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Greening the Path to Net-Zero- Rethinking Infrastructure Financing in the Age of Climate Extremes

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“NET-ZERO offers not only a solution to climate change and air pollution, but an opportunity to create a cheaper, more resilient energy system, a more productive economy, and a better quality of life for all” - Mathew Hampshire-Waugh

The world stands at a pivotal moment in its history. Climate change, once a looming spectre on the horizon, has become an undeniable reality, reshaping lives, economies, and ecosystems with unprecedented urgency. From the catastrophic floods that submerged vast regions of Libya and Pakistan to the wildfires that scorched landscapes across Europe and Canada, climate extremes have emerged as the defining challenge of our time. These events are not anomalies but harbingers of a new normal, one that demands a profound reorientation of how we envision global progress.



At the heart of this transformation lies the ambition to achieve *net-zero emissions*, a goal embraced by over 140 countries, including economic giants like China, the European Union, and India. Net-zero, the state where greenhouse gas emissions are fully offset by removals, is not merely a technical target; it represents a fundamental shift in the architecture of economic growth. Central to this shift is infrastructure, the physical and systemic backbone of modern societies. Infrastructure, historically a symbol of industrial might and urban expansion, now stands as the key player of climate resilience, economic equity, and environmental sustainability.

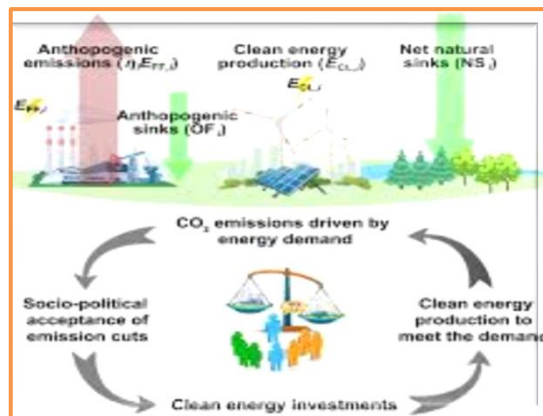
This article explores the critical nexus between infrastructure and the net-zero agenda, delving into the financing challenges, innovative global models, and actionable strategies to align infrastructure development with climate goals. With a focus on India, a nation uniquely positioned as both a climate-vulnerable country and an emerging economic powerhouse. This paper contends that rethinking infrastructure financing is not just a necessity but an opportunity to redefine progress in the age of climate extremes.

Indian Set-up: India, a climate-vulnerable yet rapidly growing economy, faces a monumental task in aligning its infrastructure with its 2070 net-zero emissions target. Infrastructure, contributing nearly 70% of India's greenhouse gas emissions through energy, transport, and buildings, is both a challenge and an opportunity. The Council on Energy, Environment and Water estimates a \$10.1 trillion investment is needed by 2070, with \$4.5 trillion for infrastructure like renewable energy, green mobility, and resilient urban systems.

The National Infrastructure Pipeline (NIP), a \$1.5 trillion initiative by 2025, aims to modernize transport, energy, and urban infrastructure. However, green projects constitute less than 20% of this spending. The PM Gati Shakti platform enhances coordination but needs

stronger climate alignment. India's 2023 sovereign green bonds, raising INR 16,000 crore, and the National Green Hydrogen Mission, with INR 19,744 crore, signal progress, yet the green finance ecosystem remains underdeveloped.

Key challenges include high upfront costs, limited bankable projects, and inadequate ESG disclosures. To bridge the \$150 billion annual investment gap, India must act decisively. A finalized green taxonomy could standardize sustainable investments, while robust Monitoring, Reporting, and Verification systems using blockchain can ensure transparency. Blended finance, combining public funds with private capital, can de-risk projects, as seen with IREDA's solar initiatives. A dedicated Green Investment Bank could catalyse funding, while state-level green bonds from Gujarat or Tamil Nadu could address regional needs.



Decentralized solutions, like Bihar's solar mini-grids or Pune's electric buses, empower communities and cut emissions. By leveraging digital infrastructure, reforming multilateral financing, and scaling carbon markets, India can lead the Global South in green infrastructure. This transformation demands bold policy, private capital alignment, and grassroots action to build a resilient, low-carbon future.

