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Climate Change Response

SMART, SUSTAINABLE GREEN INFRASTRUCTURE

India's Resilient Response to Climate Change

March 2024

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MESSAGE

Infrastructure development beyond shadow of doubt is one of India's top development priorities. This is quite evident when it has been highlighted in last ten Union Budgets as a critical component of the country's development initiatives. However, in India, infrastructure is mainly associated with 'grey' elements like engineered brick-and-mortar structures despite the fact that green projects are quickly becoming a part of state of art infrastructure projects at the national, regional, and municipal levels. PHDCCI jointly with Climate Change & Response (CCR) have come with a knowledge report to be released in PHDCCI National Green Infrastructure Conclave scheduled on 14th March 2024, New Delhi.

The goal of green infrastructure should be to obtain both economic and environmental benefits, especially to counter the challenges that arise due to development of infrastructure projects. Given that most of the structures that will exist in 2047 have yet to be created, there is ample potential and need to develop green infrastructure through a framework for future expansion while ensuring that resources are protected for future generations.

In an era when climate change and environmental degradation have been identified as the two most serious concerns of our time, India has the opportunity to reverse the trends by implementing green infrastructure approaches alongside blue infrastructure. In honouring its legacy and respecting nature, India may set an example not only for sound economic policies but also for other countries to follow.

PHDCCI which has a legacy of 119 years representing 150,000 industries and businesses from across the nation has created a niche for itself across the country through the excellent work done by Expert Committees, State Chapters, International Affairs Committees and Foundations on various subjects of importance.

This Knowledge Report highlights the investment and business opportunities and challenges of each of infrastructure sector in India provides in developing green and sustainable infrastructure by taking in out consideration, environment, technological adaptation and adherence to stringent safety standards while executing infrastructure projects.

Shri Sanjeev Agrawal
President
PHDCCI

MESSAGE

At a time when India has pledged to embark on its decarbonisation journey in order to achieve targeted green goals, the need for sustainable and green infrastructure is critical for a better tomorrow. India is now moving towards sustainable infrastructure development. The recent schemes of the government give a clear hint to make a radical shift towards sustainability. The growing focus of the government is on activities related to sustainable infrastructure. PHDCCI jointly with Climate Change & Response (CCR) have come with a knowledge report to be released in PHDCCI National Green Infrastructure Conclave scheduled on 14th March 2024, New Delhi.

Infrastructure expenditure has a high multiplier impact through a variety of routes, including job creation, enhancing the competitiveness of our industrial and service sectors, attracting FDI, and raising the standard of living in our nation. To boost infrastructure development in the country, the government has launched many programmes over the previous decade, including the National Infrastructure Pipeline (NIP), the National Monetisation Pipeline (NMP), the PM Gati Shakti plan, and the National Logistics Policy.

While the design, planning and execution principles for sustainable infrastructure remain universal, however, these will vary from region to region and within regions, depending upon the prevailing climate, site conditions, culture, traditions, available materials, construction practices, and building typology, besides the environmental, economic, and social priorities. Climate-resilient infrastructure has the potential to improve the reliability of service provision, increase asset life and protect asset returns. Building climate resilience can involve a package of management measures and use of new age technologies, will help sustainable and eco-friendly execution of infrastructure projects by use of locally available raw materials, construction aggregates, metal scrap and C&D waste.

PHDCCI which has a legacy of 119 years representing 150,000 industries and businesses from across the nation has created a niche for itself across the country through the excellent work done by Expert Committees, State Chapters, International Affairs Committees and Foundations on various subjects of importance.

This Knowledge Report highlights key actions required to create vibrant and efficient integrated transportation system, infrastructure challenges that inhibit the growth of transportation and logistics sector and potential solutions required for the development of multi-modal transportation in India.

Dr. Ranjeet Mehta
Executive Director
PHDCCI

Foreword

I am delighted to present this report on India's Smart Green Infrastructure: A Path to Sustainable Development based on the expertise, experience and ongoing research conducted by Climate Change Response.

I have always been passionate about tackling climate change through practical solutions. In a world where the impacts of climate change are getting increasingly tangible and urgent, the need for innovative solutions has never been more pressing. I believe that addressing climate change requires a holistic approach - one that integrates technological advancements, environmental stewardship, and sustainable development principles.

India stands at a pivotal moment. Its high growth economy presents both opportunities and challenges. It needs a powerful pathway for achieving a balance between environmental responsibility and economic prosperity.

This report provides exactly that - an overview of how smart green infrastructure can be a key driver in achieving a sustainable future for India. We delve into the myriad of facets of India's Smart Green Infrastructure - from its potential to mitigate carbon emissions and enhance resilience, to drive innovation and foster inclusive development. Through a comprehensive analysis, we aim to illuminate the opportunities and challenges that lie ahead on this transformative journey.

The report provides compelling data, real-world examples, and a comprehensive analysis of how smart green infrastructure can contribute to India's sustainable development and booming economy. It sheds light on various aspects of this approach, including its economic impact and the exciting job opportunities it creates in the green sector.

As we navigate the complexities of a changing climate, let us remain steadfast in our resolve to build a future where economic prosperity and environmental stewardship are harmoniously intertwined. Together, let us chart a course towards a more resilient, sustainable, and prosperous India, for the benefit of the entire world.

Dr. Om Dubey
Managing Director
Climate Change Response Pty Ltd
www.ccr.earth

About PHDCCI

PHD Chamber of Commerce and Industry (PHDCCI) have been working as a catalyst for the promotion of Indian industry, trade and entrepreneurship for the past 118 years.

It is a forward looking, proactive and dynamic PAN-India apex organization. As a partner in progress with industry and government, PHDCCI works at the grass roots level with strong national and international linkages for propelling progress, harmony and integrated development of the Indian economy.

PHDCCI, acting as the "Voice of Industry & Trade" with a large membership base of 150,000 direct and indirect members consisting of large, medium and small Industries, has forged ahead its legacy with the industry knowledge across multiple sectors to take Indian Economy to the next level.

At the global level, we have been working with the Embassies and High Commissions in India to bring in the International Best Practices and Business Opportunities.

Executive Summary

India stands at a critical juncture in its infrastructure development journey, where the imperative for sustainable growth has never been more pronounced. The convergence of rapid urbanization, increasing population, and the urgent need to mitigate climate change necessitates a paradigm shift towards smart green infrastructure. This report delves into the multifaceted dimensions of India's smart green infrastructure initiatives across various sectors, aiming to provide insights, analysis, and recommendations for fostering a sustainable and resilient future.

Introduction:

a. The rise of Green Infrastructure in India

India's journey towards sustainable infrastructure is propelled by the urgent need to balance economic growth with environmental stewardship. The traditional approach to infrastructure development, characterized by resource-intensive methods and carbon-intensive technologies, is no longer tenable in the face of mounting environmental challenges. Green infrastructure represents a fundamental shift towards a more holistic and ecologically sensitive approach to infrastructure planning, design, and implementation.

b. The Role of Technology in Green Infrastructure

The advent of cutting-edge technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain has revolutionized the landscape of infrastructure development. Smart green infrastructure harnesses the power of these technologies to optimize resource allocation, enhance operational efficiency, and minimize environmental impact. From intelligent transportation systems to renewable energy integration, technology serves as a catalyst for sustainable development across diverse infrastructure domains.

