable energy is essential for sustainable development."

— Tim Wirth

Key Words: *Energy efficiency, Emission reduction, ULGs, Streetlight retrofitting, PPP*

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India has been undergoing rapid urbanisation and economic growth, both of which require support in the form of good urban infrastructure services. Cities are the places where energy consumption is high for both public purposes and private activities. Energy conservation in cities, especially in large cities, will lead to significant cost savings to urban local governments while also resulting in emission reduction. Energy efficiency improvement projects like streetlight retrofitting in cities have the potential for contributing to this cause; private sector participation in the form of Public Private Partnerships (PPPs) can achieve this more efficiently. This paper discusses the importance of of energy efficiency and emission reduction in the context of Indian cities and how streetlight retrofitting projects under PPP of two large cities – Hyderabad and Pune – demonstrate the potential for achieving energy savings as a means of financing the retrofitting project itself. The results imply that municipal energy efficiency projects like streetlight retrofitting offer enormous potential for harnessing energy savings with the help of private sector participation in the form of PPP.

Introduction

India has been undergoing rapid transformation in the last couple of decades on several fronts, especially in achieving economic growth which is primarily driven by the rising levels of urbanisation. Urbanisation level, measured as the share of urban to total population, has been on the rise in India for last several decades. It was estimated at 32 per cent by Census (2011) and was projected to cross 40 per cent by 2025 (MGI 2010). The urbanisation spread, which is captured in the form of a rise in the number of urban areas, has also been growing, yet much of the urban population (68 per cent of total urban population) is still concentrated in large cities i.e., cities with more than 100,000 population (or, Class I cities). Amongst the large cities, the cities with more than a million population (termed as million-plus cities) have a larger share of 42.6 per cent of total urban population and metropolitan cities i.e., cities with more than 5 million population, also have another major pie with 22.6 per cent of total urban population (Census 2011). Therefore, although urban population has been becoming more spread out, larger cities, particularly metropolitan cities, continue to have a larger role to play in supporting urbanisation and economic growth of the nation.

Yet, for a long time, cities were neglected in the national development policy. Urbanisation was traditionally viewed as a negative force that exerts pressure on the country's fiscal resources. However, with the increasing concentration of economic activities in cities, they are becoming important for the overall socio-economic development of the nation. Urban areas not only generate employment and serve as shelters for population but are also the centres of knowledge, cultural resources and financial capital. The positive role of cities and urbanisation in the overall development of human society has been emphasised upon by the "New Urban Agenda", which broadly covers (UN Habitat 2016):

- ***Social transformation*** – Leaving no one behind – by ending poverty, ensuring public participation, equal rights and opportunities, socio-economic and cultural diversity, integration in urban space, enhancing liveability, education, food security, health, ending epidemics, promoting safety, eliminating discrimination and all forms of violence, providing equal access to physical and social infrastructure and basic services, as well as adequate and affordable housing.
- ***Ensure sustainable and inclusive urban economies*** - by leveraging the agglomeration benefits of well-planned urbanisation, productivity, competitiveness, innovation, by promoting full and productive employment, equal access for all to economic and productive resources and opportunities, preventing land speculation, promoting secure land tenure, and managing urban shrinking where appropriate.
- ***Ensure environmental sustainability*** – by promoting clean energy and sustainable use of land and resources in urban development, by protecting ecosystems and biodiversity including adopting healthy lifestyles in harmony with nature, by promoting sustainable consumption and production patterns, by building urban resilience, reducing disaster risks and mitigating and adapting to climate change.

The current energy systems of cities are not geared towards achieving the goals of "New Urban Agenda", which emphasises upon appropriate planning, design, finance, development, governance and management interventions to achieve the Sustainable Development Goals (SDGs). The SDG 11 on sustainable cities and human settlements emphasises upon making cities inclusive, safe, resilient and sustainable; Other SDGs viz., SDG 3 (health and well-being), SDG 7 (energy) and SDG 13 (climate) have also laid down goals towards achieving integrated planning, access to basic services, slum upgradation and decent and affordable housing (UN 2015). Reduction of energy consumption, especially in the public services like streetlights in cities, will not only have global benefits of reduced emissions but also result in several other local benefits to the citizens viz., improved illumination benefits, improved road safety, reduced crime, safe neighbourhoods and reduced ecological footprint.

Importance and potential of energy efficiency in cities

As cities are the places of concentration of people, business firms and their interaction, cities also support high energy consuming activities. Much of this energy in the developing countries comes from fossil fuel e.g., coal fired thermal power and gasoline powered automobiles, which generate a large amount of gaseous emissions. Cities, therefore, are known to be one of the largest contributors of carbon emissions that account for a majority of the green house gas emissions (GHGs) causing global climate change. But, cities are also the victims of global climate change impacts in the form of increased surface temperatures and intense rainfall that lead to damages to their infrastructure and economy.

India has 4,378 towns and cities (statutory towns) as per Census 2011, their growth thereafter has resulted in a spurt in the demand for urban infrastructure services, including the demand for public as well as private energy consumption. Much of the public energy demand is for providing various urban infrastructure services. The total connected load of street lighting in these cities and towns was estimated at 4,400 W and the GHG emissions corresponding are 15.56 million tonnes of CO2 equivalent per annum (Madhusoodhan 2011). Water pumping and street lighting take away bulk of the energy budget of municipal governments of cities, as much as 50-60% of the energy budget. Yet, energy efficiency is not given due priority in the functioning, planning and management of urban local governments (ULGs) in India.

India ranks as 7th most affected country from climate related extreme weather events i.e., storms, floods and heatwaves, according to Global Climate Risk Index 2021. Cities have to be at the forefront of addressing urbanisation and climate change challenges and strengthen climate-sensitive urban development under the new urban agenda. Climate Smart Cities Assessment Framework (CSCAF), launched by the Government of India, aims to benchmark Indian cities on five major thematic areas so that the cities understand gaps and prepare action plans. Promoting energy efficiency of cities through energy conservation in city infrastructure services – water supply, sewerage, waste management, transport, roads and streetlights – is a step in that direction.

Municipal Corporations worldwide dedicate a significant amount of their budgets towards providing water and street lighting services. In India, these two basic services often represent over 80 per cent of the total energy expenditure of the municipal corporations (of large cities), offering enormous opportunities for savings (Deshpande and Kulkarni 2011). A study of 21 Indian cities (spread over the states of Andhra Pradesh, Karnataka, Maharashtra and Delhi) by TERI found that the potential energy savings could be between 15 to 40% and the cost savings could be Rs 1,050 lakh, which translate into savings of Rs 19 per person per annum; this is apart from GHG reduction potential of about 50,000 MT (Madusoodhan 2011).

The Confederation of Indian Industries (CII) estimated that the typical Indian municipal water utility has the potential to improving water pumping system efficiency by 25 per cent. Street lighting occupies 15 per cent of the energy consumption by municipal governments, thereby reflecting the opportunity for reducing the share through efficiency improvement. Municipal governments are often unaware of the opportunities to make their water and light systems more efficient and they may simply lack the means to take advantage of these opportunities. Some of the major hindrances to municipal energy efficiency programmes include (Deshpande and Kulkarni 2011): (i) priority conflict due to several functions rendered by municipal government (ii) subsidised energy tariffs make municipal governments go slow o energy efficiency measures (iii) lack of budgetary allocations for energy efficiency (rather, budgets provide for increased spending on various expenditure heads) (iv) lack of technical expertise to manage energy efficiency programmes effectively (v) complexity of projects and lack of social awareness as well as political support.

ICLEI (2012) made a study of 42 Indian cities and 12 cities from other countries in South Asian region. It shows that carbon emission levels in most Indian cities even today are extremely low when compared to developed countries, but the scenario will change in the event of rapid population growth and the rising need for urban infrastructure services, especially when a large proportion of the population is yet to access basic services and infrastructure amenities. The Urban Climate Programme (UCP) was started as a joint effort to integrate clean and efficient measures into the development planning of urban infrastructure services in the mission cities of JNNURM. ICLEI in association with National Institute of Urban Affairs (NIUA) implemented some interventions towards adopting clean efficient technologies so as to reduce carbon emissions (Ghorpade and Bhagavatula 2011).

Energy efficiency in streetlight systems

Amongst all components of physical infrastructure of cities, streetlights are an important component in terms of linkages with climate change and energy efficiency. Streetlight systems were traditionally designed and developed to provide illumination benefits to citizens that aids transportation, individual safety and neighbourhood safety. Most of the streetlight systems were developed and installed long time ago with prevalent technology - be it lamp posts, energy cables and street lamps – which is inefficient in terms of energy consumption.

As old conventional streetlight systems are operated manually and controlled locally by the municipal staff/ contractual workers, they are prone to negligence that results in poor performance e.g., wastage due to day time glowing, quick malfunction of lamps etc. The inefficiency in streetlight systems of cities results into huge energy consumption (due to poor electric devices, especially that of incandescent/photo-luminescent lamps) by the system. As public utilities/ electricity boards no longer consider municipal bodies as public/charitable institutions, they are charged with commercial power tariffs, which leads to huge energy bills.

Most of the municipalities source energy from the State Electricity Boards for operating their energy cost centres i.e., pumping system, lighting and electrical system. Electricity is drawn from the grid via a sub-station, and then it is either stepped up or down according to the requirements and is used for operating motors and for lighting. The lighting system for a municipal body varies with reference to the city, but the following types of lamps are used for lighting the roads and public places governed by municipal government (Krishnamurthy and Gokul 2011). The wattage and lumens variance of some different lamps are given in Table 1.

(i) High pressure sodium vapour (HPSV) lamps

(ii) Fluorescent tube lights (FTLs)

(iii) Mercury vapour lamps

Table 1: Wattage and Lumens of Different Lamps

Factor ↓	FTL	HPSV			*Metal Halide*
Wattage →	40	250	160	70	400
Output (lumens)	2700	27000	13500	5600	36000
Efficiency (lumens/ watt)	55	87	75	64	90
Lamp life (hours)	10,000-20,000	18,000-24,000	15,000	10,000	15,000-20,000
Energy use	Medium	Low	Low	Low	High
Colour rendition	Good	Moderate	Moderate	Moderate	Good

Source: Krishnamurthy and Gokul (2011)

(iv) Compact fluorescent lamps (CFLs)

(v) Incandescent bulbs (including Mast Lamps)

The energy consumption (wattage) of current streetlight systems is very high as evident from the Table 1, which need to be replaced by the modern systems that use Light Emitting Diode (LED) bulbs, which provide comparable illumination and have a much longer service life. Therefore, retrofitting the current streetlight systems with the new LED devices and lighting systems is an important step towards achieving new urban agenda and SDGs. Furthermore, it also promotes the fiscal health of cities, which is rather messy in India with several cities striving hard to sustain themselves as public institutions. Retrofitting streetlight systems with modern energy efficient systems will lead to significant cost savings to municipal bodies/ ULGs, which they can use on the provision of other civic infrastructure services.

Retrofitting Urban Streetlight Systems through Public Private Partnerships

Given the rising levels of urbanisation requiring support urban services, the cities have to improve service provision, which requires a substantial amount of public and private investment into urban infrastructure services. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) has laid down foundation for providing funding support to the Indian cities to fill the gaps in urban infrastructure service provision. The Smart Cities Mission, which replaced it aims at the smart and sustainable development of identified mission cities with focus on modernisation of urban infrastructure and application of digital technologies in service delivery. Energy efficiency of cities is an important element of it. However, the upgradation & augmentation of urban infrastructure requires not just funding but the capacities of technology, finances, organisation and execution, which are in shortfall in urban local governments. Therefore, Public Private Partnerships (PPPs) can play a major role in overcoming them (Nallathiga 2007). It is also laid down that PPPs in infrastructure lead to infrastructure service improvement through reforms, competitive procurement and technical expertise (World Bank 2006). Private sector participation can bring-in technical, managerial and financial resources that can be combined with the public sector strengths of drawing service standards/ specifications and competitive procurement systems.

PPPs can play an important role in achieving municipal energy efficiency through retrofitting of current energy systems with modern and efficient energy systems. Given the not-so-capital intensive nature of municipal streetlight retrofitting projects, various service contracts are appropriate PPP model. Performance contracts can be designed for all project sizes and scope through tailoring to the energy conservation programme by taking advantage of energy saving opportunities and the supply of products and services. Performance contracting in energy efficiency programme usually consists of three independent agreements:

(i) Project development agreement

(ii) Energy service agreement

(iii) Financing agreement

Performance contracting is a common way to implement energy efficiency programmes and frequently covers the financing of needed equipment. It is an agreement between a municipal corporation and private Energy Service Provider (ESP). The ESP identifies and evaluates the energy saving opportunities and recommends improvements that can be paid for through energy savings. The ESP usually guarantees that the savings will meet or exceed annual payments that cover all project costs; in case of any shortfall, the ESP will pay the same. The contract clearly identifies the procedures by which these are to be measured and verified. The concern about ESP's ability to meet future financial obligations in the event of not achieving adequate net energy savings (after deducing project costs) can be addressed through a reserve fund mechanism. Such reserve funds, also termed as Escrow Funds, provide for meeting any funds shortfall.