The infrastructure-Emissions Nexus: A Dual Role

Infrastructure is both a driver of greenhouse gas (GHG) emissions and a critical lever for decarbonization. Globally, infrastructure-related activities encompassing energy, transport, buildings, and industry account for approximately 70% of GHG emissions. Power generation alone contributes over 30% of global emissions, while transport and buildings add another 20% and 15%, respectively. Yet, these same sectors hold the potential to deliver more than 60% of the emissions reductions needed to achieve net-zero by 2050, according to the International Energy Agency (IEA).

Net-zero emissions require balancing the greenhouse gases released into the atmosphere with those removed through natural or technological means, such as afforestation, reforestation, or carbon capture and storage (CCS). This balance demands a multifaceted approach: deploying clean energy technologies, transforming urban systems, rethinking industrial processes, and fostering behavioural changes. However, none of these solutions can scale without robust, climate-aligned infrastructure.

For instance, renewable energy systems depend on smart grids capable of integrating intermittent sources like solar and wind. Green mobility requires extensive networks of electric vehicle (EV) charging stations, high-speed rail, and non-motorized transport corridors. Sustainable urban development hinges on energy-efficient buildings, green roofs, and resilient water systems. Even nature-based solutions, such as wetlands restoration or urban forestry, require infrastructure to support their implementation and maintenance.

Thus, infrastructure is not merely another sector in the net-zero equation, it is the foundation upon which all other efforts rest. Financing climate-resilient and low-carbon infrastructure is not only essential for mitigating emissions but also for adapting to the intensifying impacts of climate change, particularly in vulnerable regions.

The Cost of Climate Inaction: A Sobering Reality

The economic and human toll of climate inaction is staggering. The United Nations Environment Programme (UNEP) *Emissions Gap Report 2023* warns that current policies place the world on a trajectory toward 2.8°C of warming by 2100, far exceeding the Paris Agreement's 1.5°C target. This trajectory carries profound economic consequences. A Swiss Re report projects that unmitigated climate change could reduce global GDP by up to 18% by

2050, with developing economies facing disproportionate losses due to their reliance on climate-sensitive sectors like agriculture and fisheries.

Between 2014 and 2023, climate-related disasters such as floods, hurricanes, droughts, and wildfires have caused over \$2 trillion in damages worldwide. In 2023, the United States alone experienced 28 climate disasters, each exceeding \$1 billion in damages, according to the National Oceanic and Atmospheric Administration (NOAA). Developing nations, however, bear the brunt of these impacts. The 2022 floods in Pakistan displaced over 33 million people, destroyed 1.7 million homes, and caused economic losses exceeding \$30 billion. In Small Island Developing States (SIDS), rising sea levels threaten entire economies, with countries like the Maldives facing existential risks.

India, one of the world's most climate-vulnerable nations, is particularly exposed. The *Global Climate Risk Index 2021* ranks India among the top 10 countries most affected by climate impacts. With over 50% of its population dependent on agriculture, fisheries, and forestry sectors highly sensitive to climate variability. India faces an estimated annual GDP loss of 2.8% by 2050 under a business-as-usual scenario. Heatwaves, erratic monsoons, and rising sea levels further exacerbate risks, threatening food security, water availability, and urban resilience.