Building a Sustainable Network: Smart Green Technologies in Action

Roads, Highways, and Expressways: Optimizing Efficiency and Safety

India's road sector remains the largest contributor to transport emissions, accounting for more than 92 per cent of transport emissions. (CEEW)

In the realm of road infrastructure, smart green technologies offer transformative solutions to enhance efficiency, safety, and sustainability. Intelligent Transportation Systems (ITS) leverage real-time data analytics and sensor technologies to optimize traffic flow, reduce congestion, and minimize carbon emissions. A 2021 study by the Indian Institute of Science found that ITS implementation in Bengaluru resulted in a 12% reduction in travel time and a 10% decrease in fuel consumption.

By harnessing the power of Artificial Intelligence (AI), traffic management systems can analyze traffic patterns and optimize signal timings, leading to smoother traffic flow and reduced fuel consumption. Additionally, IoT-enabled sensors can monitor road conditions and provide real-time alerts for maintenance, ensuring the safety and longevity of road networks while minimizing environmental impact.

The integration of green materials such as recycled plastic and energy-efficient LED lighting underscores a commitment to environmental conservation while ensuring the longevity and resilience of road networks. These sustainable materials not only reduce carbon footprint but also contribute to building greener infrastructure that aligns with India's sustainable development goals. The National Highways Authority of India (NHAI) has set a target of using at least 10% of plastic waste in road construction projects by 2024.

Railways: A Greener Journey

The railways, often hailed as the lifeline of India's transportation network, are undergoing a green revolution propelled by electrification and renewable energy integration. Electric and hydrogen locomotives represent a paradigm shift away from fossil fuel dependency, offering cleaner and more sustainable alternatives for freight and passenger transport. Smart grid integration and rooftop solar initiatives underscore Indian Railways' commitment to reducing its carbon footprint and embracing a low-carbon future. *Indian Railways plans to set up rooftop solar panels across railway stations and offices with a target of generating 5,000 MW of solar power by 2030.*

India's railway electrification efforts and transition to renewable energy sources are crucial steps towards reducing carbon emissions and achieving sustainability goals.

Furthermore, AI-driven predictive maintenance systems are being tested across the globe to monitor rail infrastructure, detect potential faults, and schedule maintenance proactively within trains. By leveraging AI technologies, railways can minimize downtime, enhance operational efficiency, and optimize energy usage, thereby further reducing environmental impact.

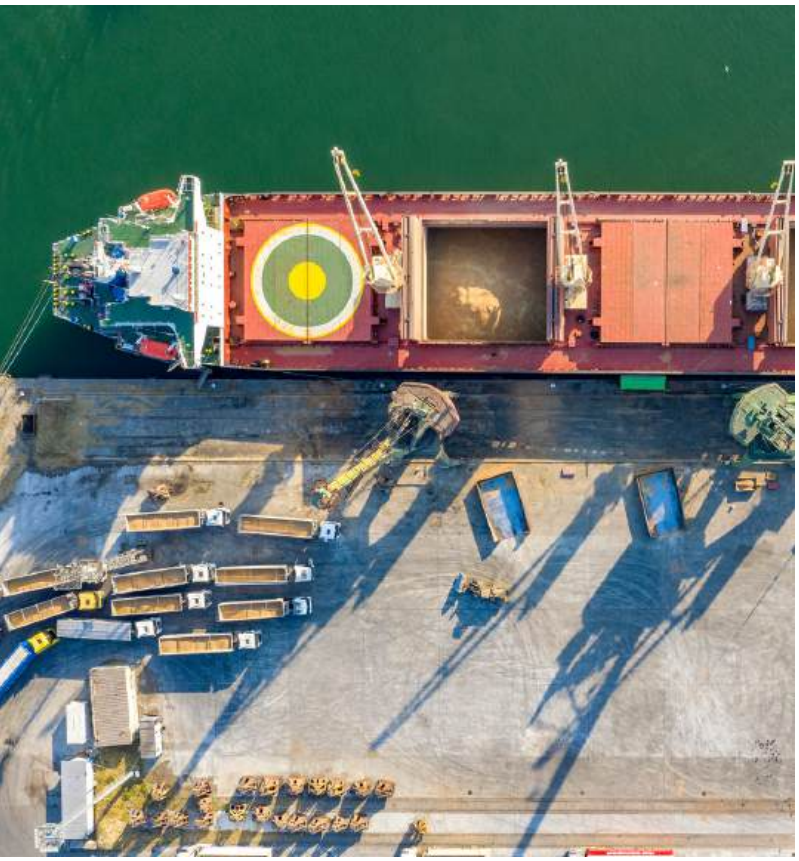
Aviation: Taking Flight Towards Sustainability

In 2023, India recorded over 190 million air passengers !

The aviation sector, indispensable for global connectivity and economic growth, faces mounting pressure to reconcile its operations with environmental imperatives. Green airports, equipped with state-of-the-art energy-efficient infrastructure and sustainable design features, exemplify the aviation industry's commitment to environmental stewardship. The emergence of biofuels and electric aircraft technologies heralds a new era of sustainable aviation, promising to reduce carbon emissions and mitigate the sector's environmental impact. Sustainable Aviation Fuel (SAF) adoption in India is still in its nascent stage, but airlines like SpiceJet have expressed interest in exploring this option

Cochin International Airport (CIAL) in Kerala became the world's first fully solar-powered airport in 2018

Moreover, AI-powered air traffic management systems optimize flight routes, reduce fuel consumption, and minimize environmental impact by optimizing flight trajectories and minimizing airspace congestion. IoT sensors monitor aircraft performance, identify fuel inefficiencies, and optimize engine performance, leading to significant fuel savings and emissions reductions. By embracing smart technologies, the aviation sector within India can pave the way for a greener and more sustainable future.



Logistics and Waterways: Streamlining Green Transportation

The logistics sector, often overlooked yet indispensable for economic vitality, is undergoing a green transformation driven by intermodal connectivity and sustainable practices. Intermodal transportation networks seamlessly integrate waterways, railways, and roadways, offering efficient and environmentally friendly alternatives to traditional freight transport.

The modernization of ports and promotion of inland waterways represent pivotal steps towards reducing India's logistics-related emissions and enhancing supply chain resilience. The Sagarmala Project aims to develop a network of inland waterways and modernize coastal infrastructure for efficient cargo movement.

AI-powered supply chain management systems optimize freight routing, minimize empty trips, and reduce carbon emissions by identifying the most efficient transport modes and routes. Furthermore, IoT-enabled cargo tracking systems provide real-time visibility into shipment status, enhance security, and optimize inventory management, reducing waste and improving operational efficiency.

Freight and Industrial Corridors: A Sustainable Engine for Growth

In case of freight and industrial corridors, smart green infrastructure serves as a catalyst for sustainable economic growth and regional development. Smart technology led management systems optimize freight movement, reduce fuel consumption, and minimize environmental impact through advanced analytics and predictive modelling. Adoption of smart technology, and development of dedicated freight corridors along with the integration of renewable energy within industrial zones underscores a commitment to decarbonizing the industrial sector, fostering innovation, and creating new avenues for sustainable growth.

Encouraging renewable energy generation and microgrids within industrial corridors can reduce reliance on fossil fuels. The Ministry of New and Renewable Energy (MNRE) has launched a scheme to promote setting up of solar power projects in industrial parks.

Green Infrastructure for Sustainable Development Goals

Smart green infrastructure isn't just about aesthetics; it's a strategic investment in India's future, contributing significantly to achieving several Sustainable Development Goals (SDGs) outlined by the United Nations.