Achieving energy efficiency through streetlight retrofitting in Indian cities

In this section, an attempt is made to shed lights on the achievements of energy efficiency in urban streetlight system by two large Indian cities – Pune and Hyderabad – by forging partnerships with private sector in the form of the PPP. The case analysis laid down below gives an account of the streetlight retrofitting project snapshots and features in the two cities.

Pune (PMC) Case

Pune Municipal Corporation (PMC) has undertaken an initiative towards achieving energy efficiency through PPP for the city streetlight system currently operated by it. The PMC entered into a service contract under PPP with M/s Tata Projects Ltd through its subsidiary – Ujjwal Pune Ltd. This project is first of its kind taken up by the PMC under PPP mode, wherein the necessary luminescence is to be maintained with no additional financial investments. The project is fully self-financed through energy consumption savings and reductions in maintenance costs brought about by streetlight retrofitting. Retrofitting of streetlight system involves the replacement of existing incandescent/ photo-luminescent streetlamps with those that function on Light Emitting Diode (LED) technology. It also involves replacement of street lamp posts as well as increasing their number in order to achieve a better illumination through better placement (or, spacing) as well as improving the monitoring and control through automation.

3.1.1 Project snapshot

Following is a snapshot of energy conservation achieved through streetlight retrofitting project in Pune.

Project title	*Intelligent Lighting for Smart Cities*
Client/ Concessioning Authority	Pune Municipal Corporation (PMC)
Contractor/ Concessionaire	Tata Projects Limited
SPV Company	Ujjwal Pune Limited ('UPL')
Project Objective	Retrofitting of 70,000 Existing Streetlights with Smart Street Lighting
Project Description	Installation of Energy Efficient dimmable LED Street lights along with per feeder basis SCADA system.
Type of PPP Contract	Design, Build, Operate, Maintain & Transfer the Project (DBOMT)
Contract Period	12 Years
Key Project Outputs	Installation of 83,000 LED streetlights and 1,500 Remote Monitoring and Control Panels
Capital cost/initial investment	₹16 crore
Project Award and Begin Year	September 9, 2016 and began in 2017
Project Status	Ongoing energy performance contract

3.1.2 Project features

Streetlight Retrofitting Project involves (i) replacing halogen lights with energy-saving LED luminaires (ii) ensuring that all the street lighting was remotely connected (iii) monitoring from a single Command & Control room through the Interact City system. There are several advantages associated with retrofitting streetlights with LED lamps:

- It involves high power LEDs that results in optimal and efficient distribution of street lights and Integrated dimming of lighting levels on request.
- Luminaire of LEDs complies with IP 66 protection and LM 79 certification and their Colour rendering index > 70
- There tends to be an efficient thermal management in the LED luminaire and the LED street light system can be operated through remote control
- The Quantified Energy Savings shall be converted to Rupee value in accordance with the existing unit rate of 5.80/ unit and PMC will pay 98.50% of the Quantified Savings to UPL monthly from the established date until twelve years (12 years).

Table 2 shows the replacement of current streetlights with LED system,

Table 2: Streetlight Retrofitting Project in Pune

Existing street light	Proposed LEDs
7 W HPSV / 4x14 W T5	45 W
4 x 24 W T5	60 W
150 W HPSV	10 W
250 W HPSV	180 W

Source: PMC

The Pune Streetlight Retrofitting project aims to achieve several benefits, some of which include:

- ➢ Achieving 30-50% energy savings
- ➢ Achieving 10-20% more service life
- ➢ Modern and maintenance free lighting system
- ➢ Carbon credits associated with the GHG emissions avoidance

- Complete system in place along with street lamps and controls
- Carries free replacement/ maintenance over the time period of 12 years.

Figure 1 shows that the break even will be achieved early with the financial cost savings from retrofitting exceeding the replacement and maintenance cost of the project.

Hyderabad (GHMC) Case

Greater Hyderabad Municipal Corporation (GHMC) has undertaken an initiative towards achieving energy efficiency through PPP for the city streetlight system currently operated by it. The GHMC entered into a service contract under PPP with M/s Energy Efficiency Services Limited (EESL) to replace the traditional streetlights (incandescent/ fluorescent bulbs) with modern LEDs.

Project title	*Intelligent Streetlighting*
City and country	Hyderabad, India
Client/ Concessioning Authority	Greater Hyderabad Municipal Corporation (GHMC)
Contractor/ Concessionaire	Energy Efficiency Services Limited (EESL)
Project Objective	Retrofitting of 4,13,029 Existing Streetlights with Smart Street Lighting System
Project Description	Installation of Energy Efficient dimmable LED Street lights along with per feeder basis SCADA system.
Type of PPP Contract	Design, Build, Operate, Maintain & Transfer (DBOMT)
Project Duration	7 Years
Key Project Outcomes	4,65,043 Number of LEDs to be Installed in place of existing streetlights
Project Begin Year	July 06, 2017.
Capital cost/initial investment	₹ 271.40 Cr
Project Status	Ongoing energy performance contract

This project is first of its kind taken up by the GHMC under PPP mode, wherein the necessary luminescence is to be maintained with no additional financial investments by GHMC. The project involved replacing the old High Pressure Sodium Vapour (HPSV) lighting fixtures, Fluorescent Tube lighting fixtures, Metal Halide lighting fixtures with new LED lighting fixtures. The project is fully self-financed through the energy consumption savings and reductions in maintenance costs brought about by LED technology.

3.2.1 Project snapshot

Following is a snapshot of energy conservation through streetlight retrofitting project in Hyderabad.

Table 3 shows the current streetlight system in terms of Wattage of power in Hyderabad.

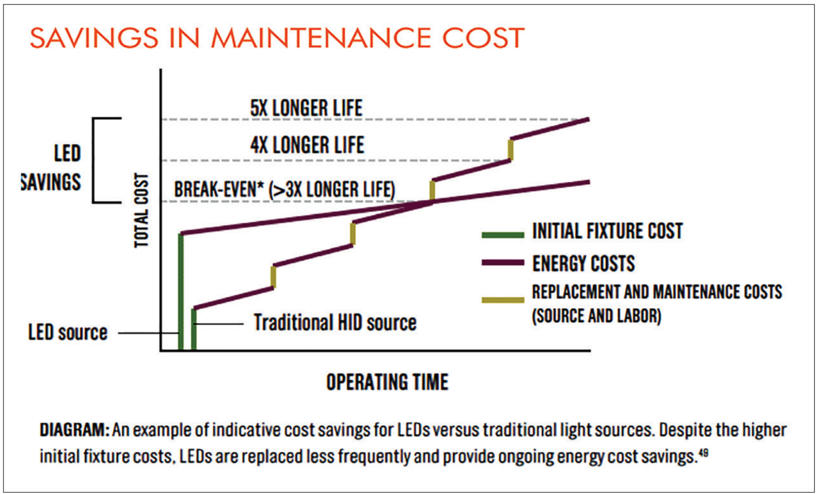

DIAGRAM: An example of indicative cost savings for LEDs versus traditional light sources. Despite the higher initial fixture costs, LEDs are replaced less frequently and provide ongoing energy cost savings.[49]

Figure 1: Break even achievement of streetlight retrofitting project

Table 3: Existing System of Streetlights in Hyderabad

Light type	Numbers
High Pressure Sodium Vapor Lights (HPSV)	
150W HPSV	2,07,793
250W HPSV	73,215
70W HPSV	47,520
40W tube lights	16,475
Metal Halide (HM(lamps	
250W	16,536
400W	18,150
120 W LED lights	254
250W Induction lamps	4

Source: GHMC

3.2.2 Project features

Although the project has a capital cost of Rs 271.40 crore, it also involves no upfront investment cost for the GHMC. EESL assured energy savings to the tune of 55% and provides free O&M support for the contract duration of 7 years. GHMC will reimburse EESL through monetized energy savings, which are paid through the Commitment account. EESL provided a guarantee of free replacement of street lamps due to manufacturing defects. Streetlight system would achieve 98% minimum incandescent rate of lamp post; Illumination levels are according to national lighting code. It also involves necessary adaptation works of existing street lighting system as well as setting up of centralized control and monitoring to improve operational efficiency.

Some of the major benefits of the project include:

- No initial investment by the GHMC on the project.
- Electricity charges/ bill reduction of Rs 85 crore/ year.
- In addition, annual maintenance cost reduction of Rs 30 crore.
- Street lamps Lighting percentage has increased from 78% to 98%.
- Lux level has been improved by 60% compared to HPSV lamps.
- Entire monitoring system is automated via CCMS and online dashboards are created.

Comparison of Streetlight Retrofitting Projects in Hyderabad and Pune

Figure 2 shows the comparison of streetlight systems retrofitting projects in Hyderabad and Pune in terms of project achievements – both physical and financial.

	Pune	Hyderabad
Proposed No. LED lights	83000.00	474125.00
Capital Cost (Cr.)	16.00	271.40
Actual No. LED lights	89582	474125
Total length of roads (in km)	1450	9000
Number of street lights/km of road	62	53

Table 4 shows the comparison of streetlight retrofitting

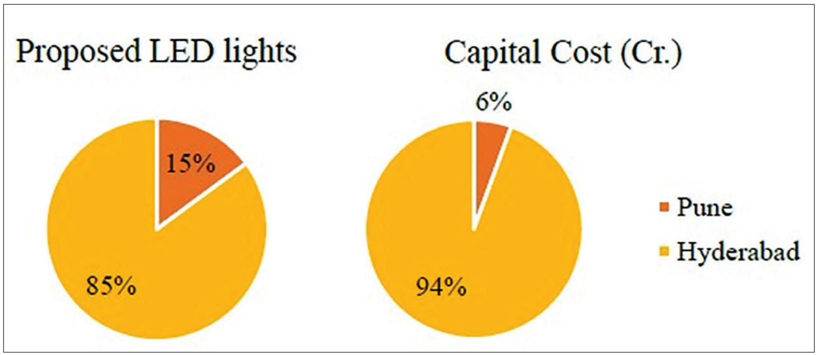

Figure 2: Comparison of Streetlight Retrofitting Projects in Pune and Hyderabad

Table 4: Comparison of Streetlight Retrofitting Projects in Hyderabad and Pune

Financial Parameter and Measure	PMC	GHMC
Conventional Streetlight Costs		
- Initial Costs (Installation) (Rs)	36,45,59,320	124,25,39,252
- Annual Maintenance Costs (Rs)	2,01,30,905	12,91,74,075
LED Streetlight Costs (Rs)	15,12,78,525	167,99,09,018
Annual Cost Savings from Reduction in Energy Consumption (Rs)	2,65,00,000	85,26,00,000
Total Annual Cost Savings from Streetlight Retrofitting (Rs)	4,66,30,905	98,17,74,075
Project Benefit Cost Ratio (BCR)	3	4
Project Pay Back Period (PBP)	5.07	3.06
Project Net Present Value (NPV)	22,93,92,864	376,88,33,917

Source: Own Calculations

projects in Hyderabad and Pune on some of the major financial parameters. It can be seen that the Streetlight retrofitting project in Hyderabad is more attractive on the parameters of annual costs savings from energy consumption reduction, total annual costs savings from streetlight retrofitting, project benefit cost ratio and project payback period. The Streetlight retrofitting project in Pune is, however, smaller in size and, therefore, has the advantage of completing quickly without much deployment of capital; it also indicates the scalability potential of the project in future. Both of them are, however, advantageously positioned in terms of good cost benefit ratio and low pay back period, which make such streetlight retrofitting projects attractive from both public and private sector perspectives.

Conclusions

Urbanisation and urban population growth are inevitable to and cities will play a major role in the economic growth and development of countries like India. As cities are the major sources of GHG emission that result in global climate change and also the victims of such climate change impacts, they need to both contribute to emission reduction as well as develop robust infrastructure, in line with the New Urban Agenda. Streetlight retrofitting is one such initiative that can achieve the objectives of energy efficiency and emission reduction; it can also offer several other local benefits. Streetlight retrofitting projects undertaken by the study cities – Hyderabad and Pune – showcase that PPP can be used to achieve results without incurring any additional municipal expenditure. The energy conservation and other benefits of Streetlight retrofitting projects in both cities outweigh their costs (while also having low pay back period), reflecting a good potential for their adoption/ replication by other cities

Energy efficiency programmes of municipal governments is identified as a major step in the country in its march towards energy security. Municipal energy efficiency projects like streetlight retrofitting offer enormous potential for harnessing energy savings with the help of private sector participation in the form of PPP. Such energy conservation projects, if designed and implemented well, can result in substantial cost savings to urban local governments. However, the major challenges are (Deshpande and Kulkarni 2011): (i) technical competence of municipal corporations and their ability to deliver savings (ii) lengthy processes and procedures of municipal governments as well as budgetary conflicts with other municipal expenditure programmes. The experience of the two case cities serves as demonstration for making similar attempts by other Indian cities.