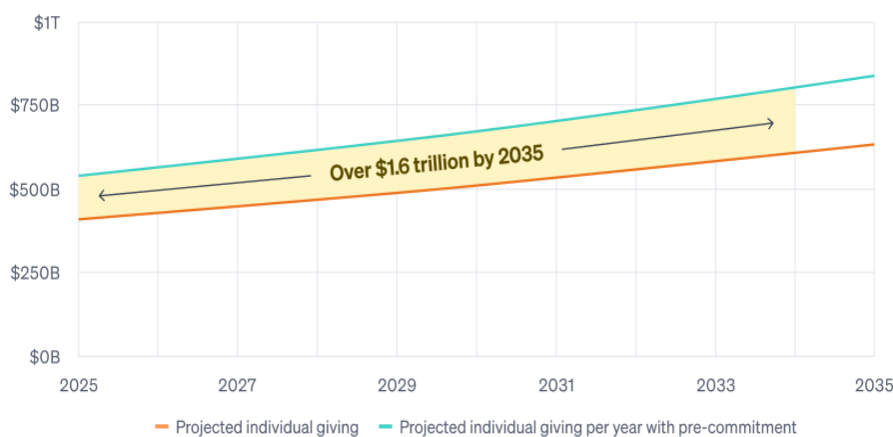
The cost of inaction extends beyond economics. Climate change amplifies social inequalities, disproportionately affecting marginalized communities, women, and indigenous populations. In India, for example, rural women in drought-prone areas spend increasing hours fetching water, limiting their opportunities for education and income generation. Addressing these challenges requires not only emissions reductions but also investments in adaptive infrastructure such as flood defences, drought-resistant irrigation systems, and resilient urban planning that can safeguard lives and livelihoods.

The Financing Challenge: A Trillion-Dollar Gap

Achieving net-zero by mid-century demands an unprecedented scale of investment. The Organisation for Economic Co-operation and Development (OECD) estimates that \$6.9 trillion per year is required through 2030 to meet global infrastructure needs aligned with climate goals. This includes investments in renewable energy, energy-efficient buildings, sustainable transport, and adaptation infrastructure. Yet, current global investments fall short by more than 50%, creating a financing gap that threatens to derail net-zero ambitions.

The Trillion Dollar Generosity Gap

Americans could give as much as 32% more to charity with pre-commitment, totaling an extra \$1.6 trillion over the next 10 years.



:Daffy

In India, the challenge is particularly acute. The Council on Energy, Environment and Water (CEEW) estimates that achieving net-zero by 2070 will require cumulative investments of \$10.1 trillion, with \$4.5 trillion directed toward infrastructure sectors like energy, transport, and urban development. This translates to an annual investment of approximately \$150 billion—a figure that dwarfs current spending levels.

Several structural barriers impede the flow of capital into green infrastructure:

1. **High Upfront Costs and Long Payback Periods:** Green infrastructure projects, such as offshore wind farms or high-speed rail, require significant upfront capital and often have payback periods spanning decades. This deters private investors seeking short-term returns.
2. **Limited Pipeline of Bankable Projects:** Many green projects lack the financial structuring or risk mitigation mechanisms needed to attract investment. In developing countries, weak institutional frameworks further exacerbate this challenge.
3. **Lack of Standardized Taxonomies:** Inconsistent definitions of “green” investments and inadequate environmental, social, and governance (ESG) disclosures create uncertainty for investors, hindering capital flows.
4. **Technology and Policy Risks:** Emerging technologies like green hydrogen or carbon capture face uncertainties around scalability and cost-competitiveness. Similarly, shifting policy landscapes can deter long-term investments.
5. **Currency and Sovereign Risks:** In emerging markets, currency volatility and political instability can discourage international investors, particularly for large-scale infrastructure projects.

Addressing these barriers requires a fundamental rethinking of how infrastructure is financed, with a focus on de-risking investments, mobilizing private capital, and leveraging public funds to catalyse systemic change.

Global Efforts: Pioneering Green Infrastructure Financing

Across the world, countries and institutions are experimenting with innovative models to finance green infrastructure, offering valuable lessons for scaling up investments:

1. **European Union: The European Green Deal:** The EU’s flagship climate initiative aims to mobilize €1 trillion by 2030 to support sustainable investments. The European Investment Bank (EIB) plays a central role, channelling funds into renewable energy, sustainable transport, and energy-efficient buildings. The EU Innovation Fund, one of the world’s largest funding programs for low-carbon technologies, supports projects in hydrogen, carbon capture, and green manufacturing. By blending public and private capital, the EU has created a robust ecosystem for green finance, with clear taxonomies and mandatory ESG disclosures.
2. **United States: The Inflation Reduction Act,** enacted in 2022, the Inflation Reduction Act (IRA) allocates \$369 billion for climate-smart infrastructure, including tax credits for electric vehicles, energy-efficient buildings, and renewable energy projects. The IRA’s focus on domestic manufacturing and job creation has spurred private investment, with companies like Tesla and First Solar expanding U.S.-based production. The act’s success lies in its ability to align economic incentives with climate goals, demonstrating the power of policy-driven financing.
3. **China: Green Bonds and Infrastructure Scale:** China, the world’s largest emitter, is also a leader in green finance. Its 14th Five-Year Plan (2021–2025) prioritizes carbon neutrality by 2060, with massive investments in high-speed rail, solar farms, and EV infrastructure. China’s green bond market, the second largest globally, issued over \$100 billion in 2022, financing projects from wind farms to urban transit systems. The country’s ability to mobilize state-led capital underscores the importance of policy certainty in attracting investment.
4. **Indonesia: Just Energy Transition Partnership (JETP)** Launched in 2022, the JETP mobilizes \$20 billion to support Indonesia’s transition from coal to renewables. The

partnership combines concessional loans, private investment, and policy reforms, offering a model for other coal-dependent nations. By aligning international finance with national priorities, the JETP demonstrates the potential of blended finance to bridge funding gaps.

5. **Chile: Sustainability-Linked Bonds:** Chile has pioneered sustainability-linked bonds, where interest rates are tied to environmental performance. Failure to meet emissions reduction or renewable energy targets triggers higher interest payments, incentivizing accountability. This innovative instrument has attracted global investors while ensuring alignment with climate goals.
6. **Kenya: Green Economy Strategy:** Kenya's Green Economy Strategy focuses on decentralized solutions like solar microgrids and sustainable agriculture. The country is also piloting blockchain-based carbon credits to attract global capital, offering a model for leveraging digital technologies in green finance.

These examples highlight the diversity of approaches to green infrastructure financing, from policy-driven incentives to innovative financial instruments. However, scaling these models globally requires addressing the unique challenges faced by developing economies, particularly in terms of risk perception and access to capital.

India's Journey: Aligning Infrastructure with Net-Zero Goals

As a rapidly growing economy and one of the world's most climate-vulnerable nations, India occupies a unique position in the global net-zero transition. With a population of 1.4 billion and a GDP growth rate among the highest globally, India's infrastructure decisions will shape its emissions trajectory for decades. The country has set an ambitious target of achieving net-zero by 2070, supported by a series of policy and financial initiatives:

1. **National Infrastructure Pipeline (NIP):** Launched in 2019, the NIP is a \$1.5 trillion plan to upgrade India's infrastructure by 2025, covering sectors like energy, transport, and urban development. While the NIP has accelerated infrastructure development, only a fraction of its investments is explicitly aligned with net-zero goals. Retrofitting the NIP with green criteria such as prioritizing renewable energy and low-carbon transport could significantly advance India's climate agenda.
2. **PM Gati Shakti:** This digital platform integrates 16 ministries to streamline infrastructure planning and execution. By incorporating climate resilience and sustainability metrics, Gati Shakti could ensure that new projects align with net-zero pathways. For example, prioritizing rail over road transport or mandating energy-efficient building codes could reduce emissions while enhancing connectivity.
3. **National Green Hydrogen Mission:** Launched in 2023 with an outlay of INR 19,744 crore (\$2.4 billion), this mission aims to position India as a global hub for green hydrogen production. By incentivizing clean energy technologies, the mission supports the decarbonization of hard-to-abate sectors like steel and cement, which are critical to infrastructure development.
4. **Sovereign Green Bonds:** In 2023, India issued INR 16,000 crore (\$2 billion) in sovereign green bonds to finance renewable energy, green buildings, and clean transport. While a step in the right direction, green bonds account for less than 20% of India's infrastructure financing, highlighting the need for greater scale and diversity in green financial instruments.

Despite these efforts, significant challenges remain. India's green bond market is underdeveloped compared to global leaders like China and the EU. Domestic investors, including banks and pension funds, often lack the expertise or incentives to integrate ESG criteria into their portfolios. Moreover, the high cost of capital in India, driven by perceived risks and currency volatility deters international investment in green infrastructure.