According to the United Nations, Infrastructure can impact up to 92% of all SDG targets

"Infrastructure is crucial for development. From transport systems to power-generation facilities and water and sanitation networks, it provides the services that enable society to function and economies to thrive. This brings infrastructure at the very heart of efforts to meet the Sustainable Development Goals (SDGs). Encompassing everything from health and education for all to access to energy, clean water and sanitation, most of the SDGs imply improvements in infrastructure."
– United Nations Office for Project Services

Smart green infrastructure stands as a potent and versatile instrument propelling India's advancement towards a myriad of Sustainable Development Goals (SDGs) outlined by the United Nations. By amalgamating nature-based solutions with technological innovations, these initiatives engender a cascade of positive outcomes.

Demonstrably, green spaces significantly enhance air and water quality, as evidenced by a 2017 study conducted by the Council on Energy, Environment and Water (CEEW), which revealed that urban parks in Delhi eliminate approximately 15 tons of air pollutants daily. This directly contributes to SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation).

Moreover, green infrastructure assumes a pivotal role in combating climate change (SDG 13: Climate Action), as emphasized by the Intergovernmental Panel on Climate Change (IPCC). Well-maintained urban forests can sequester up to 5 tons of carbon per hectare annually, as illustrated by a 2021 study by the Indian Institute of Science (IISc) Bangalore. Additionally, smart irrigation systems and integrated waste management solutions embedded within green infrastructure foster responsible consumption patterns (SDG 12: Responsible Consumption and Production) and resource efficiency (SDG 7: Affordable and Clean Energy), aligning with the World Bank's projections that municipal solid waste generation will reach 3.4 billion tons globally by 2050.

The economic benefits of smart green infrastructure are indisputable. The investments towards green infrastructure can create new job opportunities in construction, maintenance, and green technology sectors, thereby fostering economic growth (SDG 8: Decent Work and Economic Growth). Furthermore, green spaces augment property values (SDG 11: Sustainable Cities and Communities) and attract businesses and talent, thereby catalysing economic development. Studies conducted by the University of Edinburgh indicate that properties near green spaces boast property values 7-10% higher on average.

The positive impact extends beyond environmental and economic realms. Green spaces provide recreational opportunities, enhance mental and physical well-being, and cultivate a stronger sense of community, all of which are critical facets of SDG 11 (Sustainable Cities and Communities). Additionally, smart green infrastructure contributes to SDG 9 (Industry, Innovation and Infrastructure) by fostering innovation in sustainable urban development practices and fortifying infrastructure resilience (SDG 11), enabling it to better withstand extreme weather events and natural disasters.

Smart green represents a strategic investment in a more sustainable and prosperous future for India. By addressing multiple SDGs concurrently, these initiatives embrace a holistic approach to urban development, prioritising public health, environmental well-being, economic growth, and responsible resource management.

Technology: The Backbone of Smart Green Infrastructure

Green infrastructure isn't just about parks and rain gardens – it's a high-tech orchestra, where cutting-edge technologies harmonise with nature to create a sustainable future. Let's delve into the power of the Internet of Things (IoT), Artificial Intelligence (AI), smart grids, and other innovations that are revolutionising green infrastructure, backed by impressive figures:

The Power of IoT: Envision a network of 12 billion connected devices by 2025 (IoT Analytics) – that's the influence of IoT! Embedded sensors in green infrastructure gather real-time data on everything from water usage in a 20-hectare vertical garden to energy consumption in a green office building. This data serves as the conductor, guiding informed decision-making and optimization. For example, soil moisture sensors in a green roof can trigger automated watering based on real-time needs, potentially reducing water waste by up to 50% (Environmental Protection Agency).

AI for Enhanced Efficiency: AI algorithms act as the maestro, analyzing the vast amount of data collected by IoT sensors – a staggering 1.7 megabytes of data generated per second per person by 2025 (IDC). This analysis helps identify patterns, predict water demand with up to 90% accuracy (McKinsey & Company), and optimize resource allocation. Imagine an AI system managing a 100-kilowatt solar-powered biofiltration system in a new urban development. By analyzing historical data and weather forecasts, the AI can optimize water treatment, nutrient delivery, and energy use, ensuring a healthy ecosystem within the biofiltration system.

Smart Grid Infrastructure: Smart grids represent the evolution of traditional power grids. They seamlessly integrate renewable energy sources like solar and wind power into green infrastructure projects, alongside energy-efficient technologies, and leverage advanced communication systems. A smart grid in South Australia, for instance, has facilitated the integration of over 1.6 gigawatts of renewable energy (AEMO), a significant step towards a cleaner future. Think of a smart grid as an intelligent network that can adapt to fluctuations in energy demand (which can vary by 30% throughout the day) and supply in real-time. This not only optimizes energy use but also facilitates the seamless integration of more renewable energy sources into the grid, powering green infrastructure projects efficiently.

Beyond the Core: Expanding the Green Tech Toolbox

The tech symphony of green infrastructure extends beyond these core elements. Here are some additional technologies playing a vital role:

Building Information Modelling (BIM): BIM creates a digital 3D model of a green infrastructure project, allowing for better planning, design optimization, and clash detection during construction. This can minimize waste and improve the overall efficiency and sustainability of the project.

Digital Twins: A digital twin is a virtual replica of a green infrastructure project, fed with real-time data from sensors. This allows for continuous monitoring, performance analysis, and predictive maintenance, ensuring the long-term sustainability and optimal functionality of the project.

Blockchain Technology: Blockchain can be used to track the provenance of materials used in green infrastructure projects, ensuring ethical sourcing and sustainable practices throughout the supply chain.

Decarbonisation Through Smart Green Infrastructure

Decarbonisation stands as an essential imperative amidst the escalating global temperatures. In the pursuit of limiting the rise to 1.5°C, deploying renewable energy at an unprecedented scale is imperative. According to the International Energy Agency (IEA), this equates to installing the world's largest solar park each day for photovoltaic power alone. Entire sectors of the economy need a redesign, calling for the phase-out of combustion engine vehicles and fossil fuel power plants. This transition requires the creation of extensive stocks of electric vehicles (EVs) and retrofitting buildings for energy efficiency.

Smart green infrastructure plays a crucial role in India's decarbonisation efforts and in overcoming the climate change struggle. By integrating technology with nature-based solutions, these projects significantly reduce greenhouse gas (GHG) emissions, fostering a cleaner, more sustainable future. Here's how with statistics to showcase the impact:

Reducing Urban Heat Island Effect: Green roofs, urban forests, and strategically placed trees mitigate urban heat island effects, thereby decreasing energy consumption for cooling. Studies by the Indian Institute of Technology Delhi (IITD) suggest that green roofs can reduce building cooling energy needs by 20-30%. Additionally, a study by the Centre for Science and Environment (CSE) in 2019 found that green roofs in Delhi can potentially save 200-300 kWh of electricity per square metre annually, reducing CO_2 emissions by 0.8-1.2 tonnes per square metre per year.

Enhancing Energy Efficiency: Smart irrigation systems optimize water usage in green spaces, minimizing energy consumption associated with water pumping and treatment. Additionally, green buildings integrated with smart green infrastructure leverage renewable energy sources like solar panels for lighting and irrigation. A 2021 report by the World Green Building Council suggests that green buildings can achieve 25-30% lower operational energy use compared to conventional buildings.

Promoting Sustainable Transportation: Integration of bike lanes and pedestrian walkways with green spaces encourages sustainable modes of transport, reducing reliance on cars and their associated carbon footprint. A 2020 study by the Centre for Science and Environment (CSE) suggests that promoting cycling in Indian cities can reduce car trips by up to 30%, leading to significant emission reductions. In Delhi alone, a 30% reduction in car trips could translate to an annual reduction of over 5 million tonnes of CO_2 emissions.