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PM Surya Ghar: Muft Bijli Yojana launched to boost solar power adoption

The PM Surya Ghar Muft Bijli Yojana is a solar rooftop scheme launched by the Indian government to provide free electricity to households in India. The initiative aims to support households with the installation of solar power systems on their rooftops. Prime Minister Narendra Modi, on February 29 approved India's latest rooftop solar scheme - 'PM Surya Ghar: Muft Bijli Yojana' - with an outlay of Rs 75,021 crore.

Here's a brief overview of the key aspects of the PM Surya Ghar Muft Bijli Yojana:

1. **Financial Assistance and Subsidy:** The PM Surya Ghar Muft Bijli Yojana provides financial support for the installation of solar panels. Homes that opt for solar power systems on their roofs will receive 300 units of free power. The scheme offers subsidies, with Rs 30,000 subsidy for a 1 kW system, Rs 60,000 for 2 kW systems, and Rs 78,000 for 3 kW systems or higher at current benchmark prices.

2. **Loan Facility:** The scheme also provides access to collateral-free, low-interest loan products for the installation of residential rooftop solar systems up to 3 kW, with interest rates at around 7% at present

3. **Eligibility:** The eligibility criteria include ownership of a house with a suitable roof for solar panel installation and a valid electricity connection. Additionally, households should not have availed of any other subsidy for solar panels.

This initiative aims to promote the use of solar energy, reduce electricity costs for households, and contribute to a cleaner and cost-effective energy future for India. The PM Surya Ghar : Muft Bijli Yojna is a part of India's broader commitment to sustainable development and its obligations under international climate agreements. By offering generous subsidies , the government aims to accelerate the transition to renewable energy , making solar installations a viable option for a vast segment of the population.

WBPDCL
INDIA'S LEADING POWER UTILITY IN GENERATING SMILES

DR. P.B. SALIM

Dr. P.B. Salim, IAS
CMD, WBPDCL

The West Bengal Power Development Corporation Ltd (WBPDCL) has surprised its peers and patrons alike, with its historic feat of being ranked the best-performing power generation company in the country for 2022-23 by the Central Electricity Authority (CEA) under the Union Ministry of Power. In plant load factor (PLF) that measures the efficiency of power generation in any unit, the Bakreswar plant is ranked number one (PLF: 92.4%) out of the 205 thermal power plants in India. Santaldih is ranked second (PLF: 91.3%) followed by Sagardighi plant at fifth position (PLF: 90%) nationally.

Lauding the momentous exploit, the State Government said that three of our thermal power stations have made the state proud by establishing their places in the top five spots in the performance-based national ranking.

This has been achieved with relentless dedication and strong determination and also by adopting the best O&M practices and multiple lucrative Human Resource Development & Welfare schemes. Lauding the present performance of WBPDCL, Dr. P B Salim, CMD, WBPDCL, commented-

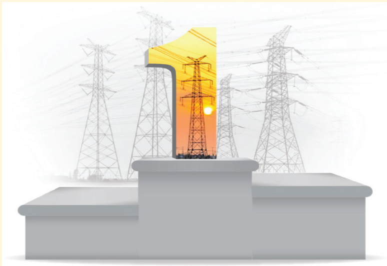
WBPDC L- Energising a brighter future for West Bengal

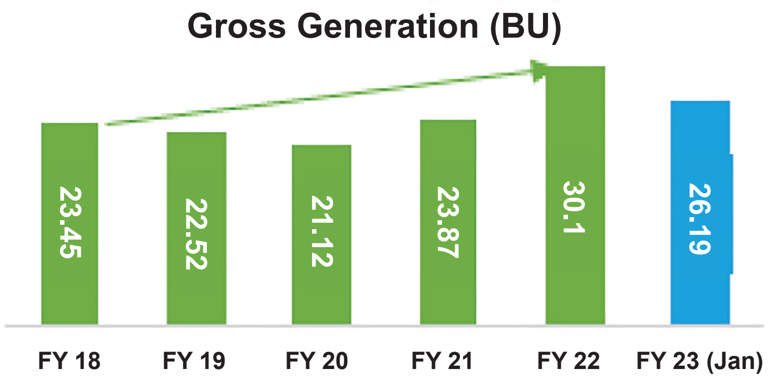
Introduction

Incepted in July, 1985 with only one generating unit at Kolaghat, WBPDCL has 05 nos. of operational thermal power plants with operating capacity of 4265 MW.

It has a total renewable (Solar) portfolio of 25.54 MW. Further, it has under

> WBPDCL which ranked the best power generation entity in the country with a PLF of 85.2% is much ahead of Central power sector undertakings like NTPC, DVC and private power companies like Reliance Power, Adani Power and Tata Power.





construction project of 660 MW of thermal and 10 MW of Floating Solar. Also, it is has 4 nos. of operational coal mines and 2 nos. of upcoming coal mines.

The overall gross generation of WBPDCL for FY 2021-22 was 30.10 BU which has been increased by 28% over the last 5 years. This impacted in reduction of average power purchase cost of WBSEDCL for FY 2021-22. The operating income has increased by 7%, non-operating income by 296% and total income by 12% in the last 5 years. Further, there was a significant improvement in profit after tax including comprehensive income and it has increased by 7.75 times in the last 5 years.

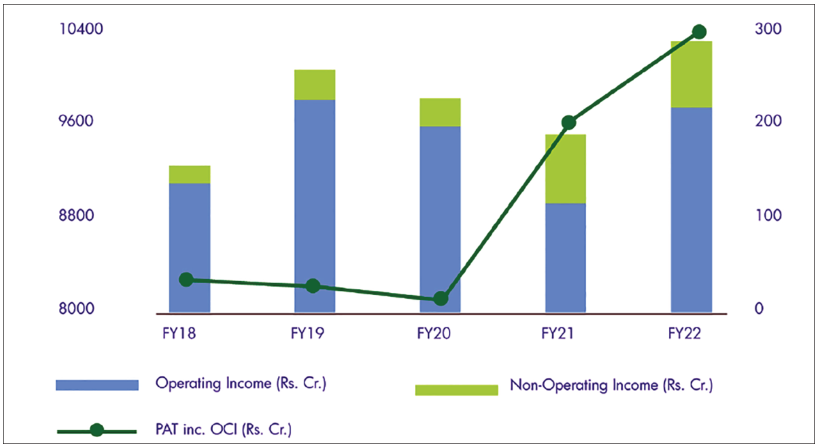
Due to improvement in total revenue Vs Expenditure, there has been a significant improvement in net profit margin and interest coverage ratio. Further, Net profit margin in creased by 6.93 times and interest coverage ratio by 1.37 times over the last 5 years.

O&M practices for better performance

WBPDCL has strengthened the O&M practices at their thermal power stations for improving their operational performance parameters. The adopted O&M practices include various aspects like technology, O&M planning, conditional monitoring, preventive maintenance, O&M procedure, enhancement in technical and managerial skills of O&M personnel and infrastructure/ facilities improvement.

Energising a greener future

WBPDCL has planned for installation of DSI technology for Kolaghat, Bandel and Bakreswar, and Wet FGD technology for Santaldih and Sagardighi in order to control the emission under permissible limit. Further, WBPDCL has taken initiatives to ensure 100% ash utilisation at all stations. It is also able to manage water consumption within permissible limits. Further, it has taken initiative for modernisation of ash handling units and renovation/ upgradation of ESP in order to improve its efficiency.



WBPDCL has launched a project name “Marching towards Excellence” in 2021 for the beautification of its plants and townships. WBPDCL has received awards on environment management at both National and International level.

A brighter future ahead

WBPDCL has been adapting to the changing times and futuristic technologies. It’s also increasing its presence in the renewable energy sector with a re-energized commitment to power West Bengal’s progress.

2000-Watt Smart Cities: Fair Path to Net-Zero

Urban centers function as intricate systems, posing significant challenges in management. Worldwide, these urban spaces play a pivotal role in accelerating detrimental climate alterations. Individual buildings have low contextual impact on the overall contribution to climate change, hence there is a need to look at the larger developments to deploy mitigation and adaptation strategies.

The 2000-Watt Society is an environmental vision introduced in 1998 by the Swiss Federal Institute of Technology ETH in Zurich, Switzerland. This concept is about reducing the overall average primary energy usage rate to no more than 2000 Watts per person and the greenhouse gas emissions to net zero by 2050, while also improving the quality of life at the same time. The vision of the 2000-Watt Smart City (WSC) is where raw materials are used in a sustainable and fair manner. It focuses on increasing energy efficiency, increasing use of renewable energies and harmonizing consumer and user behaviors.

With the 2000 WSC certificate, large development areas can be assessed in terms of density, mixed usage, and building-induced mobility. Key salient features of 2000 WSC are:

- **A whole site rather than an individual building:** The quality of density and mixed usage is considered. With smart energy networks, a variety of energy sources and storage systems are included.
- **Overall energy balance instead of reduction to operational energy:** Embodied energy of the construction of buildings and energy requirements for everyday mobility is part of the assessment.
- **A whole large development life cycle:** The certificate is focused not only on the construction phase but also on the operation phase. This offers huge potential, which can only be used in collaboration with all users.

2000 WSC had signed a MoU with the Government of Maharashtra’s Department of Environment and Climate Change to consolidate the state’s efforts towards expediting climate mitigation by implementing the successfully implemented 2000-Watts philosophy and toolkit. The “Centre for Climate Change and Cities (C4)” was established to streamline the efforts and achieve resource efficiency leading to urban resilience.

TOWARDS SUSTAINABLE URBAN FUTURES: LOW-CARBON CITY DEVELOPMENT IN INDIA

DEBANJALI SAHA[1]
DR. RUCHITA GUPTA[2]

Amidst rapid urbanisation and escalating environmental challenges, this paper comprehensively analyses the path towards developing low-carbon cities in India, highlighting the urgent need for sustainable urban planning and policy frameworks. It examines the critical intersection of urban growth and climate change, emphasising the significant contributions of cities to global greenhouse gas emissions and the critical opportunities they present for emission reduction and sustainability. Through an in-depth analysis of successful global models and pioneering Indian initiatives, the research identifies effective strategies for urban carbon footprint minimisation, including the adoption of green building technologies, renewable energy sources, and sustainable transportation systems. It underscores the importance of multi-stakeholder engagement, including Government, community, and private sector collaboration, in driving the shift towards environmentally resilient urban environments. The paper proposes a comprehensive approach for Indian cities to achieve carbon neutrality, integrating technological innovation, policy adaptation, and community participation. By presenting a roadmap for sustainable urban development, the study aims to inform policymakers and urban planners on the essential steps to cultivate low-carbon cities that ensure a high quality of life for future generations while addressing the global challenge of climate change.

Introduction

Cities, home to 56% of the global population in 2019 and expected to rise to 68% by 2050, are crucial in the climate action narrative. Their economic significance generates 70% of global GDP while occupying a mere 2% of land (United Nations, 2016). This growth amplifies cities' role in greenhouse gas emissions and susceptibility to climate-related risks, such as floods and heat waves (Lankao, 2012). The increase in atmospheric CO2 levels from 280 parts per million (ppm) during the pre-industrial period to 379 ppm in 2005 is projected to lead to temperatures between 1.1 and 6.4 degrees Celsius by the end

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of this century. This significant change is expected to impact freshwater resources, food security, and health outcomes (National Action Plan on Climate Change). India's 7% to 8% economic growth is encountering escalating challenges, including increased migration, pressure on infrastructure, environmental pollution, and overuse of natural resources. Addressing these issues requires innovative strategies for urban planning that prioritise sustainability, carbon emission reduction, and efficient resource use to ensure urban areas remain habitable and environmentally responsible.