Building an Ecosystem for Green Infrastructure Finance

To bridge the financing gap and align infrastructure with net-zero goals, India must build a robust ecosystem that integrates policy, finance, and technology. The following strategies offer a roadmap for this transformation:

1. **Green Taxonomy:** A standardized taxonomy for green investments is critical to provide clarity and reduce greenwashing. India's draft climate finance taxonomy, currently under development, should define clear criteria for what constitutes a "green" project. Once finalized, it must be integrated into financial regulations, public procurement processes, and project appraisal frameworks. For example, the Reserve Bank of India (RBI) could mandate that banks allocate a minimum percentage of their portfolios to green projects, as seen in Bangladesh's green banking guidelines.
2. **Robust MRV Systems:** Monitoring, Reporting, and Verification (MRV) systems are essential to ensure accountability and build investor confidence. India should develop digital, transparent, and sector specific MRV frameworks to track emissions reductions, project outcomes, and financial flows. For instance, blockchain-based platforms could provide real-time data on carbon credits, ensuring environmental integrity and attracting global capital.
3. **Blended Finance Mechanisms:** Blended finance combining public concessional funds with private capital can de-risk green infrastructure projects and improve bankability. The Indian Renewable Energy Development Agency (IREDA) could expand its use of subordinated debt, first-loss guarantees, and viability gap funding to crowd in private investment. For example, IREDA's support for solar projects has already catalysed significant private capital, a model that can be scaled to other sectors.
4. **Green Investment Banks:** Establishing a dedicated Green Investment Bank (GIB), modelled after the UK's GIB, could provide specialized financing for green infrastructure. A GIB could offer de-risking instruments, co-lending platforms, and project preparation facilities, addressing the pipeline challenge. It could also serve as a knowledge hub, providing technical assistance to state governments and private developers.
5. **State-Level Climate Finance Frameworks:** India's federal structure necessitates decentralized approaches to green financing. States like Gujarat, Tamil Nadu, and Maharashtra are the leaders in renewable energy could issue their own green bonds and develop climate budgets. Region-specific adaptation infrastructure, such as coastal defences in Tamil Nadu or drought-resistant irrigation in Rajasthan, would enhance resilience while attracting local investment.
6. **Digital Solutions:** India's digital public infrastructure, exemplified by platforms like UPI and Aadhaar, offers a blueprint for scaling green finance. Technologies like blockchain, artificial intelligence (AI), and the Internet of Things (IoT) can reduce transaction costs, improve traceability, and enable fractional ownership of green assets. For example, blockchain-based platforms could facilitate peer-to-peer energy trading in solar microgrids, empowering communities and attracting investment.

De-risking Green Infrastructure: A Global Imperative

The risk-return equation for green infrastructure is often skewed, particularly in emerging markets where political, currency, and technology risks loom large. Addressing these risks requires a global effort to create an enabling environment for investment:

1. **Multilateral Development Banks (MDBs):** MDBs like the World Bank and Asian Development Bank must shift from traditional lending to catalytic financing. This includes providing credit enhancements, partial risk guarantees, and technical assistance to de-risk projects. The World Bank's Climate Investment Funds (CIFs), for instance, have supported renewable energy projects in India and Africa, but their scope must expand to include adaptation infrastructure and nature-based solutions.
2. **Debt-for-Climate Swaps:** Pioneered by countries like Belize and Seychelles, debt-for-nature swaps allow debt-burdened nations to redirect debt payments toward conservation and green infrastructure. India could explore bilateral arrangements with creditors to reduce fiscal pressures while investing in climate-resilient projects, such as mangrove restoration or urban flood defences.

3. **Climate Resilient Debt Clauses:** Financial instruments that allow deferred payments during climate disasters can provide fiscal breathing space to vulnerable nations. These clauses, piloted by Grenada and Barbados, could be adopted by India to ensure liquidity during extreme weather events.
4. **Evolving Climate Investment Funds:** CIFs should transition from project-based financing to market-shaping tools. This includes supporting local government initiatives, scaling adaptation infrastructure, and fostering South-South cooperation. For example, India could lead a regional CIF to support climate-resilient infrastructure in South Asia, leveraging its expertise in renewable energy and digital innovation.