Carbon Sequestration: Urban forests and green spaces act as natural carbon sinks, sequestering carbon dioxide from the atmosphere. Well-maintained urban forests can sequester up to 5 tonnes of carbon per hectare annually, as suggested by a 2017 study by the Indian Institute of Science (IISc) Bangalore.

Waste Management and Resource Recovery: Incorporating innovative waste management solutions like composting organic waste in urban gardens reduces methane emissions from landfills. The World Bank estimates that organic waste in landfills contributes to 10-20% of global methane emissions. By diverting organic waste for composting, smart green infrastructure can play a vital role in mitigating these emissions.

The Financial Struggle of Decarbonisation

Many countries are burdened with pre-COVID underinvestment in infrastructure spending, estimated at US$3 trillion a year, in addition to the repayment of increased post-COVID debt. Add to this the costs of retrofitting infrastructure, replacing fossil fuel–related income tax, and providing financial incentives to support investment and R&D of green infrastructure. 'Just transition' costs, such as compensation of displaced workers and workforce reskilling, are also a factor as we shift away from a fossil fuel economy.

The figure below, based on research conducted by Oxford Economics for PwC, provides a framework for understanding the global green infrastructure transition across a sample of 80 representative countries and regions. On the 'decarbonisation challenge' axis, the level of current and future emissions to reduce, as well as the extent of infrastructure needing decarbonisation, is plotted. The 'capacity to pay' axis reflects each country's or region's financial capability to decarbonise both existing and future infrastructure.

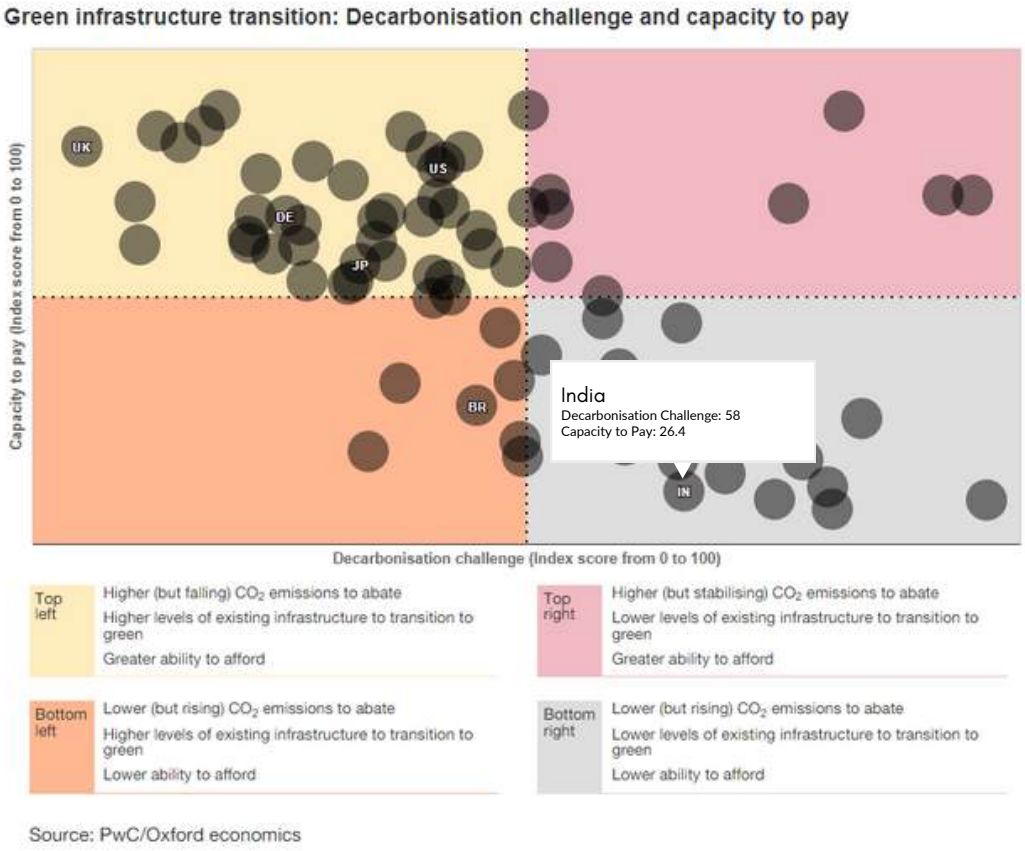


Figure 1: Decarbonisation Challenge and Capacity to Pay

In the bottom-right quadrant, middle- to low-income countries, requiring 60% of new infrastructure investment according to the OECD, struggle with funding the green transition despite lower carbon emissions than developed nations. These regions, mainly in Africa and Asia, confront acute trade-offs due to less mature infrastructure but a substantial population of over 3.2 billion. Approximately 1 billion lack electricity, and 1.6 billion lack safe drinking water globally. Leaders must balance investments in carbon-intensive industries for GDP growth with the higher costs of a green agenda. *India, heavily reliant on fossil fuels, faces accelerating carbon emissions due to population and GDP per capita growth, highlighting the urgency of sustainable solutions.* Foreign direct investment (FDI) and foreign grants, crucial for financing and technology access, can support these countries in achieving their net-zero targets. Initiatives like the proposed US$50 billion International Monetary Fund (IMF) climate resilience fund can significantly aid their sustainability efforts.

Green Infrastructure's Economy Boom

Smart green infrastructure isn't just good for the environment; it's a blossoming economic opportunity for India. Here's how this innovative approach is poised to drive sustainable growth and create a greener future:

Unlocking Cost Savings:

A 2023 report by the World Green Building Council estimates that by 2030, green buildings alone can generate a staggering $366 billion in cost savings globally. In India, the trend is mirroring this. With the budget allocation for the Ministry of New and Renewable Energy reaching a record ₹8.6 trillion ($108.7 billion) in the 2023-2024 budget, the government is sending a clear message about prioritizing sustainable development. Smart green infrastructure extends beyond buildings, encompassing advancements like:

- **Precision irrigation systems:** These data-driven systems optimize water usage in agriculture, a crucial sector for India's economy.
- **Renewable energy microgrids:** These localized grids powered by solar, wind, or biofuel can provide clean and reliable energy to rural communities and urban neighbourhoods, reducing dependence on fossil fuels and increasing energy security.
- **Smart waste management:** Sensor-based waste management systems optimize collection routes and promote recycling, creating cost efficiencies and fostering a circular economy.
- **Job Creation and Green Skilling:** The transition to a smart green infrastructure landscape necessitates a skilled workforce. This creates new employment opportunities in areas like:
    - **Data analysis:** The vast amount of data collected by smart infrastructure systems needs to be analysed to optimize operations. This opens doors for data scientists and engineers.
    - **System maintenance:** Maintaining and repairing these cutting-edge systems requires a skilled technical workforce.
- **Green technology development:** As India strives to become a leader in the green economy, investment in research and development of innovative green technologies will create jobs for scientists, engineers, and entrepreneurs.

By embracing smart green infrastructure, India can unlock a multitude of economic benefits. Reduced operational costs, improved resource efficiency, and a skilled workforce in the green sector can propel sustainable growth and create a thriving green economy for the nation.

Driving Sustainability: Government Initiatives and Policies

Despite the growing momentum towards smart green infrastructure, several regulatory and policy challenges hinder the pace of progress. Complex land acquisition processes, inadequate regulatory frameworks, and the absence of standardized green building codes pose significant barriers to sustainable infrastructure development. Addressing these challenges requires a concerted effort to streamline regulations, enhance stakeholder engagement, and foster policy innovation.