Literature Study on Low-Carbon Cities

Numerous researchers have conducted comprehensive studies on low-carbon cities. A study by Fei Chen (2013) analysed urban carbon emissions through empirical studies in ten large American cities, focusing on transportation, heating, air conditioning, and everyday activities in city centres and suburban outskirts. Goodall (2007) analyzed household carbon emissions by evaluating the consumption of electricity, petrol, and natural gas. In contrast, Chen and Dajian (2013) focused on the energy usage and carbon outputs of residential buildings and public structures in China. Japanese scholars investigated emissions across various sectors, proposing emission reduction strategies through building innovations, transportation enhancements, industrial realignment, and the implementation of energy-efficient technologies. Furthermore, Price et al. (2013) introduced an innovative low-carbon indicator framework specifically designed for China. This framework provides a set of methodologies for creating comprehensive indicators at macro and micro levels, marking significant strides in understanding and mitigating urban carbon footprints globally.

In India, research has centred on developing localised, city-specific indicators for low-carbon transportation, utilising household survey data. Moreover, a focus has been on creating comprehensive macro-level indicators across technical, social, economic, and strategic areas to promote low-carbon transportation solutions. This paper outlines the necessity for low-carbon cities in India. It begins by outlining the research goals, approaches, and methodologies, followed by a review of literature that discusses global and Indian urbanisation challenges and the drive towards low-carbon cities. This review includes an analysis of successful models from around the world and Indian efforts in this direction, concluding with a presentation of the study's findings.

Towards Low-Carbon Urban Development In India

In the face of escalating urban challenges, India's mega cities, such as Delhi and Mumbai, are encountering severe environmental degradation. This degradation manifests in excessive traffic congestion, escalating air pollution levels, and the unsustainable consumption of non-renewable resources, culminating in a spectrum of climate-related adversities. The situation is further aggravated by urban sprawl, loss of vegetative cover, and the exploitation of natural resources, presenting a grim forecast for ecological sustainability and public health. The construction of large-scale infrastructure and uncontrolled urbanisation disrupt natural ecosystems, leading to soil degradation, diminished groundwater resources, and climate change-induced risks. These include heightened flood and drought occurrences, infrastructural damage, agricultural setbacks, and a jeopardized food supply chain.

A critical analysis of Mumbai's vulnerability to climate change exemplifies the dire consequences of neglecting sustainable urban planning. The root causes, including widespread concretisation and inadequate urban planning, are linked to temperature anomalies and exacerbating the urban heat island effect. This effect hampers the natural absorption of rainwater, overwhelms the city's drainage capacity, and elevates health risks by facilitating disease proliferation (Chinmayi, 2012).

This paper argues for a strategic redirection towards developing low-carbon cities to counter climate change impacts, drawing insights from Malaysia's successful greenhouse gas reduction initiatives. It advocates for integrating green building practices, innovative energy solutions, and a cultural transformation embracing sustainability and energy conservation. By examining these approaches, the study proposes actionable frameworks for Indian cities to navigate the transition towards carbon neutrality, highlighting the critical role of community engagement and policy reform in fostering environmental resilience.

Global Perspectives and Indian Pathways In Urbanisation

In the 21st century, urban areas have become the living spaces for more than half of the world's population, marking a significant shift in global demographics (United Nations, 2011). This demographic shift, primarily driven by the pursuit of employment opportunities and industrialisation, places immense pressure on urban infrastructure, leading to multifaceted environmental issues such as pollution, resource scarcity, and a decline in quality of life (QOL). These urban challenges contribute significantly to climate change, a phenomenon exacerbated by the emission of greenhouse gases identified by the Kyoto Protocol (World Bank, 2010). The Ministry of Land, Infrastructure, Transport and Tourism Japan (2011) identifies specific sectors responsible for carbon dioxide emissions (Jing, 2009). The transportation sector's emissions primarily stem from the increased use of passenger cars, reflecting a broader trend towards motorisation. Expanding offices and retail spaces and the heightened energy consumption necessitated by continuous operations contribute significantly to CO2 output in the business sector. The residential sector sees increased emissions due to the expansion of living areas, driven by the rise in nuclear families and single households, advancements in information technology, and the growing size of home appliances.

Moreover, buildings and infrastructure that do not meet energy efficiency or low-carbon emission standards, as the focus often shifts toward immediate comfort, convenience, and cost-saving rather than prioritising energy conservation, compound the issue. The Urban Heat Island effect further intensifies urban temperatures compared to rural areas due to increased heat absorption and air pollution, contributing to the overall urban CO_2 emissions footprint. This scenario underscores the challenges urbanisation poses and its impact on carbon emissions. The subsequent section will explore the concept of low-carbon cities as a potential solution to these challenges, examining the planning initiatives underway at various levels to address the carbon footprint of urbanisation (The World Bank, 2011).

In 2001, India was home to roughly 286 million urban residents, ranking it second worldwide in terms of urban population size (Vaidya, 2009). Future projections indicated a 38% increase in urban dwellers, reaching 534 million by 2026 (Registrar General, 2006). The initiation of significant projects like the Delhi Mumbai Industrial Corridor and Gujarat's GIFT City highlights an upcoming urban expansion. While generating employment through substantial foreign investment, this growth is also likely to boost energy use, traffic congestion, and dependence on various transport systems. This growth presents a challenge as it coincides with prevalent power shortages affecting half of the population, highlighting the disparity between energy demand and supply.

The situation underscores the urgency for developing low-carbon cities, emphasising the construction of energy-efficient buildings, promoting public transport, and implementing water recycling and rainwater harvesting practices. As the third-largest source of CO_2 emissions globally, India faces a critical need to curb its emissions, projected to increase fivefold by 2050 if current trends continue, further exacerbating the reliance on scarce fossil fuels (British High Commission, 2012b). This trajectory threatens significant sectors of India's economy, such as employment, water supplies, agriculture, and infrastructure, due to the impacts of rising global emissions and climate change.

This backdrop sets the stage for a shift towards sustainable urban development, focusing on utilising renewable energy sources and reducing carbon footprints. The forthcoming section explores the concept of low-carbon cities alongside various national and international initiatives aimed at addressing the environmental impact of urbanisation. This study explores India's approach to low-carbon urban development, examining national initiatives promoting a sustainable future. It focuses on measures to counter climate change's negative impacts, ensuring a healthier environment for future generations.

Concept Of Low Carbon Cities

While lacking a uniform definition, low-carbon cities are recognised for their commitment to sustainable practices and technologies, achieving significantly reduced carbon and GHG emissions compared to conventional standards. Their goal is to mitigate the negative impacts associated with climate change (Keitha, 2011). These cities are envisioned as desirable places for living and working, address the needs of present and future residents, maintain environmental sensitivity, and enhance the quality of life through safety, inclusivity, thoughtful planning, and equitable access to urban services (Mustafa, 2012).

Global Interventions for Low-Carbon Cities

Globally, initiatives in Taiwan, Malaysia, and the UK, among others, have undertaken significant assessments and developed frameworks for low-carbon cities. Cities like New York, London, and Tokyo have launched low-carbon planning programs. Meanwhile, Barcelona, Berlin, Hangzhou, and Copenhagen focus on policies that enhance energy and industrial structures, upgrade public transport systems, optimise building design, reduce household consumption, and elevate public consciousness about environmental issues. This global movement towards low-carbon development is evidenced by over 1,050 cities in the United States, 40 in India, and more than 100 in China setting goals to reduce carbon emissions (Meirong et al., 2013).

For assessing GHG emissions in urban settings, Taiwan's Environmental Protection Administration (EPA) utilizes key indicators such as GHG emissions per capita and the recycling rates for both solid waste and wastewater.

These metrics promote waste resource reuse, solid waste recycling, wastewater reuse, and biomass energy utilisation and contribute to creating low-carbon cities characterised by high self-sufficiency ratios in renewable energy and energy conservation. The Asia Pacific Economic Cooperation report outlines parameters for low-carbon city achievement, including reductions in CO_2 emissions, energy consumption, traffic volume, waste production, and public transportation usage improvements. Furthermore, the Pittsburgh University Department of Civil Engineering (2009) suggests a structured approach to GHG emissions management, encompassing baseline surveys, emissions reduction targets, local action plans, policy implementation, and results monitoring and verification (Figure 1).

Case Study Keetha, Malaysia- The Low Carbon Cities Framework and Assessment System in Malaysia emphasises the critical role of local governments in initiating carbon emission reduction plans. The process begins with identifying relevant local authorities and stakeholders, including NGOs and local communities, to form a core team. The team establishes carbon reduction goals, outlines the boundaries of the city or jurisdiction sources of CO2 emissions, selects a baseline year, and compiles baseline data. Quality assurance and estimation of emissions follow this foundational step. Subsequently, cities must finalise their targets and devise strategies and programs for implementation, encapsulating these efforts in strategic documents such as a Carbon Reduction Plan, Green City Action Plan, or Low Carbon City Action Plan (KEETHA, 2011).

Renewable energy + energy conservation	Low carbon buildings	Green transportation system	Low carbon living
❖ Renewable energy planning ◆ Wind power ◆ Natural gas replace by Solar thermal energy ◆ Photovoltaic ◆ Bio-mass energy ◆ Hydrogen energy ❖ Energy consrvation ◆ Replacement into highly efficient air-conditioners and refrigerators ◆ Installation of LED and compact fluorescent lamps ◆ Smart meter installation	❖ Low carbon building management ◆ Including foundation conservation, foundation water conservation, water saving, waste reduction, water resource, waste water and refuse improvement ❖ Green building material ❖ Life cycle assessment (Production, process, use, demolition disposal)	❖ Low carbon transportation ◆ Public transport system ◆ Bicycle (electric bicycle) ◆ Electric scooter ◆ Hybrid Car ◆ Low carbon bus (electric, bio-mass, hydrogen) ❖ Smart transport system ❖ Bicycle network system ❖ LED lighting and traffic light ❖ Vehicle lowest efficiency standard	❖ Carbon fixation/sink-planting and green roof ❖ Low carbon consumption – energy saving label, water saving label, environmental protection label products. ❖ Low carbon – eat local foods, eat seasonal foods, do not use disposable cutlery. ❖ Low carbon education – promotion in family, society, school and office.

Figure 1. *Low carbon community promotion*

(Source. Report on Towards Low Carbon Cities in Taiwan (EPA) (2009))

KEETHA in Malaysia has developed performance benchmarks for reducing greenhouse gas emissions, concentrating on four principal areas: Urban Transport, Urban Environment, Buildings, and Urban Infrastructure. Each of these elements encompasses specific strategies for reducing carbon footprints:

i. **Urban Transport:** Emphasising a shift towards sustainable transport modes such as BRTS and MRTS, promoting walking and cycling over private vehicle use, adopting clean vehicles, and implementing vehicle speed and traffic management. The development of pedestrian- friendly infrastructure is also highlighted.

ii. **Urban Environment:** Strategies include site selection that prioritises development within urban footprints to limit sprawl and encourage

Table 1. Assessment for National Green House Gas Inventories

SECTOR	SUB SECTORS	GREENHOUSE GASES
Energy	◦ Stationary Combustion ◦ Mobile Combustion ◦ Fugitive emissions ◦ CO_2, transport, injection and geological storage	◦ Carbon Dioxide ◦ Methane Nitrous Oxide ◦ Perfluorocarbons
Industrial processes and product use	◦ Mineral industry emissions ◦ Chemical industry emissions ◦ Metal industry emissions ◦ Non-energy products from fuels and solvents used ◦ Electronics industry emissions ◦ Emissions of fluorinated substitutes for ozone-depleting substances ◦ Other products manufactured and used	◦ Sulphur hexafluoride ◦ Nitrogen trifluoride ◦ Trifluoromethyl sulphur pentafluoride ◦ Halogen ethers ◦ Other Halocarbons
Agriculture, forestry and other land use	◦ Forest land ◦ Cropland ◦ Grassland ◦ Wetlands ◦ Settlement ◦ Others ◦ Emissions from livestock and manure management ◦ N_2O emissions from managed soils and CO_2 emissions from lime and urea application ◦ Harvested wood products	
Waste	◦ Solid waste disposal ◦ Biological treatment of solid waste ◦ Incineration and open burning of waste ◦ Wastewater treatment and discharge	

Source. (1) Intergovernmental Panel on Climate Change (2006), Guidelines for National Greenhouse Gas Inventories, Cambridge University Press, Cambridge. (2) Dodman (2009) (3) Sahni and Aulakh (2014).

growth within existing urban areas. This approach encourages infill development, redevelopment, and development around transit nodes. The criteria also emphasise mixed-use development to enhance urban density and self-sufficiency and preserve natural ecosystems and green open spaces.

iii. **Buildings:** Focuses on reducing energy usage by incorporating renewable energy sources and adopting energy-efficient methods in the design and management of buildings.

iv. **Urban Infrastructure:** Includes the integration of wastewater management and recycling, the use of recycled water for irrigation, the encouragement of rainwater harvesting, and the construction of retention ponds and canal systems to manage water sustainably.