Mobilizing Private Capital: Aligning Profit with Purpose

Private capital is indispensable to achieving net-zero goals, yet institutional investors, pension funds, insurance companies, and sovereign wealth funds have been slow to embrace green infrastructure. To align private capital with climate objectives, the following measures are critical:

1. **Mandatory ESG Disclosures:** Climate-related financial disclosures, as mandated in New Zealand and the UK, should be introduced in India. The Securities and Exchange Board of India (SEBI) could require listed companies to report climate risks and opportunities, enabling investors to make informed decisions.
2. **Sustainability-Linked Loans (SLLs):** SLLs, where interest rates are tied to environmental performance, can incentivize companies to pursue net-zero pathways. For example, a steel manufacturer could secure an SLL with lower rates contingent on reducing emissions through green hydrogen adoption.
3. **Carbon Markets:** India's forthcoming Carbon Credit Trading Scheme, announced in 2023, must ensure environmental integrity and transparency to attract global capital. Linking with international carbon markets, such as the EU's Emissions Trading System, could unlock new revenue streams for green infrastructure projects.

Empowering Communities: The Bottom-Up Approach

Net-zero cannot be achieved without grassroots participation. Local governments, panchayats, and civil society must be empowered to lead climate infrastructure projects:

1. **Community-based Solar Mini-Grids:** In states like Bihar and Jharkhand, solar mini-grids have provided reliable electricity to remote communities, reducing emissions and improving livelihoods. Scaling these projects through public-private partnerships can enhance energy access while supporting net-zero goals.
2. **Sustainable Urban Mobility:** Cities like Pune and Chennai are pioneering low-carbon transport solutions, such as electric bus fleets and non-motorized transport corridors. Expanding these initiatives to tier-2 and tier-3 cities could reduce urban emissions while improving air quality and mobility.
3. **Climate-Resilient Agriculture:** The National Mission for Sustainable Agriculture promotes practices like zero-tillage farming and drip irrigation. However, greater financial backing and convergence with infrastructure missions such as rural road networks and cold storage facilities are needed to scale impact.

Toward a Net-Zero Financial Architecture

Achieving net-zero through infrastructure transformation requires a complete reorientation of the global financial architecture:

1. **Global Reporting Standards:** International bodies like the International Sustainability Standards Board (ISSB) must converge on common frameworks for sustainability disclosures, impact measurement, and carbon accounting. This would reduce fragmentation and enhance investor confidence in green infrastructure.
2. **Reform of MDB Governance:** MDBs must give greater voice to developing nations, ensuring that the Global South is an active partner in shaping climate finance. India, as a

leader in the G20, could advocate for governance reforms that prioritize equitable access to capital.

3. **Technology Transfer and Capacity Building:** A dedicated Global Climate Innovation Fund could support research and development, technical training, and South-South cooperation. For instance, India could share its expertise in solar energy and digital infrastructure with African nations, fostering mutual learning and innovation.

Conclusion: A Defining Moment for India and the World

Infrastructure is destiny. The roads we build, the cities we design, and the energy systems we deploy will determine whether we lock in a carbon-intensive future or pave the way for a sustainable one. Green infrastructure is not just a tool for achieving net-zero, it is the foundation of a resilient, equitable, and thriving world.

India, as a rising economic power and a climate-vulnerable nation, has a unique opportunity to lead by example. By aligning its \$1.5 trillion National Infrastructure Pipeline with net-zero goals, scaling green financial instruments, and empowering local communities, India can chart a path to sustainable growth that inspires the world. However, this vision requires a robust ecosystem that rewrites risk, blends capital, and amplifies innovation.

The journey to net-zero is not merely a technical or financial challenge, it is a civilizational one. The tools exist, from green bonds to blended finance to digital platforms. The finance can be mobilized, through public-private partnerships and global cooperation. The question is whether we have the collective will to act. Let this be the decade where infrastructure financing becomes the bridge to a greener, safer, and more just world.

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