Central Government Programs

India's central government has embarked on a series of pioneering initiatives to drive the shift towards smart, eco-friendly infrastructure. At the forefront is the PM Gati Shakti National Master Plan, which was introduced in 2021. This visionary plan outlines a comprehensive blueprint for infrastructure development, emphasizing sustainability and the integration of various modes of transportation. Additionally, the Bharatmala Pariyojana and Sagarmala Project stand out as pivotal endeavours designed to bolster highway networks and revamp coastal infrastructure, all while prioritizing environmental concerns.

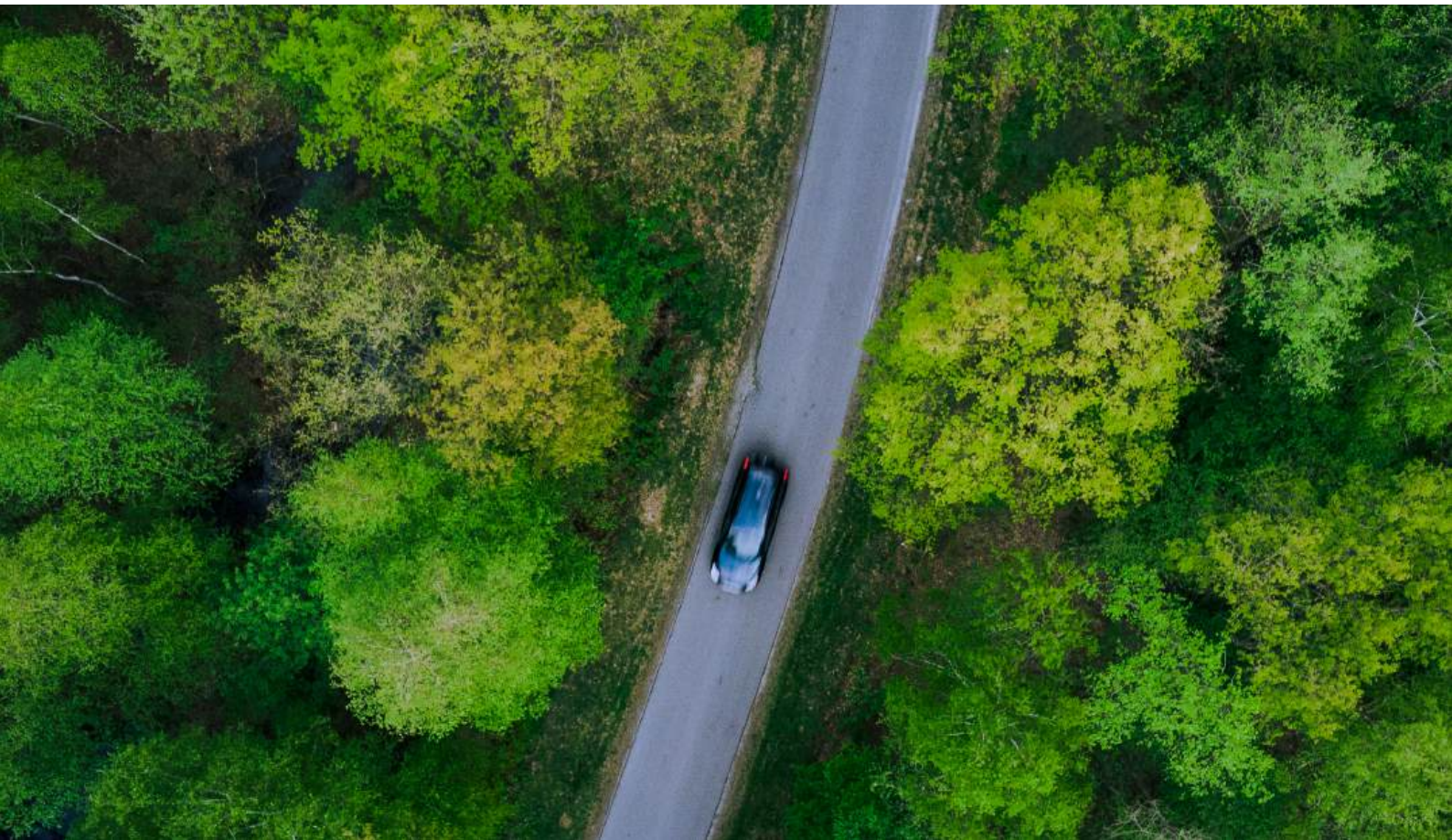
Another noteworthy endeavour launched in 2019 is the Sustainable Structured Investment Mechanism (SSIM). This mission aims to foster innovation and secure financing for sustainable infrastructure projects. SSIM extends financial support to initiatives focused on water management, waste management, and urban mobility, aligning with India's broader commitment to building greener and more resilient communities.

Some State Government Initiatives

State	Project/Initiative	Focus Area
Andhra Pradesh	Amaravati Green Field Capital City Development	Sustainable urban planning with focus on green buildings and renewable energy
Arunachal Pradesh	Pakke Tiger Reserve Eco-tourism Development Project	Promoting eco-tourism while conserving biodiversity
Assam	Guwahati Metro Rail Project	Reducing traffic congestion and promoting public transport with a focus on energy-efficient operations
Bihar	Atal Mission for Rejuvenation and Urban Transformation (AMRUT)	Upgrading urban infrastructure with a focus on water supply, sanitation, and solid waste management
Chhattisgarh	Surya Lamp Yojana	Installation of solar-powered streetlights in rural areas
Maharashtra	Green Highways Mission	Plantation of trees to create a green corridor to mitigate climate change and improve air quality
Maharashtra	Nagpur Smart Logistics Hub	Developing a multi-modal logistics hub with focus on efficiency and sustainability through automated warehousing systems, intelligent transportation systems for first and last mile connectivity.
Tamil Nadu	Renewable Energy Integration	Ambitious targets to achieve 50% of its energy needs from renewable sources by 2030. In the context of green infrastructure, the state is promoting solar power generation at railway stations and airports

Some State Government Initiatives

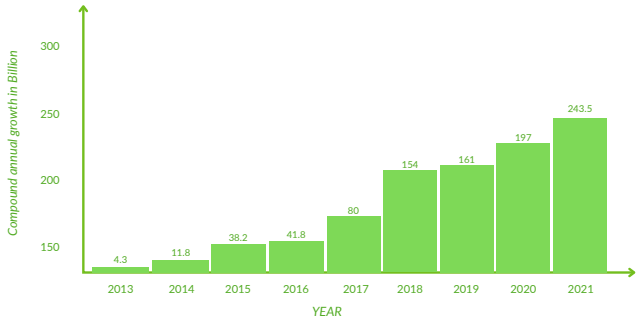
State	Project/Initiative	Focus Area
Gujarat	Statue of Unity Solar Power Plant	World's tallest statue powered by a dedicated solar power plant managed through AI for maximizing energy production
Haryana	Delhi - Mumbai Expressway	Intelligent Transportation Systems (ITS) for traffic management, real-time incident detection, and automated toll collection
Karnataka	Namma Metro (Bengaluru Metro)	Predictive maintenance systems incorporated into the metro systems for infrastructure using sensor data analysis
Jammu and Kashmir	Leh-Kargil-Manali Highway Improvement Project	Upgrading a strategic highway with a focus on minimizing environmental impact and use of Smart tunnel management systems for efficient ventilation and safety
Jharkhand	Jharkhand Renewable Energy Development Agency (JEREDA) Initiatives	Promoting solar power installations, bio-gas plants, and other renewable energy sources in the state. The project utilises Blockchain technology for secure and transparent renewable energy certificate (REC) trading
Kerala	Kochi International Airport (India's first fully solar-powered airport)	Utilizing solar energy to meet a significant portion of the airport's electricity needs. The project also incorporates a smart Building Management System for optimizing energy consumption in airport facilities



Ambitious Investments for a Greener Future

Figure 2 illustrates the upward trajectory of investment in green projects for sustainable development from 2012 to 2020. The data clearly indicates a consistent increase in investment in green infrastructure since 2012.