The Malaysian Government's approach involves a comprehensive process for identifying and developing low-carbon cities or townships. This process encompasses the measurement of GHG emissions, definition of carbon reduction strategies, periodic tracking of emission levels, application of online calculators for establishing baseline emissions, implementation of measures, and strategising for additional measures to progress towards net-zero carbon emissions. (Figure 2).

This successful case study from Malaysia offers valuable lessons for Indian cities pursuing low-carbon development. While work is underway at the national level in India, examining and adapting successful international examples can provide a roadmap for effectively addressing urban carbon footprints and advancing towards low-carbon urban development.

Indian Interventions for Low-Carbon Cities

India's initiatives for developing low-carbon cities span policy and planning, program implementation, agency involvement, and city-level actions. These concerted efforts are designed to mitigate the effects of climate change and foster sustainable growth in cities.

i. **Policy and Plan Level:** India's National Action Plan on Climate Change (NAPCC) represents a comprehensive approach towards mitigating greenhouse gas (GHG) emissions by adopting new technologies and institutional mechanisms. Enacted in 2006, the Integrated Energy Policy underpins India's commitment to enhancing energy efficiency across all sectors, prioritising mass transportation systems, and fostering renewable energy sources, including bio-fuel plantations. It also accelerates the development of nuclear and hydroelectric power as sources of clean energy and strongly emphasises research and development in clean energy technologies. Furthermore, the NAPCC introduced the Energy Conservation Building Code (2007). This code provides energy efficiency guidelines for the design of new, large commercial buildings, considering the varied climatic conditions across India. In the same year, energy audits became mandatory for large industrial consumers to facilitate annual reporting on energy use and conservation efforts. The plan encourages the widespread use of public transportation and non-motorised modes of travel alongside the expansion of Mass Rapid Transit Systems (MRTS) in Delhi and other cities.

Clean air initiatives form a crucial aspect of the NAPCC, including introducing Compressed Natural Gas (CNG), phasing out older, polluting vehicles, and reinforcing mass transportation systems. Some state governments have implemented incentives such as subsidies for purchasing and using electric vehicles. The Bureau of Energy Efficiency has also played a pivotal role in promoting energy-saving devices, alongside advocating for the increased use of bio-diesel and bio-fuels.

The NAPCC delineates eight specific missions to guide India's climate change strategy: the National Mission for Enhanced Energy Efficiency, the National Solar Mission, the National Water Mission, the National Mission on Sustainable Habitat, the National Mission for Sustaining the Himalayan Ecosystem, the National Mission for Sustainable Agriculture, the National Mission for Green India, and the National Mission on Strategic Knowledge for Climate Change. Each initiative focuses on a distinct environmental issue, creating an integrated strategy for India to tackle the challenges of climate change.

ii. **Program Level:** The United Nations Environment Programme (UNEP) has taken significant steps to encourage the adoption of low-carbon transportation methods in India, allocating a budget of 2.49 million pounds for a project spanning from 2010 to 2013. Partnering with local institutions, the program aims to develop a national 'Transport Action Plan' alongside 'Low Carbon Mobility Plans' for up to four cities. The SIM-air model, created by Urban Emissions. info, has been utilized in cities like Rajkot, Vishakapatnam, and Udaipur to assess the impact of transportation emissions on local air quality and health. This model connects vehicle emissions data with air concentration levels to provide insights into their effects.

- The SIM-air Model (Simple Interactive Models for better air quality), serves as a comprehensive air pollution analysis tool, facilitating the transition from emission estimation to evaluating pollution impacts and optimising for improved air quality. This model, accessible under the 'Modelling Tools/SIM-air' section, showcases case studies from various cities.
- VAPIS (Vehicular Air Pollution Information System) is a calculator for estimating and comparing vehicular emissions inventories, supported by a comprehensive database of emission factors.
- Smart-CART (Carbon Analysis for Road Transport) provides a user-friendly method for conducting carbon analyses on road corridors, with the flexibility to account for various pollutants.
- The Air Quality Index Calculator simplifies the process of estimating real-time or predicted AQI and is extensively used in numerous cities worldwide.
- The Atoms Dispersion Model, a Fortran-based Varangian dispersion tool, generates transfer matrices for different sources and pollutants, allowing for integration with the SIM-air model for comprehensive evaluations.

- V-Dust provides a user-friendly tool for estimating fugitive dust emissions from road vehicles.

Collectively, these tools support the assessment and planning for low-carbon mobility and improved air quality in urban areas, reflecting UNEP's commitment to sustainable transport initiatives in India.

iii. **Agencies Involved:** ICLEI South Asia, in collaboration with the British High Commission, USAID, and the United Nations Environment Programme (UNEP), actively contributes to low-carbon development by publishing reports on clean energy funds and financing opportunities for low-carbon growth in Indian cities. These reports extensively discuss how local governments can initiate low-carbon development strategies. Funded by the British High Commission, the program executed by ICLEI South Asia resulted in the development of carbon emissions inventories for 41 Indian cities. This comprehensive inventory includes emissions from community-level activities—such as residential, commercial, industrial, transportation, and waste disposal—and corporation activities, including building facilities, street lighting, water supply, sewerage, and transportation (Figure 3).

iv. **City Level:** The Eco-City Initiative in Auroville, Puducherry, has been a pioneering model for sustainable living and low-carbon development since its inception in 1968. Recognized by UNESCO as a prototype of the future's universal city, Auroville focuses on low-cost building technologies, sustainable lifestyles, food security, and organic farming. The community promotes using battery-operated vehicles and bicycles, eschewing conventional cars within the village. Innovative technologies have been introduced, such as solar and wind-powered electric pumps for wells, environmentally friendly septic tank systems that facilitate composting for forest use, and bio-

Table 2. The ICLEI Study on 41 Cities - Distribution of GHG Emissions Across Different Sectors

Sector	Contribution of Emissions from Each Sector
Community Level Activities -	
◦ Residential	05–20%
◦ Industrial	10–60%
◦ Transport	10–40%
◦ Solid Waste	03–15%
Corporation Level Activities	
◦ Street Lighting	40–70%
◦ Water Supply	15–25%
◦ Building and Facilities	20–40%
◦ Transportation	05–15%

Source: Urban Low Carbon Growth, ICLEI, 2012 gas stoves for efficient cooking. Inspired by Auroville's initiatives, the Indian Government's Ministry of Environment and Forestry launched six pilot eco-city projects in 2001. These projects aimed to implement eco-friendly practices in the pilgrimage cities of Puri, Kottayam, Thanjavur, Ujjain, Tirupati, and Vrindavan to promote sustainable urban living. This effort aimed at integrating sustainable urban development practices within these historic cities. In 2010, the Ministry of Commerce and Industry unveiled plans to build four new eco-cities (Changodar, Dahej, Manesar Bawal, Shendra) along the Delhi–Mumbai Corridor. This initiative aims to expand the eco-city concept into newly developing urban spaces, emphasising sustainable urban development and environmental preservation. In addition to these initiatives, the Ministry of New and Renewable Energy launched a 'solar cities' program in 2011, with 36 pilot projects to promote renewable energy and reduce dependence on fossil fuels. Collectively, these efforts mark a significant step towards fostering environmentally sustainable and low-carbon urban environments across India.

Approaches For Developing Low- Carbon Urban Areas In India

In "Low Carbon City: Policy, Planning and Practice," Ashok Kumar Jain advocates for a critical need for an integrated approach to managing ecology and conserving natural resources in urban environments. He advocates for addressing environmental challenges at multiple spatial levels to create a strategic matrix that guides policy, strategic, and operational actions, focusing on essential environmental infrastructures like water, sewerage, solid waste, and transportation (Jain, 2009). Strategies for carbon reduction often involve changes in consumption patterns, such as transitioning from personal to public transport, exemplified by Delhi's rail-based mass transit system (IIR, 2010). Colliers International in China recommends several remedial actions for urban areas, including enhancing energy efficiency in transportation and buildings, fostering low-carbon industries, raising public awareness about energy conservation, supporting clean energy sectors, consolidating industrial energy savings, improving forestry management, and promoting eco-agriculture (Colliers International, IBE, 2012).

According to ICLEI, urban planning should incorporate Transit Oriented Development (TOD) bylaws, low-carbon development and city green guidelines, and development control regulations, adopting green development principles in municipal services and planning schemes. The organization emphasises the significance of adopting green procurement policies, monitoring carbon emissions, and encouraging renewable energy production. It also features initiatives like solar water heating systems and solar-powered billboards. Moreover, collaborative efforts among various entities have facilitated the development of macroeconomic and city-specific indicators to advance low-carbon transportation initiatives in India.

Lessons for Developing Low-Carbon Urban Planning

Establishing a low-carbon city begins with formulating an elaborate master plan that specifies land use zones and controls over building parameters such as height and density, integrating carbon reduction strategies focused on enhancing low-carbon transportation options like Bus Rapid Transit, Light Rail Transit, and Mass Rapid Transit systems. This comprehensive approach requires the involvement of a broad spectrum of stakeholders, applying regulatory frameworks to govern air, water, and energy standards (APEC, 2011). The subsequent phase involves analysing the city's energy consumption patterns and setting quantifiable carbon emission reduction targets, which entails detailed data collection on energy utilisation and CO_2 emissions across key sectors, including residential, transportation, and energy.

Without an international standard for city emission assessments or a structured guide for urban emission inventories, urban planning authorities have taken the initiative to compile such inventories independently. These initiatives focus on measuring the overall carbon footprint resulting from urban activities, raising awareness about the urgency of mitigating climate change, and setting standards for assessing the success of emissions reduction efforts (Dodman, 2009).

Conclusion

The imperative for future generations is the establishment of low-carbon cities, necessitating a systematic approach to managing carbon footprints and implementing rigorous carbon emissions assessments in India, akin to practices in Malaysia and Europe. The master plan for such cities must articulate norms and standards akin to those of eco-cities, including spatial standards for varied land uses. Moreover, adopting low-carbon transport mobility plans should be mandated across all Indian states. The implementation of rainwater harvesting systems, as exemplified by Tamil Nadu, must become obligatory to ensure timely groundwater recharge. Additionally, the calculation of carbon footprints, expressed in CO_2 equivalents, should extend to all states and districts, facilitating a comprehensive inventory of GHGs for various Indian cities, a task currently undertaken by ICLEI. Envisioning cities with minimal or zero carbon emissions represents a visionary goal for urban planners, with successful realization heralding accolades from future generations.

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CLIMATE RESILIENT, GREEN AND LOW CARBON BUILT ENVIRONMENT

ASHOK KUMAR JAIN

Author of Book: Climate Resilient, Green and Low Carbon Built Environment

Book Review by: *Dr. Akshaya Sen, GM(Economics), HUDCO aksen@hudco.org*

Christopher Benninger in his Foreword states "A.K. Jain, the author of Climate Resilient, Green and Low Carbon Built Environment brings into play profound personal attributes that no other urban thinker in Asia holds. He is India's most experienced urban planner and policy maker, nurtured through his years in public service. He has enriched this saga of experience, with the devoted curiosity of a true guru, with unbound intellectual energy and passion, sharing his thoughts through his years of writing. From the time I founded the School of Planning at CEPT in 1971, until now he has been a mentor and guide. Rather than asking questions, A. K. Jain catalysed my thinking with new possibilities, interesting options, and in the current book straight forward answers."

Introduction

We are midway in implementing the 2030 Agenda for Sustainable Development Goals and the Paris Agreement on Climate Change, which both were adopted in 2015. In the midst of intense heatwaves, and floods, we are slipping in holding temperature rise to 1.50 C. Also, the Sustainable Development Goals Report (2022) indicates a backlog in the progress in achieving the SDGs.

The backlog in achieving the SDGs and rise in temperatures, recurring floods and extreme weather events warn us to revisit our development models. This involves a shift towards development that converges health, happiness, knowledge, greenery, ecology, water, energy, financial and material aspects. Built environment is an integral part of development that integrates ecology, service networks, transport and heritage.

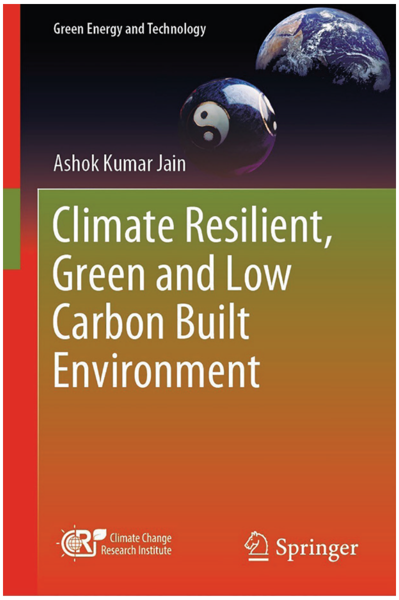
A.K. Jain, the author of 'Climate Resilient, Green and Low Carbon Built Environment' points out that the cities face significant impacts from climate change, which have serious consequences for human health and livelihoods, especially for the urban poor. Cities around the world have begun to plan for climate change by developing climate action plans and policies, which aim at heat mitigation and climate resilience.

According to the author, buildings in India account for 40 % of energy use, 30% of raw material use, 20% of water use and 20% of land use. They generate 30% and 20% of solid waste and liquid effluents, respectively. The building sector is responsible for 24% of India's CO_2 emissions, contributing to climate change, warming and poor air quality. They also impact the availability of water, recurring floods, and drainage. As buildings are the largest energy users, making them net zero and incorporating energy storage into them are essential for low carbon development. The concept of energy efficiency, renewable energy and Zero-fossil Energy Development (ZED) can reduce the energy demand and consequential pollution. A series of low carbon zones with renewable and tri-generation energy systems can lead to green energy.

The author emphasises that the urban networks with circular metabolism can give as much to the environment as they take out, thus reducing the ecological impact. An ecological city and the buildings respect the nature to minimise the use of energy and natural resources. The natural environment can be protected by minimising the use of energy and mechanical systems and design with nature- the sun, wind, water, earth and space. A major component of planning must be Heat Mitigation Plan, that mandates use of heat reflective and permeable materials for rooftops, pavements and roads together with insulation, white paint, cavity walls, water, fountains, vegetation and ventilation.

The book Climate Resilient, Green and Low Carbon Built Environment underlines that the cornerstone of making a city sustainable is to adopt an integrated approach towards the regional, physical, environmental, transport, social, legal, management, financial and other aspects. It aims to strike a balance between individual freedom versus community interests, commercial opportunity versus environmental sustainability and public service versus mandatory procedures. This requires a radical transformation of the planning and development of the built environment.

According to the author, the plans of built environment should adopt a circular loop integrating the nature (climate, greens and low carbon), the people (socio-economic, circular economy, culture, education, health, mobility, community participation) and fourth industrial revolution (digital planning, smart, intelligent and interconnected processes, SCADA, blockchain, discreet optimisation, algorithm, AI, big data, etc.). According to the author, for a smooth transition towards a climate resilient, net zero and low carbon urban development, digital processes such as Computer-Aided Manufacturing (CAM) and Computer Integrated Manufacturing (CIM) are essential. Smart chips can be embedded almost in every urban service. With digital chips, cities are increasingly getting digitally scripted and coded. It can enable digitisation of urban planning and design, land uses, housing and infrastructure services for efficiency and climate resilience.



The breakthrough in digital technology and informatics can help in the engagement of citizens for on-line participation and services by adopting the GIS, SDI, big data analytics, ERP solutions, digital dashboard, blockchain, AI, ML DL, etc. The urban plans should converge with the recent flagships of Government of India, viz. Sustainable Urban Networks for Dynamic and Resilient (SUNDAR) India and Lifestyles for Environment (LiFE) Missions.

URBAN CENTERS & ANTHROPOGENETIC CONTRIBUTION TO CLIMATE-ALTERING GAS EMISSION

ABHIK DAS[1]
SOMSUBHRA PANDA[2]

Because of the high population density, industrialisation, transportation, and infrastructure in cities, these places contribute significantly to the world's greenhouse gas emissions. This paper delves into the topic of cities and greenhouse gas emissions, specifically looking at where these gases come from, how urbanisation affects them, and what can be done to reduce them. Greenhouse gas emissions from buildings, transportation, and waste management account for the bulk of global emissions, and urban areas are major contributors to this problem. Factors contributing to this phenomena include the high population density and energy-intensive activities seen in urban areas. The task of lowering emissions is growing in importance in response to the rising rate of urbanisation.

Keywords: *Policies, environmental effect, rising temperatures, energy use, climate change, and a case study.*

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1. First Things First

The advancements and innovations in cities have become detrimental to the environment. The environment is being depleted of life-sustaining substances due to the impact of urban areas, which are home to millions of people, automobiles, industries, and structures. While technological advancements have made people's lives easier, we must now use these same tools to discover a way to preserve Earth and its inhabitants. Since we can't turn the clock back to an earlier era, we need to update our current technology and systems to lessen the impact of the greenhouse effect. Earth is becoming hotter due to greenhouse gas emissions, which cover the globe and trap heat. Cities contribute significantly to the release of greenhouse gases, which include carbon dioxide, methane, and nitrous oxide. Urban areas are vital to economies worldwide, but the environmental impact of fossil fuel-powered machine is a major area of concern. Scientists the world over are working tirelessly to find ways to wean humanity off of these fuels and replace it with renewable energy sources. To encourage sustainable behavioural pattern cities must enact laws to facilitate investment in green infrastructure, making buildings more energy efficient, and making public transport more appealing. [1].

Increasing Global Temperatures: The greenhouse effect is the process by which certain gases in the atmosphere absorb and retain heat from the sun's rays. Greenhouse gas concentrations have risen due to deforestation, industrial gas emissions, fossil fuel consumption (coal, oil, and natural gas), and other human activities. Sea level rise, ecological and biodiversity impacts, more frequent and intense weather extremes, and ice and glacier melting are all results of a steady increase in global warming [2].

Extreme Weather Events: Climate change exacerbates extreme weather events, such as heat waves, droughts, floods, storms, and wildfires, making them more often and catastrophic. Natural disasters are notorious for displacing whole communities and wreaking havoc on vital infrastructure.

Loss of Biodiversity: Climate change has altered marine, terrestrial and fresh water ecosystem around the world. It has caused the loss of local spaces resulting in the climate driven extinction. This endangers the planet's health and impacts human services. Even if they haven't contributed to greenhouse gas emissions it is the poorer people and developing countries that are bearing a disproportionate share of the burden of climate change [3].

2. Urbanisation and Emissions

The world is more urbanised, which is causing environmental degradation. Overheating, glacier melting, steadily increasing global temperatures and other problems are all consequences of the carbon footprint of human activities.

2.1 Relationship Between Urbanisation and Increased Greenhouse Gas Emissions

Factor	Explanation	Ref.
Density of population	As more and more people settle in one area, challenges arise in areas such as energy consumption, transportation, and construction density, as well as the overcrowding of already-limited land. More people using it means more fossil fuels used overall, which means more greenhouse gas emissions.	4
Boost to the economy	The environment is benefiting from economic progress, but individuals need to overcome the barrier to economic growth while also aiding the environment by reducing greenhouse gas emissions. Toxic emissions from transportation and industry have a negative impact on environmental health. People need to realise that a healthy atmosphere is essential to their success.	5
Transportation	A normal daily increase in the usage of personal vehicles has an impact on the environment via the expansion of carbon footprints. Additionally, infrastructure and use determine the environmental impact of public transportation systems.	2
Land-use change	Reduced plant and soil carbon sequestration capability is a common consequence of urbanisation, which entails turning natural land into built-up regions.	5
Infrastructure development	The development and maintenance of new infrastructure, including power stations and transport networks, may result in the release of pollutants. Renewable energy decisions made in the interest of sustainable infrastructure, however, might lessen this effect.	3
New developments in technology and creative thinking	Innovations in sustainable practices, energy efficiency, and renewable energy may flourish in urban settings because of the easier access to more sophisticated resources and technology. In the long term, this may cause emissions to decrease.	4

2.2 Greenhouse emissions in urban areas [6]:

i. **Population Density:**

- More people per unit area means more energy consumption, which in turn means more pollution from power plants and less sustainable consumer habits in already overcrowded urban areas.
- The need for structures, transportation systems, and garbage collection systems all increase in tandem with population growth. Dust, vehicle use and resource exploitation are adding to emissions.

ii. **Business Operations:**

- Industrial processes: In order to generate energy, power generating agencies need fossil fuels, which release harmful gases and particles into the air and harm the ecosystem. In addition to adding to global warming, these emissions may have an immediate effect on air quality.
- Manufacturing and processing waste results in a great deal of garbage, some of which, when dumped in landfills, may produce toxic gases like methane. Emissions from vehicles and machines are also a major contribution to GHG emissions.

3. Sources of Greenhouse Gas Emissions in Cities [7].

Transportation	Pollutant: Nitrogen oxides (NO_2), carbon monoxide (CO), and volatile organic compounds (VOCs) Sources: Cars, trucks, mostly older models and those powered by fossil fuels.
Energy consumption	Pollutant: Carbon dioxide (CO_2), NO_2, SO_2 (sulfur oxides) Sources: 1. Creating power, especially from coal-fired power stations, is a major source of greenhouse gas emissions. 2. The use of heating, cooling, and electricity in both business and residential buildings results in the release of pollutants.
Environmental cleanup	Pollutant: Methane (CH_4), CO_2, VOCs Sources: 1.Organic waste decomposes on land, releasing the powerful greenhouse gas methane. 2. Vehicles that gather and carry garbage also add to air pollution. 3. Despite its occasional application for energy production, burning garbage generates damaging chemicals and particles.

iii. **Transportation:**

Commuters in urban regions often use big personal automobiles, which result in a substantial amount of exhaust emissions. This is particularly the case in places where public transport options are few or when the city layout priorities the use of private automobiles. There is an urgent need to transition from gas-powered to electric cars.

4. Real-Life Examples

Pune: The "Pune Climate Change Action Plan" had a greater focus on renewable energy, energy-efficient construction methods and enhanced public transport, all of which contributed to a decrease in greenhouse gas emissions in Pune. Electric car usage and the introduction of programmes like the Rainbow BRT (Bus Rapid Transit) system helped Pune reduce emissions from transportation [9].

Ahmedabad: In light of the fact that heat waves are becoming more often and intense due to climate change, Ahmedabad has instituted the "Ahmedabad Heat Action Plan" to confront this problem. Early

3.1 The major sources of Emissions in urban environments such as [8] :

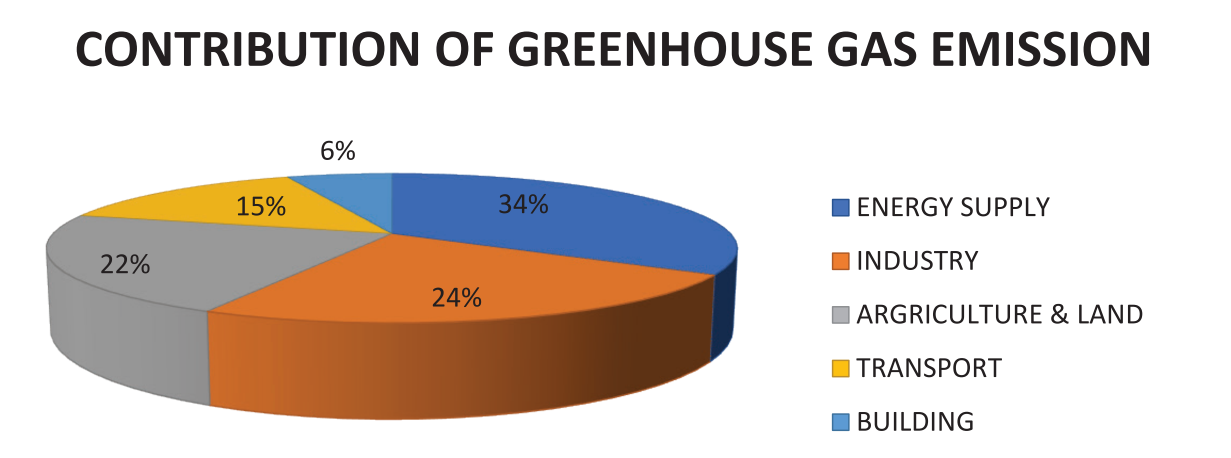


Fig 1: Analyze the relative contributions of different sectors to overall greenhouse gas emissions

warning systems, public awareness campaigns, and infrastructure enhancements were the main focuses of the strategy to reduce the impact of heat waves. The city of Ahmedabad successfully decreased its emissions of greenhouse gases by enacting measures to increase green space and decrease energy use [10].

4.1 Highlight Strategies and Policies Implemented by these Cities, such Assustainable Urban Planning, Public Transportation Improvements, and Renewable Energy Adoption.