Recognizing the vital role of green infrastructure in achieving sustainable development, the Indian government is making substantial financial commitments to this sector. A recent report by CRISIL estimates a staggering Rs 143 lakh crore (US$ 1.7 trillion) investment in infrastructure development between fiscals 2024-30, with a strong emphasis on sustainability principles. This represents a significant leap compared to the previous seven-year period, which saw Rs 67 lakh crore (US$ 0.8 trillion) invested in infrastructure.

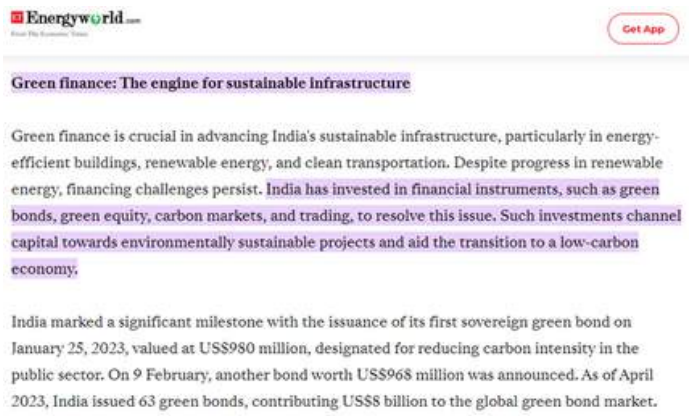


Source - Author's Compilation
Figure 2-Compound annual growth in Green Infrastructure in India (inBn.)

Within this ambitious plan, green projects are poised to receive a significant share of the pie. An estimated Rs 36.6 lakh crore (US$ 0.43 trillion) is earmarked for renewable energy, sustainable transportation, and other green initiatives. This translates to a fivefold increase in green infrastructure investment compared to the prior period, showcasing the government's commitment to accelerating the transition towards a greener future.

The focus areas within green infrastructure spending are likely to be diverse. Renewable energy, a cornerstone of India's clean energy goals, is expected to receive a lion's share, with investments directed towards expanding solar and wind power capacities. Sustainable transportation will see significant allocations for developing electric vehicle charging infrastructure, modernizing railway networks with a focus on energy efficiency, and promoting green public transport systems. Additionally, investments are anticipated in areas like green buildings, smart water management solutions, and waste-to-energy plants, fostering a holistic approach to sustainable development.

These figures paint a promising picture of India's growing commitment to green infrastructure. By strategically allocating resources and fostering public-private partnerships, India can leverage green infrastructure as a powerful tool for achieving economic growth, environmental sustainability, and climate resilience. However, it's crucial to acknowledge that translating these ambitious plans into reality will require overcoming challenges like ensuring efficient project execution, mobilizing private sector capital, and developing a skilled workforce equipped to handle these emerging technologies. Nevertheless, India's trajectory towards a greener future fuelled by smart green infrastructure investments is a positive step with the potential for significant long-term benefits.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Green finance: The engine for sustainable infrastructure

Green finance is crucial in advancing India's sustainable infrastructure, particularly in energy-efficient buildings, renewable energy, and clean transportation. Despite progress in renewable energy, financing challenges persist. India has invested in financial instruments, such as green bonds, green equity, carbon markets, and trading, to resolve this issue. Such investments channel capital towards environmentally sustainable projects and aid the transition to a low-carbon economy.

India marked a significant milestone with the issuance of its first sovereign green bond on January 25, 2023, valued at US$980 million, designated for reducing carbon intensity in the public sector. On 9 February, another bond worth US$968 million was announced. As of April 2023, India issued 63 green bonds, contributing US$8 billion to the global green bond market.


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Feedback

India to investment Rs 36.6 lakh crore in green infra in FY24-30 period: CRISIL

Within green investments, it expects the renewable energy space to receive the lion's share of funds at Rs 30.3 lakh crore, followed by transportation at Rs 6.3 lakh crore

Case Studies from across the Globe

Los Angeles Leads the Way: Smart Highways Transforming Traffic and Emissions

Addressing the Challenge:

Traffic congestion stands as a prevalent issue in cities globally, resulting in wasted fuel, heightened emissions, and prolonged commute durations.

The Innovative Solution in Los Angeles:

Los Angeles, California, serves as a notable case study for the implementation of a Smart Highway Traffic Management System. This system leverages:

- Real-time traffic data collection sourced from sensors embedded within freeways and vehicles.
- Dynamic speed limit signs that adapt based on traffic conditions, optimizing speeds and alleviating congestion.
- Travel time information systems furnishing drivers with real-time updates, facilitating informed route planning.

Measurable Impact:

According to a 2022 study conducted by the Los Angeles Department of Transportation (LADOT), highways integrated with the Smart Traffic Management System witnessed a substantial reduction of 10% in peak-hour congestion. This outcome equates to an estimated annual fuel cost saving exceeding $100 million for drivers, alongside a commendable 2% decrease in CO_2 emissions from vehicles traversing these highways.

Germany's Deutsche Bahn: Pioneering Smart Railways for Enhanced Efficiency and Passenger Satisfaction

Addressing the Challenge:

Traditional railway systems often grapple with delays, resulting in passenger inconvenience and operational inefficiencies.

The Innovative Solution by Deutsche Bahn (DB):

Germany's Deutsche Bahn (DB) stands at the forefront of Smart Railway technologies, implementing:

- Advanced Train Control Systems (ATCS) guaranteeing safe and efficient train operations through automated speed control and maintaining safe distances.
- Predictive maintenance systems that monitor train components, enabling proactive maintenance and minimizing delays caused by equipment failures.
- Real-time passenger information systems that keep passengers informed about train schedules, enhancing their travel experience.

Measurable Impact:

DB reports a remarkable 30% reduction in train delays attributable to the adoption of Smart Railway technologies. This improvement translates into enhanced on-time performance and increased passenger satisfaction. Furthermore, DB estimates a significant 15% reduction in energy consumption through the optimization of train operations and the implementation of regenerative braking systems.

Amsterdam Airport Schiphol: Leading the Way with Smart Airways for Environmental Sustainability and Operational Efficiency

Addressing the Challenge:

Air travel's substantial greenhouse gas emissions and airport congestion pose challenges, leading to delays and frustration for passengers.

The Innovative Solution at Amsterdam Airport Schiphol (AMS):

Amsterdam Airport Schiphol (AMS) in the Netherlands emerges as a frontrunner in Smart Airway technologies, implementing:

- Air Traffic Management (ATM) Systems empowered with AI to optimize flight paths and airspace usage, thereby reducing delays and fuel consumption.
- Self-service check-in and baggage drop options, streamlining passenger processing and mitigating congestion at the airport.
- Sustainable airport infrastructure, integrating solar panels and renewable energy sources to diminish reliance on fossil fuels.

Measurable Impact:

Eurocontrol data reveals that Schiphol Airport has achieved an impressive 8% reduction in fuel consumption for departing flights through optimized air traffic management utilizing AI. This achievement signifies substantial cost savings for airlines and a consequential reduction in CO_2 emissions. Moreover, Schiphol reports a notable 20% decrease in passenger wait times at check-in and baggage drop locations due to the implementation of self-service options.

Singapore's Inland Waterway Network: Revolutionizing Navigation for Sustainable Logistics

Addressing the Challenge:

Singapore, a prominent global trade hub, sought to diminish its dependence on road transportation for cargo movement while exploring environmentally friendly alternatives.

The Ingenious Solution in Singapore:

Singapore has invested in a Smart Inland Waterway Network, harnessing technology to augment efficiency and sustainability:

- Vessel Traffic Management System (VTMS): The VTMS monitors vessel movements in real-time, optimizing navigation and averting collisions.
- Smart Buoys: Equipped with sensors, buoys collect data on water levels, currents, and weather conditions, ensuring safe navigation and facilitating efficient route planning.
- Electric and Autonomous Vessels: A burgeoning fleet of electric and autonomous vessels mitigates emissions and explores the potential for unmanned cargo transportation.
- Intermodal Connectivity: The waterway network seamlessly integrates with ports, warehouses, and industrial zones, facilitating swift and efficient cargo movement.

Measurable Impact:

The Singapore Maritime and Port Authority (MPA) projects a notable 15% reduction in traffic congestion on roads owing to the transition of cargo movement to inland waterways. A 2022 study conducted by the MPA indicates a commendable 5% decrease in CO_2 emissions from cargo transportation within Singapore, attributed to the utilization of electric vessels and optimized logistics.

Challenges and Opportunities: Navigating the Road Ahead

Despite the growing momentum towards smart green infrastructure, several regulatory and policy challenges hinder the pace of progress. Complex land acquisition processes, inadequate regulatory frameworks, and the absence of standardized green building codes pose significant barriers to sustainable infrastructure development. Addressing these challenges requires a concerted effort to streamline regulations, enhance stakeholder engagement, and foster policy innovation.

Land Acquisition and Environmental Concerns

Green infrastructure projects, while essential for long-term sustainability, often face formidable challenges related to land acquisition and environmental impact mitigation. Balancing the imperative for development with the need to safeguard ecological integrity and community well-being requires innovative approaches and robust stakeholder engagement mechanisms. Collaborative decision-making processes, informed by scientific evidence and community participation, can help reconcile competing interests and foster consensus-driven solutions.

Investment and Funding Requirements

Smart green infrastructure projects often entail substantial upfront investment costs, necessitating innovative financing mechanisms and strategic public-private partnerships. Mobilizing private sector capital, leveraging climate finance instruments, and tapping into multilateral funding mechanisms represent viable pathways for scaling up investment in sustainable infrastructure. Moreover, fostering an enabling environment for green finance, including tax incentives, subsidies, and regulatory reforms, can incentivize private sector participation and catalyze the transition towards a low-carbon economy.

Business Opportunities in Smart Green Infrastructure

The transition towards smart green infrastructure unlocks a myriad of business opportunities across diverse sectors, ranging from renewable energy development to green technology innovation. Companies that embrace sustainability as a core business principle stand to gain a competitive edge in the rapidly evolving marketplace. From renewable energy startups to sustainable construction firms, the green economy offers fertile ground for innovation, entrepreneurship, and value creation. Harnessing these opportunities requires a strategic commitment to sustainability, coupled with a proactive approach to market differentiation and stakeholder engagement.

- Development and deployment of smart technologies like IoT sensors and AI-powered management systems.
- Manufacturing of sustainable construction materials and green building solutions.
- Providing consultancy and expertise in green infrastructure planning and execution.
- Investment in renewable energy generation and microgrids for powering infrastructure projects.

Financing India's Way to Green Infrastructure

Financing smart green infrastructure in India requires a multi-pronged approach.

Government initiatives play a crucial role, with bodies like the Indian Renewable Energy Development Agency (IREDA) exploring becoming a green bank to leverage public funds and attract private investment.

Public-private partnerships (PPPs) offer another avenue, where private companies partner with the government to develop and manage green infrastructure projects, sharing risks and rewards.

Green bonds, debt instruments specifically earmarked for environmentally friendly projects, are gaining traction in India's capital markets. Institutional investors and pension funds increasingly recognize the value of sustainable investments, making green bonds an attractive financing option.

Additionally, innovative mechanisms like carbon credits and environmental impact bonds can provide additional streams of revenue for green infrastructure projects.

Financing green infrastructure in India is a dynamic landscape with various options emerging. Here are some examples of funded projects and avenues to explore for securing funding for your own green infrastructure initiative:

Kochi Metro Rail: A Sustainable Ride Towards Urban Mobility

The Kochi Metro Rail Project in Kerala stands as a testament to India's commitment to developing green infrastructure through a well-structured financing model. Let's delve deeper into the financial aspects of this pioneering project:

Total Project Cost: The Kochi Metro Rail Phase 1, spanning 25.61 km from Aluva to Thrippunithura, was completed in March 2024 with an estimated cost of ₹51.81 billion (approximately US$650 million).

Public Funding Sources:

Government of India (GoI): The GoI played a significant role, contributing approximately 20.26% of the total project cost, translating to ₹1,002.23 crore (around US$130 million). This contribution likely came through budgetary allocations or grants from the Ministry of Urban Development's Urban Metro Rail Policy.

Kerala Infrastructure Investment Fund Board (KIIFB): This state-level infrastructure financing agency emerged as a key partner, providing substantial loans for the project. The exact loan amount isn't publicly available, but it likely constituted a significant portion of the remaining project cost after the GoI's contribution.

Private Sector Participation:

Debt Financing: While details are not publicly disclosed, the Kochi Metro Rail Limited (KMRL), the responsible agency for project implementation, likely secured loans from a consortium of public sector banks and financial institutions. This debt financing helped bridge the gap between public funding and the total project cost. The specific loan amount and participating institutions remain unknown.

Another project on the tracks is Chennai's Metro Rail Phase II

The Chennai Metro Rail Phase II (CMRP II), a massive ₹63,000 crore project, serves as a prime example of the multifaceted financing approach adopted for green infrastructure projects in India.

The financial model for the project follows the following approach:

Public Funding Sources:

Government of India (GoI): While the exact share hasn't been finalized, the GoI is expected to contribute a significant portion of the project cost. This contribution could come through budgetary allocations, grants from central ministries like the Ministry of Urban Development, or loans from central financial institutions.

Tamil Nadu Government (TNG): The TNG has committed to co-financing the project, demonstrating its commitment to developing sustainable urban mobility solutions. The specific share from TNG is still under negotiation, but their contribution is crucial to bridge any potential gaps in funding.

Private Sector Participation:

Japan International Cooperation Agency (JICA): JICA has emerged as a key partner, extending a substantial loan for the project. JICA's involvement not only brings in crucial financial resources but also signifies international confidence in India's green infrastructure initiatives.

Potential Public-Private Partnerships (PPPs): While details are yet to be finalized, the possibility of PPPs for specific aspects of the project like station development or operation and maintenance (O&M) cannot be ruled out. PPPs can leverage private sector expertise and efficiency, potentially reducing the overall financial burden on the public sector.

The Green Angle: How Funding Supports Sustainability

The financing mechanisms for CMRP II go beyond just rupees and cents. Here's how the funding structure promotes green infrastructure principles:

JICA's loan likely incorporates green lending criteria: JICA is known for its focus on sustainable development in its loan programs. The loan agreement might include conditions that encourage the use of green technologies and sustainable construction practices during project execution.

Potential for Green Bonds: While not confirmed yet, TNG or CMRP II authorities could explore issuing green bonds to raise funds specifically earmarked for the project's green features. This approach would attract investors seeking environmentally responsible investment opportunities.