State	Sustainable Urban Planning	Public Transportation Improvements	Renewable Energy Adoption	Ref.
Pune	The Pune Metro Rail project aims to provide a carbon-friendly transit option, hence reducing the city's dependency on private vehicles. The 'Pune Streets Programmed' program aims to encourage non-motorized mobility by improving pedestrian walkways and adding bike lanes to upgraded highways. More than 1,000 km of major road improvements are being made in cities to improve commuting safety for all users, including bikes and pedestrians.	Despite the dearth of data on extensive usage of renewable energy, Pune is embracing sustainable practices. Examples of programmes that aim to preserve resources include the "knowledge management for sustainable use of groundwater" programme.	The municipal corporation (PMC) is deploying a fleet of green buses that run on compressed natural gas (CNG) in an effort to combat air pollution. In addition, they are encouraging people to install rooftop solar panels for the production of sustainable energy by offering tax rebates, financial incentives, and government subsidies. Additionally, in an effort to diversify its energy sources and lessen its reliance on fossil fuels, the PMC is funding renewable energy projects like solar parks and wind farms. To reduce energy usage and carbon emissions, energy-saving enhancements are also being made to public infrastructure, streetlights, and municipal buildings.	9, 12

State	Sustainable Urban Planning	Public Transportation Improvements	Renewable Energy Adoption	Ref.
Ahmedabad	Janmarg, Ahmedabad's Bus Rapid Transit (BRT) system, gives high-frequency buses a dedicated corridor. Travel times, air pollution, and traffic congestion are all decreased as a result. The city concentrates on improving public areas like parks and plazas to make the area more bike- and pedestrian-friendly. Preservation of the Past Ahmedabad places a high priority on maintaining its historic districts and rich heritage monuments, encouraging cultural identity.	With the completion of the Ahmedabad Metro rail project, the city will have a high-capacity rapid transit system. The city encourages non-motorized transportation, such as walking and biking, by building bike lanes and improving infrastructure. By providing short-term bike rentals to both residents and visitors, the Amdavad Cycle Share programme promotes bicycling as a sustainable and healthy mode of transportation.	Initiatives for Solar Power: To encourage rooftop solar installations on residential and commercial buildings, the city has launched a number of initiatives. Ahmedabad makes use of waste-to-energy plants, which turn waste materials into electrical power that may be used. Green building regulations: To promote environmentally friendly building techniques for new construction, the city has put green building guidelines into place.	10,13, 14
Delhi	The Master Plan Delhi-2041 places a strong emphasis on the construction of green space, mixed-use development, and smart land use to minimise the need for travel. Encouraging Transit-Oriented construction (TOD) reduces dependency on private vehicles and promotes walkability by ensuring that construction is centered around public transportation hubs.	The goal of Delhi's EV Policy is to decrease pollution and dependence on fossil fuels via the widespread use of electric cars (EVs), with a particular focus on 500,000 EVs. There has to be a system in place to facilitate the sharing of bikes and feeder buses between public transit stops and final destinations.	With the aim of meeting 10% of the city's energy demands using solar power, the Delhi Solar Policy promotes rooftop solar installations. Incorporating energy-saving features into buildings, streetlights, and other infrastructure to decrease total energy use and carbon emissions.	11, 15

Delhi: The Delhi Electric Vehicle Policy was introduced by the Delhi government to promote the use of electric cars (EVs) and to provide charging infrastructure throughout the city. The city has also invested in the expansion of the metro rail system to minimise air pollution and its reliance on private vehicles [11].

5. Challenges Faced by Cities

5.1 Challenges faced by cities in mitigating greenhouse gas emissions [16]:

Various sectors, including transportation, construction, manufacturing and waste management, contribute to GHG emissions in urban areas.

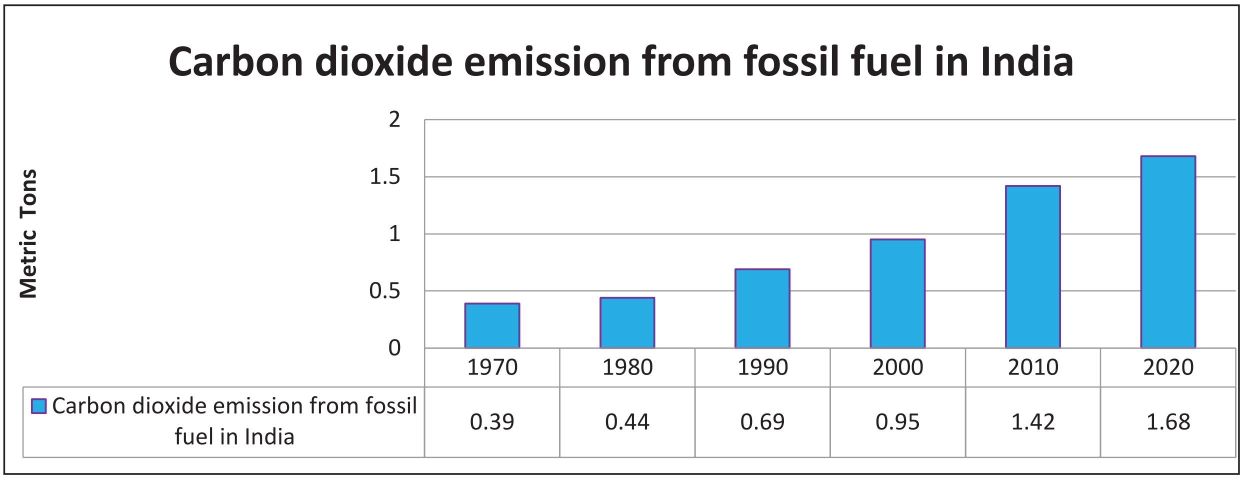


Fig 2: Carbon emission in India

5.2 Address Mitigating issues:

Limited resources [17]:

- Limitations on available funds: Municipal governments often have financial crunch/ constraints, which provide a challenge when it comes to funding extensive initiatives aimed at reducing emissions, such as improving renewable energy infrastructure or expanding public transportation.

- Problems with available human resources: Cities may have a dearth of qualified individuals with the requisite experience to carry out and oversee intricate sustainability projects.

Conflicting interests among stakeholders [18] : Even if environmental protection measures might be beneficial in the long term, companies may fight against rules or laws that raise their operating expenses. Also, Even if they are aware of the environmental advantages, residents may still be resistant to changes that interfere with their everyday lives, such as new sustainable infrastructure development projects or limits on automobile use. The optimal way to reduce emissions may be difficult to agree upon since many community groups may have competing goals.

6. Technological Solutions

Technology is vital for a country's progress.

6.1 Cities can reduce emissions with help of such solutions as smart grids, energy-efficient buildings, and sustainable transportation solutions [19] [20].

A. Smart grid: A "smart grid" is one that generates electricity not from fossil fuels but from renewable sources, such as solar and wind. Reduce emissions from power generation by switching to renewable energy sources and dismantling backup fossil fuel power stations. With smart grid technology, customers may respond to changes in supply and demand by adjusting their use. Smart networks assist decrease emissions by shifting consumer electricity demand to off-peak hours, when renewable energy supply is high. This helps minimise reliance on thermal power plants that use fossil fuels during peak hours. By facilitating the installation of sophisticated metering infrastructure and smart metres, smart grid technology improves the ability to track energy usage trends in real time. In the end, this data

6.2. Assess the Feasibility and Effectiveness of these Technologies in Different Urban settings.

	Feasibility	Effectiveness	Ref
Infrastructure	The feasibility of infrastructure projects depends on factors such as available land, financial resources, and technological capabilities. Larger cities may have more resources and expertise to implement complex infrastructure projects, while smaller cities may face budgetary constraints and logistical challenges.	Well-designed infrastructure projects can have significant positive impacts on emissions reduction. For example, implementing efficient public transportation systems in densely populated urban areas can encourage residents to use cars less frequently, leading to reduced emissions.	21
Regulations	Implementing regulations to curb emissions may face challenges such as resistance from industries, legal constraints, and enforcement issues. The feasibility of regulations depends on factors such as political will, public support, and regulatory capacity.	When it comes to reducing emissions, well-designed rules may work wonders. Greenhouse gas emissions may be significantly reduced, for example, by establishing car emission regulations or by requiring energy efficiency measures for buildings.	23
Resource	The execution of programmes to reduce emissions is dependent on the accessibility of resources, including human and financial capital. It may be simpler to finance infrastructure improvements and execute laws in cities with robust economies and access to financial sources.	If we want to reduce emissions, we need to make sure that resources are used correctly. Take renewable energy projects as an example. They may assist cities in their transition away from fossil fuels. However, these endeavours may face challenges in obtaining sufficient money and support to really make a difference.	22
Stakeholder Engagement	Important considerations for the viability of infrastructure projects include the availability of land, funding, and technical expertise. Complex infrastructure projects may be more easily accomplished by larger cities due to their access to greater resources and knowledge, whereas smaller communities may face challenges related to funding and logistics. Important considerations for the viability of infrastructure projects include the availability of land, funding, and technical expertise. Complex infrastructure projects may be more easily accomplished by larger cities due to their access to greater resources and knowledge, whereas smaller communities may face challenges related to funding and logistics.	Better decisions, greater public support, and longer-lasting results may result from genuine stakeholder participation. Emission reduction plans may be better adapted to meet the requirements and goals of specific communities if stakeholders are involved in their development and execution.	21

may help decrease emissions and energy consumption by revealing inefficiencies and allowing for the implementation of energy-saving techniques like load balancing and load shifting.

By controlling how EVs charge during off-peak times, smart grids ease grid congestion and facilitate their widespread adoption. Smart grids may also work in tandem with renewable power plants to reduce transportation-related emissions even more by charging electric vehicles first during peak renewable power production times.

B. Energy-Efficient Buildings: Compared to conventional buildings, energy-efficient designs are designed to use less energy for a variety of systems, including HVAC, cooling, and lighting. By reducing the need for mechanical heating and cooling, proper insulation, orientation, and natural ventilation in buildings energy consumption and emissions can be significantly brought down. Automation systems and smart thermostats work together to provide precise control over energy use, which lowers emissions by using energy only when it's needed. Making the most of natural light minimises the need for artificial lighting, which lowers power output emissions.

Sustainable building materials also cut emissions by lessening their impact on the environment during production and transit. Further lowering energy use and emissions in buildings can be achieved by educating people about effective building utilisation and promoting habits like switching off lights and appliances when not in use.

C. Sustainable Transportation Solutions: Electric vehicles (EVs), public transit, and micro-mobility solutions are some of the most environmentally friendly automotive options; then conventional, fossil fuel-powered cars.

7. Policy and Governance

7.1 Examine the role of government policies and regulations in shaping cities' approaches to greenhouse gas reduction [24] :

i. **Advancing Sustainable Energy:** The goal of the Development of Solar Cities Scheme is to encourage the installation of solar water heating systems in buildings and to provide financial and technical assistance in order to increase energy efficiency and the utilisation of renewable energy sources in sixty cities. The government of India has proposed regulations and subsidies for rooftop solar installations on residential, commercial, and public buildings via net metering. Urban areas may benefit from solar park designs and energy-efficient roof shading systems. In order to encourage the use of solar electricity and reduce carbon emissions from the grid, the Indian government has instituted a number of policies and subsidies aimed at the end user or solar user.

ii. **Smart, sustainable cities** are the aim of this mission, which may prioritise the reduction of emissions via the enhancement of public transport, waste management, and traffic control. The goal of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) programmes is to decrease greenhouse gas emissions by encouraging cities to finance green infrastructure, solid waste management and urban forestry.

Evaluate the effectiveness of different policy measures and identify potential areas for improvement.

Find ways to make policy better by analysing the results of various initiatives.

The "Development of Solar Cities Scheme"—Muft Bijli Yojana—and other solar power initiatives have led to a dramatic rise in the capacity for renewable energy. This has the immediate effect of decreasing emissions and dependence on fossil fuels.

Improved Vehicle Standards: Tighter emission regulations (BS VI) have probably made people drive cleaner cars, which has helped lower pollution levels and greenhouse gas emissions, especially in cities.

Smart City Potential: The Smart Cities Mission is an encouraging movement towards more environmentally friendly policies and procedures, such as more efficient building design, better public transit, and more effective waste management. Reducing emissions is possible with all of these.

Final Thoughts and Suggestions: There are some good things about the ideas put forth by the Indian government, but in order to turn them into reality, we need to improve local capacity, we must provide cities more authority and better tools so that they can carry out federal plans.

Innovating in the Financial Sector: Finding new ways to raise money, luring investors from the private sector, and looking into foreign financing possibilities may all help cities implement their climate action plans.

Comprehensive Strategy: Addressing Emissions from All Sources, Not Just Renewable Energy, Including Power Generation and Industry.

To encourage further reductions in emissions, market-based solutions should look at carbon pricing systems, such as emissions trading programmes or carbon taxes.

Engaging the Public: Raising Climate Change Awareness and Emphasising the Need for Sustainable Lifestyles.