Lucknow's 50-50 Green Rail Model

The recent announcement of the Lucknow Metro's East-West Corridor expansion (Phase 1B) demonstrates a significant stride in India's green infrastructure development. This project, estimated to cost ₹5,880 crore (approximately US$735 million), embraces a collaborative financing approach, fostering a sustainable and well-connected future for Lucknow.

Equity Sharing Model: Public-Private Partnership (PPP) for a Specific Scope

While the East-West Corridor project incorporates a public-private partnership (PPP) model for development and operation of a major portion of the line, the initial construction phase will be implemented by the Uttar Pradesh Metro Rail Corporation (UPMRC). *The initial phase, stretching from Munshipulia to Chaudhary Charan Singh Airport, Lucknow, is funded through a 50:50 equity sharing model between the Central Government and the Government of Uttar Pradesh.*

Transition to PPP for Broader Project Development:

Following the completion of the initial phase funded through the equity sharing model, the remaining sections of the East-West Corridor will likely transition to the previously mentioned PPP model. This two-pronged approach allows the project to benefit from both:

Public Investment: The initial phase receives substantial public funding, ensuring timely progress and potentially lower financing costs.

Private Sector Expertise: PPPs in the later stages can leverage private sector expertise in construction, operation, and potentially attracting additional investment for further expansion.

3 Ps to Green Infrastructure in India

Public-Private Partnerships (PPPs) offer a range of benefits for financing green infrastructure projects in India. Here's a breakdown of some key advantages:

Resource Mobilization:

Reduced Burden on Public Finances: PPPs allow the government to leverage private sector capital for infrastructure development. This helps alleviate the pressure on public funds, which can then be directed towards other social welfare programs.

Attracting Additional Investment: Private partners often bring additional sources of financing to the table, such as equity investments and loans from commercial banks. This broadens the funding pool for green infrastructure projects.

Efficiency and Expertise:

Private Sector Efficiency: Private companies often possess specialized skills and experience in project management, construction, and operation & maintenance (O&M). Their involvement can contribute to efficient project execution and potentially faster completion times.

Transfer of Knowledge and Technology: PPPs can facilitate the transfer of knowledge and technology from the private sector to the public sector. This can enhance the overall capacity for developing and managing green infrastructure projects in the long run.

Risk Sharing and Innovation:

Sharing of Risks: A well-structured PPP can distribute risks and responsibilities between the public and private sectors. The private sector might bear construction risks, while the government could manage regulatory and land acquisition challenges. This risk sharing promotes a sense of shared ownership and accountability for project success.

Innovation in Design and Construction: The private sector often has a strong incentive to innovate in design and construction methods to reduce costs and improve project efficiency. This can lead to the development of more sustainable and cost-effective green infrastructure solutions.

Recommendations and the Way Forward

Fostering Public-Private Partnerships (PPPs)

Public-private partnerships (PPPs) serve as a linchpin for mobilizing resources, sharing risks, and leveraging complementary expertise in smart green infrastructure projects. To foster a conducive environment for PPPs, policymakers should prioritize clarity of relevant regulations, streamline approval processes, and provide targeted incentives for private sector investment. Moreover, enhancing transparency, accountability, and risk-sharing mechanisms can enhance investor confidence and unlock new avenues for sustainable infrastructure financing.

Promoting Innovation and Research & Development

Investing in innovation and research & development (R&D) is critical for unlocking the full potential of smart green infrastructure and fostering technological breakthroughs. Government agencies, research institutions, and industry stakeholders should collaborate to support R&D initiatives, facilitate technology transfer, and promote knowledge exchange.

Enhancing Regulatory Frameworks and Policy Incentives

Streamlining environmental regulations, establishing clear green building codes, and providing tax breaks or subsidies for green infrastructure projects can incentivize private sector participation and accelerate adoption.

Leveraging Technology

Through the integration of AI-driven predictive analytics, infrastructure stakeholders can anticipate maintenance needs, optimize resource allocation, and mitigate operational risks, thereby ensuring the longevity and resilience of critical assets. Similarly, IoT-enabled sensors facilitate real-time monitoring and data-driven decision-making, enabling proactive interventions to address environmental concerns and optimize resource utilization. Furthermore, blockchain technology offers transparent and immutable record-keeping mechanisms, enhancing accountability and trust in sustainable infrastructure projects. By harnessing the power of technology, India can unlock new opportunities for innovation, collaboration, and sustainable growth, laying the foundation for a greener and more resilient infrastructure network for future generations.

Capacity Building and Skill Development

The shift towards smart green infrastructure requires a skilled workforce with expertise in new technologies and sustainable practices. Government and industry can collaborate to develop training programs and skill development initiatives to bridge the skill gap.

Conclusion

India stands at a critical juncture where the intersection of its burgeoning infrastructure demands and the imperative for environmental sustainability presents a unique challenge as well as opportunity for transformation. Embracing smart green infrastructure solutions not only addresses the pressing need for economic growth but also underscores a commitment to minimize environmental impact and foster resilience. This report has delved into the multifaceted dimensions of smart green infrastructure development, illuminating the role of technology, government initiatives, and the challenges that accompany this paradigm shift.

As India navigates the complexities of its infrastructure landscape, fostering innovation emerges as a linchpin for driving sustainable development. By harnessing the power of technology, from AI-driven analytics to IoT-enabled sensors, India can optimize resource allocation, enhance operational efficiency, and minimize environmental footprint across diverse infrastructure domains. Moreover, promoting collaboration between public and private sectors facilitates knowledge exchange, resource mobilization, and the co-creation of sustainable solutions tailored to India's unique needs and challenges.

However, the journey towards sustainable infrastructure is not without its hurdles. Regulatory complexities, funding constraints, and socio-economic considerations pose formidable challenges that demand collaborative action and innovative solutions. By creating an enabling policy environment, streamlining regulatory frameworks, and incentivizing private sector participation, India can surmount these barriers and accelerate progress towards a greener future.

In conclusion, India's pursuit of smart green infrastructure signifies more than just a technological revolution—it embodies a commitment to building a more equitable, resilient, and sustainable society. By embracing innovation, fostering collaboration, and leveraging the transformative power of technology, India can pave the way for a future where economic prosperity harmonizes with environmental stewardship. As we embark on this collective journey, let us seize the opportunity to shape a brighter, greener tomorrow for generations to come.

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About Climate Change Response (CCR):

CCR is a leading company empowering businesses in their journey towards achieving net-zero emissions. With expertise in ESG, Energy, Infrastructure, Environment, Agriculture, and Climate Change Risk Mitigation and Adaptation Intelligence and Advisory services. CCR offers comprehensive and sustainable solutions across diverse industry sectors. CCR services enable industries and economies enhance capabilities, align with the global ESG movement, strengthen reporting and communication, and drive operational efficiency to maximize overall business value. Through cutting-edge AI-driven, IOT and Digital Transformation applications, CCR transforms organizations with the necessary tools to gain a competitive edge in the race towards net-zero emissions. With a proven track record, CCR's portfolio encompasses a wide range of strategic and operational services, including energy transitions, net-zero pathways, monitoring and reporting systems, sustainability strategies, carbon credits trading, greenhouse gas abatement and renewable energy systems.

At CCR, our commitment extends beyond traditional consultancies; we provide value driven essential services and technology to support the entire sustainability journey. Leveraging our extensive industry experience and comprehensive suite of solutions, CCR partners with organizations to achieve their sustainability objectives and drive positive sustainable impact.