8. Community Engagement [25]

a. Importance of community involvement in emission reduction efforts.

i. Changing Behaviour: We can bring about a greener world by collaborating with local citizens, companies, and groups. One way to lessen the impact of the greenhouse effect is to push for more eco-friendly lifestyle choices in individuals. This may include switching to renewable energy, using public transportation. There is a greater feeling of communal pride and solidarity when people pitch in to lower emissions. There may be a snowball effect of good change if this momentum encourages and inspires others to join in.

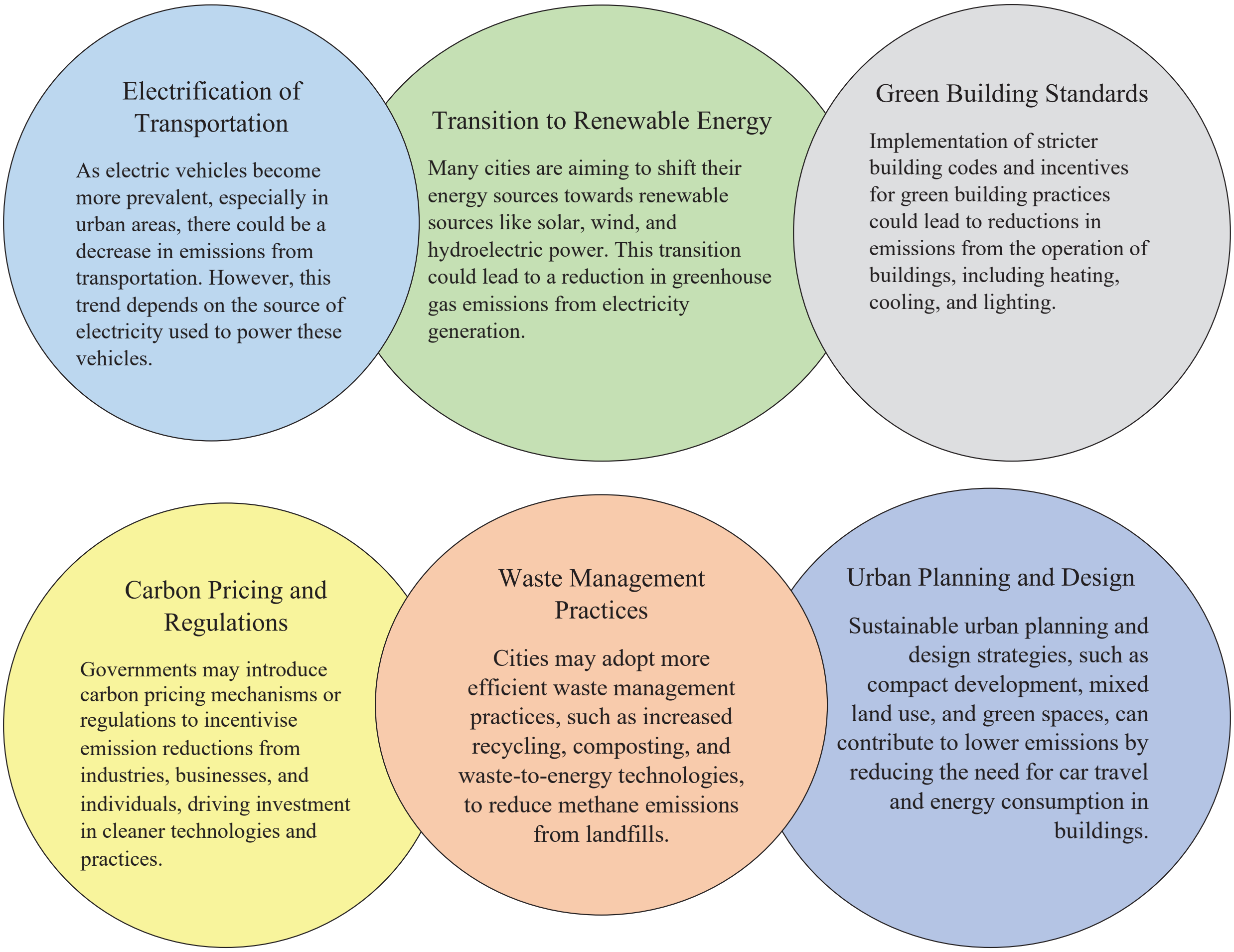
ii. Education and Awareness: With the help of the community, word gets out about how harmful emissions are to the ecosystems and people's health. Communities may enable people to act and make educated decisions by educating them on sustainable practices and increasing awareness of the significance of reducing emissions. To bring attention to the issue of climate change and the need of reducing emissions, community groups may organise events, seminars, and campaigns. Through sector collaboration, innovation, and partnership, community, local government agencies, non-profits, and corporations may identify effective ways to reduce emissions.

iii. Advocating for Change: A Strong Community Has Power. Citizens may encourage their state and federal governments to invest in renewable energy and implement stronger restrictions to reduce emissions by

B. Highlight Successful Community-Based Initiatives that Contribute to a Sustainable Urban Environment.

Programmes for the Control of Waste
Waste management is one of the biggest problems in India's cities. Some cities have seen a rise in community-driven trash management efforts, such as the "Zero trash" movement in Bengaluru and Pune. Citizens have banded together to compost organic trash, recycle non-biodegradable materials, and sort garbage at the source. These programmes help the circular economy by reusing and recycling materials, which eases the load on city waste management systems [23].
Water Conservation
There has been a rise in community-based water conservation initiatives in water-scarce cities like Bengaluru and Chennai. Recharging aquifers, reducing floods, and ensuring that ecosystems and people have access to clean water have all resulted from community-led efforts in rainwater collecting, watershed management, and groundwater recharge [23].
Community Gardens and Open Areas in Cities
As a solution to the problems of food insecurity and ecological degradation, several Indian cities have taken up urban gardening. Initiatives like community farms and rooftop gardens not only provide access to healthy food, but they also foster a more diverse ecosystem, lessen our impact on the environment, and bring people together. A number of initiatives, such as Delhi's "Urban Agriculture Network" and Mumbai's "Green Revolution," have shown how urban farming can make cities better places to live. Urban gardening initiatives have taken root in three major Indian cities—Delhi, Mumbai, and Kolkata—and are transforming abandoned lots and roofs into verdant urban parks. Along with enhancing biodiversity and air quality, communal gardens like this also facilitate local food production and social engagement. They also provide a forum for teaching people about eco-friendly lifestyle choices [24].
Environmentally Friendly Mobility
With pollution from cars on the rise and traffic jams becoming worse, it's more important than ever to encourage environmentally friendly transit options for city dwellers. Pune, Bengaluru, and Chennai are just a few of the places where community-led programmes encouraging walking, bicycling, and public transit have been really taking off. These efforts decrease carbon emissions, ease traffic congestion, and encourage better lifestyles among inhabitants [25]. They include organising bicycle events, pushing for pedestrian-friendly infrastructure, building carpooling networks, and advocating for bike lanes.
Renewable Energy Adoption
To lessen our impact on the environment and our reliance on fossil fuels, we must go down the road of renewable energy. A number of metropolitan Indian cities have launched renewable energy initiatives to collect power from the sun, the wind, and other natural phenomena. Cleaner and more sustainable energy is the future thanks to projects like rooftop solar panels and community-owned wind farms. Initiatives such as Gandhinagar's "Solar City Initiative" and Hyderabad's "Green Energy Movement" show how community-driven renewable energy initiatives can power cities sustainably. Renewable energy sources, including solar panels and bio-gas digesters, have been the focus of community-led initiatives in many Indian cities. Through the use of renewable energy sources, these endeavor's lessen the dependence on fossil fuels, lessen the effects of climate change, and enable communities to fulfill their energy demands independently [25].

9. Future Trends and Recommendations [26]



speaking out in favour of sustainable policies and infrastructure. Participation from members of the community enhances the ability of individuals to lobby for legislation that bolsters initiatives to reduce emissions.

iv. Promoting Social Equity: Engaging the community is essential to successfully reducing emissions on a large scale. People and places can make a difference in the future by cooperating to build a greener world. Community involvement in initiatives to reduce emissions may also help make areas more resilient to the effects of climate change. Community resilience development, which includes green infrastructure, disaster preparation, and fair resource access, may help communities adapt to and reduce the impact of climate change.

Conclusion

Studies of cities and their emissions of greenhouse gases have provided important information on the dynamics of sustainable urban development and the fight against climate change. Recent research has shown that urban areas are major sources of greenhouse gas emissions due to human activities such as waste management, energy consumption, and transportation. But they also serve as centers for implementing practical mitigation strategies. Spending on public transportation, switching to renewable energy, and creating environmentally friendly cities are all essential measures to reduce pollution. Also, green spaces and urban forestry help regulate temperature and sequester carbon, thus it's important to include nature-based solutions in urban design projects.

Consistent action to decrease urban emissions of greenhouse gases is required to achieve the global climate targets. Cities are major contributors to global warming, yet they are also places where real change is possible. By bolstering public transportation, promoting the use of renewable energy, establishing green infrastructure, and executing sustainable urban design, cities may significantly reduce emissions. Because they are home to a disproportionate share of the world's population and GDP, urban areas play a crucial role in the fight against pollution. Therefore, these actions must be given top priority and implemented immediately to reduce the impact of climate change on a worldwide scale.

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Dholera Smart City Project: An Envision of a Sustainable, Futuristic Urban Hub

Nestled in the heart of the Indian state of Gujarat, Dholera is poised to become one of the world's most ambitious and futuristic smart cities encompassing an area of approximately 114 square kilometers. Envisioned as a shining example of India's commitment to sustainable urban development, Dholera Special Investment Region (SIR) is a city that aims to redefine urban living with a focus on innovation, technology, and environmental sustainability. Dholera Smart City is a flagship project of the Delhi-Mumbai Industrial Corridor (DMIC), one of India's most significant infrastructure development programs.

The city's development is guided by six key principles:

1) Infrastructure of the Future: Dholera's infrastructure is designed to be state-of-the-art, with world-class facilities and connectivity. The city is strategically located, and well-connected to major cities like Ahmedabad, Bhavnagar, and Vadodara.

2) Eco-Friendly Initiatives: Dholera is committed to sustainable development. The city incorporates green building practices, renewable energy sources, and waste water management systems. Its goal is to reduce its environmental impact and create a healthier and more liveable environment.

3) Innovation and Technology: Dholera Smart City places a strong emphasis on technology and innovation. It plans to integrate the Internet of Things (IoT), smart grids, and digital infrastructure to enhance the quality of life for its residents.

4) Economic Opportunities: The city is designed to be an economic powerhouse. It will host a diverse range of industries, including manufacturing, logistics, and IT, creating numerous employment opportunities for both local and international talent.

5) Sustainable Mobility: The city promotes sustainable mobility with an integrated transportation system. Dholera will have a comprehensive network of roads, a Bus Rapid Transit (BRT) system, and even plans for an international airport in the vicinity.

6) Investment Potential: Dholera's ambitious development has attracted significant investment from both domestic and international sources. It offers a plethora of opportunities for investors, developers, and entrepreneurs looking to participate in the city's growth story.

The city's vision is to create a vibrant, sustainable, and technologically advanced urban hub that will serve as a model for future smart cities in India and around the world. The first phase of development, encompassing 500 acres, is nearing completion, with infrastructure projects such as roads, drainage systems, and electricity networks in place.

GENERAL GUIDELINES: CHECKLIST FOR SUBMISSION OF ARTICLES

The following checklist should be used when preparing an article for submission. Please be sure to follow the specifications exactly and completely to ensure that your article is reviewed in a timely manner and any delays avoided further along in the publishing process should your article be accepted for publication.

1. The paper should be created using a word-processing program (such as Microsoft Word) and should be between 3,000 and 5,000 words in length. The file may be in .docx or.doc format.
2. The paper should be typewritten, double-spaced, and formatted to print on 8.5" x 11" (or A4) size paper. It should be written in the third person in a clear style, free of jargon.
3. The first page of the article should include the following:
   i. the paper's title; and
   ii. an approximately 200-word abstract that emphasises the paper's contribution to the field and its practical architectural/ planning social/ economic implications.
   iii. the name(s), position(s), professional or academic affiliation(s), and email address(es) of the author(s), as well as the full postal address of the corresponding author;
4. The body of the paper should include the following:
   i. an introduction to the subject,
   ii. background information,
   iii. discussion of procedure,
   iv. results,
   v. conclusions,
   vi. implications for practice and advancement of research,
   vii. references,
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   ix. an autobiographical sketch.
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   iii. References contain the following information, in the order shown: names of all contributing authors (last name followed by first initial), date of publication, title of article, names of editors (edited books only), title of journal or book, volume and issue numbers (journals only), location and name of publishing company (books only), and inclusive pages (journals and articles in edited books).
   iv. Figures/ pictures/ graphs submitted are:
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